Independent Noise Working Group

Wind Turbine Amplitude Modulation &
Planning Control Study

Work Package 2.1
Review of Reference Literature

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Contents

Abbreviations

ADD	Active damping device (added to a wind turbine)
AM	Amplitude modulation, of wind turbine noise
AMWG	(Wind turbine noise) Amplitude Modulation Working Group of the IoA
BWEA	British Wind Energy Association, forerunner to RenewableUK (q.v.)
EAM	Excess(ive) amplitude modulation
ETSU	ETSU-R-97, the Assessment and Rating of Noise from Wind Farms
HMP	Hayes McKenzie Partnership
INWG	Independent Noise Working Group
IoA	Institute of Acoustics
LFN	Low frequency noise
NASA	National Aeronautics and Space Administration (USA)
NIA	Northern Ireland Assembly's
OAM	Ordinary amplitude modulation
ReUK	RenewableUK, wind industry trade association
SERI	Solar Energy Research Institute
VLF	Very low frequency
WT	Wind turbine
WTN	Wind turbine noise
WP	Work Package (of the INWG)

1. Executive Summary

1 This work package presents the results of a review of the literature on wind turbine noise (WTN). Over 160 documents are reviewed by the INWG for this study of amplitude modulation. Evidence spanning over the past 30 years shows a clear evolution of knowledge relating both to the science behind WTN and its effects on people exposed to it. Starting with the NASA research during the 1980s through to the Northern Ireland Assembly inquiry report of March 2015, the key scientific aspects of WTN including its amplitude modulation (AM) are now well understood and defined. However, further research is required especially regarding the effects on health. It is also apparent that despite a wealth of evidence indicating adverse health effects, the wind industry has no plans to investigate this or amend its practices.

2 The most important conclusion from this review is that the official UK WTN guidance, ETSU-R-97 (ETSU) is unfit for purpose and is failing to protect wind turbine neighbours against the effects of noise including both amplitude modulation (AM) and low frequency noise (LFN).

3 Throughout the period reviewed, aided by its acoustic, political and legal consultants, the UK wind industry has sought to hide the true science behind WTN and its effects on people though a concerted strategy of obfuscation and political lobbying. Studies under the auspices of The Institute of Acoustics (IoA), by the wind industry and government into AM and its excess (EAM) are shown to be a diversion to avoid answering the scientific questions that really matter. This has been aided by compliant government officials who have been focused on removing barriers to the deployment of wind power generating capacity and by the wind industry effectively taking control of the IoA's successive 'Noise Working Groups'. As a result all efforts to date to have the ETSU noise guidelines replaced with an effective science based alternative have been successfully resisted.

4 The evidence shows that EAM is not a rare occurrence as the wind industry claims but can and does occur frequently and often for lengthy periods for most if not all wind turbines.

5 The evidence regarding low frequency noise (LFN), a significant component of WTN including AM, is compelling. Despite the wind industry's continual denial of the significance of LFN, the available evidence demonstrates conclusively that:

- LFN including infrasound is an integral component of WTN;
- Complaints regarding WTN currently classified as AM or EAM or OAM by the wind industry is an obfuscation of the true nature of the problem;
- Conditions giving rise to noise complaints are often characterised by 'sensation' as being the major form of disturbance. In some cases, the 'noise' may not even be audible;
- Noise measurement using the A weighting may be unsuitable for WTN where low frequency components are present;

- Noise measurements should be made inside homes when investigating noise complaints;
- Noise measurements where LFN is present should be made using suitable instrumentation. IEC 61672 compliant 'Class 1', instrumentation may be unsuitable for LFN measurement or where background noise levels are low as in typical rural areas.

2. Introduction

6 This report reviews the literature relevant to wind turbine noise (WTN) amplitude modulation (AM) and consolidates the reference material considered by the Independent Noise Working Group (INWG) in the various work packages (WP) making up our study into amplitude modulation (AM). Note that some of the medical reference documents referred to in WP 3.2 – 'Wind Turbine Noise, Sleep and Health' are not included in this review

7 The objectives of this WP are to:

- Review the evolution of knowledge regarding WTN and AM;
- Collate the reference literature relevant to this INWG study of WTN AM and produce a common reference list for the study work packages;
- Provide a short description of each reference document.

8 Although this study focuses on the most recent findings and knowledge surrounding WTN and AM, it also includes earlier work where this remains relevant. Much of the literature dating from more than around 3 years ago has been superseded by more recent and relevant sources. The last 2 years have seen a surge in research activity with the release of numerous technical papers and other developments as the awareness of wind turbine noise problems has increased and the *status quo* imposed by the wind industry and its consultants has been challenged. As a result, knowledge on the subject of WTN, AM and its effects on people has advanced rapidly.

9 The more important reference documents are summarised below at Section 3. This section reviews the evolution of knowledge leading to the current knowledge base relating to wind turbine noise and especially amplitude modulation.

10 The significant volume of recently emerging evidence relating to low frequency noise (LFN) has justified a separate discussion at Section 4 of this work package (WP).

3. Knowledge Evolution

11 The first notable research into WTN noise took place during the 1980's by NASA in the USA. This included evaluation of human exposure to wind turbine noise by Stephen *et al*. March 1982, noise induced house vibrations by Hubbard, Sept 1982, and Hubbard & Shepherd, Nov 1984. Hubbard discovered that the effects of WTN could cause buildings to vibrate and concluded that: "*Interior noise spectra have peaks at frequencies corresponding to structural vibration modes and room standing waves; and the levels for particular frequencies and locations can be higher than the outside levels*".

12 Research included noise annoyance from the MOD-1 wind turbine, Kelley et *al*. Feb 1985, and in their November 1987 paper confirmed that "*The modern wind turbine radiates its peak sound power (energy) in the very low frequency (VLF) range, typically between 1 and 10 Hz. This is a direct consequence of its small rotor solidity and relatively low rotational (shaft) speed (17.5-300 rpm)*".

13 They also confirmed that:

- *People do indeed react to a low frequency noise environment; and*
- *A-weighted measurements are not an adequate indicator of annoyance when low frequencies are dominant.*

14 It was therefore clear even in the 1980s that WTN could cause annoyance, that it contains a large low frequency component that can excite building structures such that low frequency noise levels could be higher inside than outside the building, and that that A weighted measurement is not adequate when low frequencies are dominant.

15 However, all these key scientific findings were seemingly ignored when, during 1996, the UK then Department for Trade and Industry and wind industry produced the ETSU guidelines for the assessment of WTN. Released in Sept 1996, ETSU is still the official but much criticised guidance regarding wind turbine noise assessment in the UK. The Government and wind industry have managed to maintain this document and its noise limits as official guidance for WTN assessment despite the overwhelming evidence that it is scientifically deeply flawed and 'not fit for purpose'.

15 BS4142:1997 is also included as a reference document as it formed some of the original basis for the ETSU guidance although the latter was based mainly on the earlier BS4142:1990 version. This has now been superseded by BS4142:2014, (q.v.).

16 ETSU-R-97 Why it is wrong by Bowdler (2005) provides a clearly argued discussion of the deeply flawed assumptions supporting ETSU and points out that the ETSU limits can easily allow turbine noise levels of 20 to 25dB above background noise levels in rural areas.

17 As we move to more recent times, one of the still relevant older papers is Lee *et al.* 2009, which concluded that there is a correlation between noise annoyance and amplitude modulation, adding that not only equivalent sound level but also spectral modulation depth should be considered when assessing community response to WTN.

18 Fiumicelli and Trinder for DEFRA, 2011 discuss statutory nuisance as applied to resolving wind farm noise complaints. Their report states that effective noise control is '*best achieved by using adequate separation of the turbine from noise sensitive receptors*'. It also recognises that '*When considered with the authorised grounds for appeal and defence against Statutory Nuisance actions, this can mean that the protection that can be secured under Statutory Nuisance is less than might normally be achievable using planning pow*ers'.

19 Di Napoli, 2011 revealed that significant AM can be detected 2km away from the nearest turbine, it does not decrease with distance as was previously thought. Additionally, measurements revealed pulsating infrasound emitted from the turbines.

20 In contrast, McLaughlin, 2011 makes several claims that AM in the far field is rarely observed but provides no evidence to support this claim. However, he does suggest that AM may be influenced by unusual wind shear conditions and convergence zones.

21 McCabe, 2011 observes that there may be more annoyance associated with WTN than with other sources of environmental noise for comparable sound levels. AM of the broadband sound is suggested as one qualitative factor that may increase the annoyance. His data support the idea that increased periods of AM occur when the wind shear is high. The data also indicate that a high rotor rotational speed tends to be required for high degrees of modulation and that wind direction clearly affects the degree of modulation at any given location.

22 Lundmark, 2011 recognised that amplitude modulated noise is a characteristic for wind turbines and is considered by many to be extra annoying. He also notes that by using standard measurement methods, it is not possible to distinguish the broadband noise from the amplitude modulated noise and that reports by wind turbine manufacturers utilise integration times of at least 1 minute, which effectively hides the 'swish' noise. In Sweden there have been serious complaints about the swish noise but the specific sound characteristic that some people have complained about have not been analysed.

23 Di Napoli, 2012 reveals deficiencies when assessing AM on WTN when using the IEC 61400-11:2002 standard. Since AM may significantly increase the perception as well as annoyance of wind turbine noise, new near field measurement methods are required to ensure that sufficient information from modulated noise and possible annoyance corrections are presented. When planning a new wind farm the guarantee test certificates , to which consultants and environmental impact assessment authors often refer, are typically the only official noise measurement documentation available.

His measurements found that modulation depths in the near field were not more than 5 or6 dB while at the same time in the far field were 8 to 9 db. If the turbines sound power level was calculated using one minute LAeq results and the basic sound propagation model used with a spherical sound source, the deviation (under prediction) to the measured maximum sound pressure levels at immission point would be about 10 to 12 dB. Also, the modulation impulsivity increased as one moves further from the turbine.

24 Cox *et al.* 2012 provide a detailed critique of ETSU and how it is being implemented by the wind industry and its acoustic consultants. Key deficiencies include:

- A failure to use suitable microphone wind screens and as a consequence background noise levels will be measured artificially high due to wind noise contamination resulting in an overestimation of masking background noise;
- A failure adequately to consider the effects of wind shear in noise assessments so underestimating turbine noise levels;
- A failure to correctly analyse background noise data when deriving average noise curves so overestimating background masking noise;
- A failure to correctly use the ISO 9613-2 noise propagation model resulting in an under prediction of turbine noise;
- A failure to allow for measurement tolerances (or uncertainties) that can easily amount to +/- 10dB resulting in a doubling or halving of the WTN;
- A failure to consider EAM and LFN.

In almost all of these issues they show that either there is no formal guidance or that when it is offered it is so vague as to allow almost any implementation whatsoever. Their report highlighted that these failures of guidance have continued throughout the period since 1997 when Government policy on wind farms closely followed the advice provided by two acoustic consultancies, HMP and Hoare Lea Acoustics.

25 The Wisconsin report, 2012 into the Shirley wind farm was a significant step forward in our understanding of WTN nuisance and particularly LFN. Commissioned for the Wisconsin Public Service Commission in the USA, this consists of separate reports by four different consultants who between them represent both developers and resident groups. A unique feature of this report is that the consultants jointly agreed the overall report conclusions:

1. Channel Island Acoustics remarked, '*residents report being intensely affected despite inaudibility and to be aware of turbine operation even when the turbines are not visible*';

2. Hessler Associates concluded, '*the study also showed that a wind turbine is indeed a unique source with ultra-low frequency energy. In general, enough was learned by these investigators, all with quite different past experiences, that it can be mutually agreed that infrasound from wind turbines is an important issue that needs to be resolved in a more conclusive manner by appropriate study*';

3. Rand Acoustics concluded that nauseogenicity is a factor at Shirley. Acceleration of the inner ear is suggested and is due to extremely low-frequency pulsations at the rotation and blade pass rates that occur in or near the frequencies of highest potential for nauseogenicity and are coupled strongly into the homes now abandoned. More research is recommended to understand nauseogenicity from wind turbine operations, properly to design and site large industrial wind turbines (over 1 MW) near residential areas to prevent these possibly severe health effects.

The correlations to nauseogenicity at the 2.5MW power rating and size suggest worsening effects as larger, slower-rotating wind turbines are sited near people.

4. Schomer and Associates noted that currently the wind turbine industry only presents A-weighted octave band data down to 31 Hz and claims that wind turbines do not produce low frequency sound energies. However, the measurements at Shirley have clearly shown that low frequency infrasound is clearly present and relevant. Also that A-weighting is totally inadequate and inappropriate for description of this infrasound. The A-weighting, and also the C and Z-weightings for a Type 1 sound level meter have a lower tolerance limit of -4.5 dB in the 16 Hz one-third-octave band, a tolerance of minus infinity in the 12.5 Hz and 10 Hz one-third- octave bands, and are totally undefined below the 10 Hz one-third-octave band. Thus, the International Electro-technical Commission (IEC) standard needs to include both infrasonic measurements and a standard for the instrument by which they are measured.

26 Lee *et al.* 2013 produced a ground breaking paper modelling the propagation of WTN. They discovered that its acoustical characteristics are quite different with respect to the distance and direction from the wind turbine, although the operating and atmospheric conditions are identical. In the vicinity of a wind turbine, typical swishing sounds are perceived from all azimuthal directions. On the other hand, at long distances from a wind turbine, low-frequency amplitude-modulated sounds are heard in particular directions. This effect may make the wind turbine noise seem more impulsive at long distances despite the fact that its overall sound pressure level is low.

They also report that strong wind shear can increase the strength of the AM in the WTN. At long distances in the directions where the blade passes downward, the amplitude-modulated sound occurs when the blades are at the top of the rotor disk. Hence, if the vertical wind shear is strong, the effective angle of attack at the top of the rotor disk will increase, as will the level of the amplitude-modulated sound in these directions. Furthermore, in the downwind directions, sound rays are bent toward the ground in a strong wind shear. This effect will also raise the level of the amplitude-modulated sound in the downwind directions.

27 Gabriel, 2013 concluded it is not the loudness of the broadband WTN that causes complaints, nor the tonality or impulsiveness according to the standardised definitions. Residents complain about sound identified as different from the natural background noise even if the loudness of this sound is so low as to be hardly perceptible.

28 In a study informed by data collected at the Cotton Farm wind farm site in Cambridgeshire and elsewhere in UK, Stigwood *et al.*, Aug 2013 concluded:

- AM should be measured during the evening (after sunset), night time or early morning;
- AM is generated by all wind turbines including single wind turbines;
- Propagation conditions, mostly affected by meteorology and the occurrence of localised heightened noise zones determine locations that will be affected;

- Their surveys confirm that AM occurrence is frequent and can readily be identified in the field by measuring under suitable conditions and using appropriate equipment and settings; audible features of AM including frequency content and periodicity vary both within and between wind farms. Noise character can differ considerably within a short time period. The constant change in AM character increases attention and cognitive appraisal and reappraisal, inhibiting acclimatisation to the sound.

29 Fukushima *et al.* 2013, stated that AM sound, the so called swish sound, generally contained in WTN causes serious annoyance in areas around wind farms. As a result of investigation using 81 measurement results obtained at 18 wind farm sites in Japan according to this assessment method, sensible AM sounds were found in about three-quarters of the wind turbines. These finding reconfirmed that AM is not infrequent as claimed for many years by the wind industry and its consultants.

30 Cooper and Evans, Nov 2013 concluded that on the balance of the available data at a residence it would appear that the ambient noise level there is a more important factor in the detection of EAM than the influence of wind shear. Periods judged to be 'excessive' modulation using a 6 dB third octave test in NZS 6808:2010 occurred under periods of both low and high wind shear.

31 The report on AM released by RenewableUK (ReUK), during Dec 2013 claimed to represent a significant advancement in the understanding on AM. This 500 plus page report has since been heavily criticised (by Cox, Jan 2014 & Mar 2014, Moroney, Mar 2014 and others) for its lack scientific accuracy and rigour and the disconnect between the report detail and subsequent conclusions and claims made by ReUK.

32 Larson and Ohlund, Jan 2014 concluded:

- Higher prevalence of AM is detected when the sun is close to or under the horizon, which corresponds well with when temperature inversions occur on clear nights. A temperature inversion near the ground changes the angle of incidence of the sound waves and affects the ground attenuation. The reflected sound waves are normally less damped if the sound comes more from the zenith than parallel to the ground;

- Analysing approximately 30 hr of AM measurements recorded simultaneously at both an emission and an immission point shows that enhanced AM at an immission point could not be explained by enhanced AM at the emission point. This is a most significant finding indicating that AM is partially at least the result of propagation effects;

- Amplitude modulated sound from wind turbines is more common under certain meteorological conditions and is observable approximately 20%–30% of the operational time, depending on the distance from the turbines. This again confirms that AM is a frequent occurrence.

33 Much the same conclusion is supported by the work reported by Stigwood, March 2014 in which he shows that:

- All wind turbines cause EAM;
- EAM occurs in heightened noise zones;
- Meter location and site observation is critical if EAM is to be detected;
- Some locations regularly experience higher AM than others;
- Crosswind EAM exhibiting large peak to trough values can arise at significant distances in excess of 400m;
- Upwind EAM can be as bad as downwind AM when within a reasonable proximity of the wind farm;
- External EAM measurements outside of residences do not reflect what is observed internally;
- ETSU fails to address EAM arising from large wind turbines;
- The proposed RUK AM condition was tested and found to allow even the worst cases of EAM,

34 In a study of WTN EAM at Knockglass Farm , Huson, May 2014 discovered that:

- Amplitude modulation at rotor speeds typical of 2.3 MW wind turbines (17.4 rpm) were observed inside a bedroom with a peak to trough levels exceeding 20 dB(A).
- The source of this amplitude modulation is a wind farm located approximately 1000 m SE of the farm from which a repetitive transient has been observed corresponding to the shaft rotational speed. This is a significant finding: the measured EAM corresponds to rotor rotational frequency, not only blade passing frequency.

35 Vanderkooy and Mann, Oct 2014 concluded:

- *"Our analysis reveals a characteristic infrasonic pulse. We conjecture that the pulse from a single WT is caused by the interaction of the blades against the pylon, while the rather more complex background signal relates to the radiation of the Tyler-Sofrin spinning modes*.

- *The random component of the infrasonic signal exceeds the coherent part, and this random component is related to wind noise, which appears to be similar whether one is near or far from a wind farm*."

36 It should be clear from the above that although ETSU concentrates on the absolute sound pressure volume, EAM most annoys by virtue of its tonal and impulsive characteristics.. BS4142:2014, Oct 2014 provides an important update on the guidance for assessing industrial and commercial sound. This may be become more relevant than earlier versions of the Standard as a means of assessing wind turbine sound and provide more effective noise control for people living near wind turbines. Section 9 describes how to determine the rating level and corrections to be applied in the event of tonal or impulsive characteristics of the specific sound. Also corrections can be applied in the event of intermittency and other sound characteristics. However, it is to be expected that the wind industry will fiercely oppose any efforts to replace ETSU with BS4142:2014.

37 A report by Stigwood *et al.* Nov 2014 provides an update on their March 2014 paper that documents for the first time the results of the continuous long term monitoring of noise at a UK wind farm site where intrusive EAM is a regular occurrence for local residents.

38 In a study that looks carefully at WTN character, Large and Stigwood, Nov 2014 concluded that:

- WTN character can be unique to each development and highly variable within each;
- Different assessment metrics result in contradictory outcomes of acceptability at each site. Whilst one aspect of noise character might be well characterised by a modulation index another noise characteristic might be better defined by a prominence rating. Other characteristics, such as rhythm, are ignored by all assessment parameters;
- The worst metric of assessment for noise character is that of a penalty applied to a noise limit, as currently proposed in the UK (by ReUK). Even where multiple assessment parameters are adopted, significant character features can still be neglected. The ability of noise measurements accurately to reflect the perception of the listener, including within the dwelling, is further questioned;
- Character in WTN is in need of serious review by the acoustics community. The current methods adopted to assess noise impact fail those affected and suggest compliance where significant adverse impacts continue to exist;
- Studies investigating how multiple character features interrelate to judgement of impact and the longitudinal impact of noise with character are also recommended.

39 Madsen *et al.* Nov 2014 concluded:

- The analysis of the spectra from flush mounted surface microphones on a 2MW turbine conducted in the DANAERO experiment shows a strong increase at low frequencies when the angle of attack (AoA) reaches 12-13^{o} where trailing edge stall initiates. For the turbine operating in a strong wind shear a modulation of the surface spectra for frequencies below 200Hz is 14dB. This is expected to generate AM or OAM in the far field;
- The statistics based on an analysis of about 2000 10min time series of measured AoA on the same turbine over a period of three weeks has shown that transient stall over part of a rotor revolution is likely to occur and in particular during wake operation. The meandering of the velocity deficit in the wake can cause abrupt changes in wind speed over the rotor disc and for a variable speed turbine the rotor might not be able to accelerate fast enough to avoid transient stall for a few revolutions. This intermittent occurrence corresponds well to the reported typical characteristic of OAM and the mechanism might explain many of the occurrences of OAM.

40 A significant advance in the recognition and understanding of low frequency effects has been made by Steven Cooper in Australia. Cooper, Nov 2014 found that the resident's observations identified "sensation" as the major form of disturbance from the Cape Bridgwater wind farm. Observations from the residents with respect to sleep disturbance indicate that for the rural setting of Cape Bridgewater, where the ambient noise levels at

night inside dwellings are typically below 15 dB(A), the 30 dB(A) Leq threshold level identified in the New Zealand Standard would appear to be an inappropriate threshold for the assessment of internal noise levels associated with wind farms. Cooper's work also confirms that there is a unique signature attributed to wind farms that involves a peak at the blade pass frequency and the first five harmonics of that frequency. He labels this unique infrasound pattern as its 'wind turbine signature'. When the turbines are operating there is a distinct frequency generated at 31.5 Hz that exhibits side bands on either side of that frequency at multiples of the blade pass frequency. This pattern confirms the presence of an amplitude modulated signal that is not present when the turbines are not operating. The study further confirms that the infrasound obtained in a wind farm affected environment is different to that in the natural environment. Monitoring in proximity to the WT towers found a significant variation in noise levels from the tower structure including the typical 'aircraft that never lands' signal often quoted by residents. The noise appeared to change with loading on the turbine. Monitoring of vibration near the towers indicates surges associated with wind gusts where a significant increase above the ambient vibration was recorded. The vibration surges described by some residents as disturbances during shutdown could be attributed to wind gusts exciting resonances of the blades/towers and requires further investigation.

41 Cooper's work was followed by an Australian Government statement NHMRC, Feb 2015 in which they call for more research on the health effects of WTN: '*Given the poor quality of current direct evidence and the concern expressed by some members of the community, high quality research into possible health effects of wind farms, particularly within 1,500 metres (m), is warranted*'.

42 In Huson-1, April 2015 it is shown that stationary turbines subject to high winds emit infrasound pressure below 8 Hz at levels similar to the infrasound emissions at blade pass frequencies and its harmonics. The stationary V112 turbine infrasound emissions are caused primarily by blade and tower resonances excited by the wind. This confirms the findings of Cooper, 2014 above.

43 In Huson-2, April 2015 the uncertainties and limitations associated with measuring instrumentation conforming to the IEC 61672 standard are identified. IEC 61672 is a commonly used instrumentation standard for sound level meters to ensure consistent results between different manufacturers. Whilst this and similar older versions of the standard provide some comfort regarding repeatability, they are not necessarily appropriate when trying to push the envelopes of sound level meter use. The author (Huson) is aware of numerous wind farm assessments, made in accordance with the ETSU methodology, where data has been used in preparing trend lines from background and post-construction operating conditions that is outside the range of measurement for which the sound level monitoring equipment is compliant with IEC 61672. Such charts are presented as examples of good practice in the IoA Good Practice Guide. Huson knows of no ETSU type assessment where account has been made for such non-compliant data that is outside the measurement range of the instruments. The IoA Supplemental Guideline Note 1, Data Collection needs to be amended to address these issues. Huson recommends that:

- Future research into AM record time histories utilising currently available sound level meters with sample rates of around 10ms as short Leq (not time weighted with Fast response). Such equipment is also compliant with IEC 61672;

- Z-weighting can provide large differences in readings between different sound level meters if the source contains infrasound typically found in wind turbine noise emissions at frequencies below 6 Hz. It would be a mistake to assume that dB(Z) results are accurate because there is compliance with IEC 61672;

- IEC 61672 currently does not include the standardisation of instruments suitable for the measurement of infrasound. Such a standard would prove useful considering the amount of planned research in this area.

44 The Northern Ireland Assembly's (NIA) Anna Lo, 2015 full inquiry into wind energy conducted by the Committee for the Environment provides what is probably the most comprehensive and credible review of the impacts of wind turbines carried out to date. The report stated that the issue of wind turbine noise was the most contentious aspect of the inquiry. The key recommendations from the report released March 2015 include:

- *'The Department should review the use of the ETSU-97 guidelines on an urgent basis, with a view to adopting more modern and robust guidance for measurement of wind turbine noise, with particular reference to current guidelines from the World Health Organisation. The Department should bear responsibility for ensuring that arrangements be put in place for on-going long-term monitoring of wind turbine noise;*
- *The Department, working with local universities, should commission independent research to measure and determine the impact of low-frequency noise on those residents living in close proximity to individual turbines and wind farms in Northern Ireland.'*

ETSU is heavily criticised in this report, which suggests that the BS4142 revisions (BS4141:2014) be considered when determining if ETSU should be updated. It is difficult to see how the administrations in the rest of the UK can reasonably ignore these most carefully evidenced recommendations.

45 Several informative papers were presented at the 6th International meeting on WTN in Glasgow during April 2015. Bradley 2015 showed that trailing edge noise from a turbine blade comprises sources that are not at fixed positions, but instead move periodically up and down. Corresponding to this sinusoidal vertical motion of the sound source, the intensity pattern on the ground moves in and out. At any one listener location, there is therefore a fluctuating intensity. A simple straight-line ray model shows that this mechanism explains the observed characteristics of WTN AM. This mechanism does not depend on intermittent stall, although increased source intensity obviously leads to increased modulation noise. Downward refraction also enhances the effect. This paper confirms the findings of Lee *et al.*, 2013 and others.

46 However, Cand 2015 continues with his weakened argument from the ReUK 2013 report that AM is the result of blade stall. This is continued by Cassidy 2015 representing the developer RES.

47 The significance of tower and blade resonance identified by Cooper, 2014 and Huson-1, April 2015 is made clear by Engelhardt 2015 in his paper describing the retrofitting of an active damping device (ADD) to wind turbine structures to reduce vibrations. Specific details of where the ADD is fitted are not provided but it can be assumed from Figure 2.3 in the paper that these devices are fitted to the turbine tower. The excitation source of the vibrations is not made clear although gearbox vibration from approximately 80Hz to several hundred Hz as one possible source of excitation is mentioned. However, once excited, the tower could not vibrate at these frequencies as tower and blade natural frequencies would be much lower.

48 Teruo Iwase Niigata *et al.* 2015 observed and analysed the vibrations from wind turbine components and detected near 1Hz vibrations on blades and towers. They concluded that for sound source modelling, these results clearly show the existences of two sound sources in the WTN. One is aerodynamic sound with broadness and low frequency prominent components caused by rotating blades in the strong wind flow and the other is remarkable discrete frequency components originated in the vibration of the power generation mechanical system (blades and tower). They together propagate to far surroundings.

The Conclusion

49 This review of evidence spanning over 30 years shows a clear evolution of knowledge relating to the science behind WTN and its effects on people. Starting with the NASA research conducted during the 1980s through to the NIA inquiry report of March 2015 and beyond, many of the key scientific aspects are now well understood and well defined.

50 The most important conclusion from this evidence is that the official UK wind turbine noise guidance, ETSU, is totally unfit for purpose and is failing to protect against the effects of EAM noise. Despite it being mildly updated and acquiring an IoA developed Good Practice Guide it was developed using evidence relevant only to small turbines far removed from the 80m hub height devices being deployed almost twenty years later, and does not reflect the more recent science.

51 Throughout this period since 1997 the wind industry, aided by its acoustic, political and legal consultants has sought to hide the true science behind EAM in WTN and its effects on people though a concerted strategy of obfuscation and political interference. This has been aided by compliant government officials who have been focused on removing barriers to the deployment of wind power generating capacity and by the wind industry effectively taking control of the Institute of Acoustics (IoA). The IoA Good Practice Guide to the application of ETSU, Perkins May 2013, subsequently approved by government is an example of how commercial interests and political lobbying have triumphed against science and wind turbine neighbours. At no point does it tackle any of the issues identified by the

research into EAM that we have reviewed above. Complaints regarding wind turbine noise currently classified as AM or EAM or OAM or 'greater than expected AM' by the wind industry is an obfuscation of the true nature of the problem. As a result, all efforts to date by third parties to have the ETSU noise guidelines revised or replaced with a science-based alternative have been successfully resisted.

4. The Case regarding Low Frequency Noise

The Denial

52 Section 3 of this review has looked at the science behind WTN prediction and especially what is known about EAM, it's most annoying feature. The wind industry in the UK and elsewhere were for many years successful in hiding this problem from government and the planning system and only now (2015) is beginning to face up to the implications of its existence. For many years the wind industry in the UK and in other countries has also been denying that there is a *low frequency noise* (LFN) issue. However the subject refuses to go away. Leading the effort to deny the LFN problem has been the UK wind power trade association, ReUK. The British Wind Energy Association (BWEA) Briefing Sheet, 2005 (BWEA has now become ReUK) is just one of the attempts by the wind industry and its acousticians to play down or simply deny that LFN is a problem. This briefing sheeting included the now infamous statement by Dr Geoff Leventhal that "*I can state quite categorically that there is no significant infrasound from current designs of wind turbines*."

53 Hayes McKenzie Partnership (HMP) in their 2006 report 'The measurement of low frequency noise at three UK wind farms' for the UK Government DTI also played down any LFN issue. The findings of this study were:

- *'Infrasound associated with modern wind turbines is not a source which will result in noise levels which may be injurious to the health of a wind farm neighbour;*
- *Low frequency noise was measureable on a few occasions, but below the existing permitted Night Time Noise Criterion. Wind turbine noise may result in internal noise levels within a dwelling that is just above the threshold of audibility, however at all sites it was always lower than that of local traffic noise;*
- *That the common cause of complaint was not associated with LFN, but with the occasional audible modulation of aerodynamic noise especially at night. Data collected showed that the internal noise levels were insufficient to wake up residents at these three sites. However once awoken, this noise can result in difficulties in returning to sleep.'*

The significance of infrasound, low frequency noise and vibration was also denied by McKenzie of HMP at All Energy 2005, McKenzie and a three year duration study and report into amplitude modulation by ReUK, Dec 2013 also avoided any connection with, and downplayed the significance of, LFN.

The Breakthrough

54 This consistent and persistent denial by the wind industry, its acousticians and by government officials charged with the deployment of wind power, that LFN was a problem for wind turbine neighbours received a serious setback with the release of the Wisconsin report, Dec 2012 by Walker, Hessler, Rand & Schomer. This report , discussed in more detail in the previous section, provides clear evidence that a wind turbine is indeed a unique

source of ultra-low frequency energy. It was also agreed by each of the authors that infrasound from wind turbines is an important issue that needs to be resolved in a more conclusive manner.

55 The report also noted that currently the wind turbine industry presents only A-weighted octave band data down to 31 Hz and have stated that wind turbines do not produce low frequency sound energies. Their measurements at Shirley have clearly shown that low frequency infrasound is present and relevant and that A-weighting is totally inadequate and inappropriate for the description of this infrasound.

56 These Wisconsin report findings correlate with the NASA research from the 1980s regarding the significance of LFN discussed in the previous section.

The Evidence

57 During December 2014 another major advance in understanding LFN was the release of the Cape Bridgewater study by Steven Cooper of The Acoustic Group, Australia. This study appears to be the first of its kind in Australia and is a joint exercise between a wind farm operator and residents. It therefore provides information not normally available in the usual a one sided acoustic assessment of a wind farm.

58 As we have seen, the study found that the resident's observations identified "sensation" as the major form of disturbance from the wind farm. It was confirmed that there is a unique signature attributed to wind farms that involves a peak at the blade pass frequency and the first five harmonics of that frequency. This unique infrasound pattern has been labelled by the author as the 'wind turbine signature'. This signature is present when the turbines are operating but does not occur with the wind farm shut down.

59 Monitoring in proximity to the towers found a significant variation in noise levels from the tower structure including the typical 'aircraft that never lands' signal often quoted by residents. The noise appeared to change with loading on the turbine. Monitoring of vibration near the towers indicates surges associated with wind gusts where a significant increase above the ambient vibration was recorded. The vibration surges described by some residents as disturbances during shutdown could be attributed to wind gusts exciting resonances of the blades/towers and requires further investigation.

60 This report has been well received in the acoustics community with letters to its authors from:

- Robert Rand Jan 2015 who wrote; "Congratulations *on this superlative work investigating the neighbor reports and correlating (unintended) adverse effects of the facility. The scope and detail of your report is sure to assist acoustic investigators, planners, utilities, and the public to understand without any further doubt or dismissal what wind turbine neighbors have been saying for years, as you so clearly sum up, ("What we found was that previously they were complaining about the noise, but it wasn't really the noise, it was sensations.").*

- And from Stephen Ambrose Jan 2015 who wrote; "*Your study goes far beyond the 1980s Neil Kelley et al. studies that identified operating wind-turbines can produce airborne transmissions that humans detect as "sensations". Bray/James research showed that one-third octave band filters could not measure the low-frequency peaks produced by wind-turbines. Neighbors' complaints were ignored by the majority. Acoustic experts failed to understand the limitations of their instruments and analysis methods*".

61 When we review these Kelley *et al*. studies we discover that much of what is being 'discovered' now about LFN was well known during the 1980s following research carried out in the USA by NASA and the Solar Energy Research Institute (SERI) for the US Department of Energy. Research was carried out on the MOD-1 wind turbine, a downwind design followed later by research on the MOD-2 wind turbine, Kelley 1988, an upwind design. Both turbine types were found to generate LFN with the upwind type (a design feature adopted for modern large turbines) producing reduced but still significant levels of LFN. Findings from the MOD-1 turbine, Kelley et al. SERI Feb 1985 were:

- *The annoyance was described as an intermittent "thumping" sound accompanied by vibrations;*
- *A "feeling" or "presence" was described, felt rather than heard, accompanied by sensations of uneasiness and personal disturbance;*
- *The "sounds" were louder and more annoying inside the affected homes.*

Field measurements and model results led to the following conclusions:

- *The annoyance was real and not imagined;*
- *The responsible acoustic impulses were being propagated through the air and, in some instances, being focused on the complainants' homes as a consequence of ground reflection and refraction by the atmosphere.*

62 Research was carried out on the response of buildings excited by noise from a wind turbine by Hubbard *et al.* Nov 1984. Their report concluded that WTN input pulses resulted in acceleration pulses for the wall and window elements of two test buildings. The levels for particular frequencies and locations can be higher than the outside levels. Closing windows and doors will not protect residents from this internally generated LFN.

63 A paper on assessing community annoyance from wind turbine LFN, by Kelley Nov 1987 found that it was possible to cause annoyance within homes in the surrounding community with relatively low levels of LFN. An extensive investigation of the MOD-1 situation revealed that this annoyance was the result of a coupling of the turbine's impulsive LF acoustic energy into the structures of some of the surrounding homes. This often created an annoyance environment that was frequently confined to within the home itself. The paper presented results showing internal sound pressure levels of up to 10dB greater than external where low frequencies are present.

64 The ranked responses to four annoyance categories were correlated with the four stimuli sequences by regression. Immediately obvious is the superiority of the five metrics (weightings) that pass significant low frequencies in comparison with the A-weighted scale. These results, limited as they are, seem to confirm that:

- *People do indeed react to a low frequency noise environment; and*
- *A-weighted measurements are not an adequate indicator of annoyance when low frequencies are dominant.*

65 Styles *et al*. in their April 2011 paper concerned with monitoring wind turbine LFN provide evidence of the low frequency vibration of the towers in the 4 to 5 Hz band confirming the 1980s US government research.

66 A letter from the wind turbine manufacturer Vestas, Engel June 2011 to the Danish government demonstrates knowledge that LFN is a problem for the wind industry. This request to allow higher levels of low frequency noise from wind turbines than was being proposed at the time. This request was clearly based on commercial considerations ignoring any potential impact for people who may be affected.

67 As we have seen, analysis of WTN by Vanderkooy and Mann, Oct 2014, reveals a characteristic infrasonic pulse:

- "*We conjecture that the pulse from a single WT is caused by the interaction of the blades against the pylon, while the rather more complex background signal relates to the radiation of the Tyler-Sofrin spinning modes. The random component of the infrasonic signal exceeds the coherent part, and this random component is related to wind noise, which appears to be similar whether one is near or far from a wind farm*".

68 Huson 1, April 2015 provides evidence of stationary wind turbines emitting infrasound below 8 Hz during high wind conditions due to resonances of blades and towers confirming the findings of Cooper Nov 2014. In Huson 2, April 2015 he provides evidence that available sound meters compliant with IEC 61672 are unsuitable for measurements where infrasound is present as typically found in WTN emission at frequencies below 6 Hz or where there are low background noise levels.

69 Finally, we have seen, the NIA's inquiry, Anna Lo, 2015 into wind energy conducted by the Committee for the Environment provides what is probably the most comprehensive and credible review of the impacts of wind turbines carried out to date. One of the key recommendations from the Northern Ireland Assembly's inquiry into wind energy is:

- "*The Department, working with local universities, should commission independent research to measure and determine the impact of low-frequency noise on those residents living in close proximity to individual turbines and wind farms in Northern Ireland*".

The Conclusion on LFN

70 The available evidence demonstrates conclusively that:

- LFN including infrasound is an integral component of WTN emissions;
- Conditions giving rise to noise complaints are often characterised by 'sensation' as being the major form of disturbance. The 'noise' may not even be audible in some cases;
- Noise measurement using the A weighting is unsuitable for measuring WTN where low frequency components are present;
- Noise measurements should be made inside homes when investigating noise complaints;
- Noise measurements where LFN is present should be made using suitable instrumentation. IEC 61672 compliant instrumentation is unsuitable for LFN or where background noise levels are low as in typical rural areas;
- ETSU is not 'fit for purpose' for assessing LFN in WTN.

5 The case against ETSU

71 Given the earlier results of research into EAM and LFN, it is surprising to find that they were ignored when during 1996 the UK Government and wind industry produced the ETSU noise guidance for the UK. When we read ETSU we find:

- LFN is not considered despite the evidence that it is a significant component of wind turbine noise;
- Amplitude modulation greater than 3dB (EAM) is not considered despite the evidence from the 1980s research;
- Noise measurement is made using the A weighting despite the evidence that this is the most unsuitable when low frequency is present;
- Measurements are made only outside (in free field conditions) and not inside homes despite the evidence that LFN can result in higher noise levels and annoyance inside;
- It failed to properly consider wind shear and its effects on noise levels, especially at night;
- Night time noise limits were set higher than day time limits.

It is even more surprising to find that the more recent 2012 IoA sponsored Good Practice Guide to the implementation of ETSU, now more or less mandatory in wind turbine noise assessments in UK, also by and large ignores these same issue. It is difficult to believe that the acoustic experts that have provided advice to government when ETSU was being written and since would have been unaware of them.

72 ETSU has been heavily criticised including Bowdler July 2005 who stated:

- "*ETSU is so poor technically that its conclusions have to be queried. It is put together through a series of unfounded assertions and there has been no research drawn on to justify them*";
- "*The night time level is 43dB(L_{Aeq}) and the day time level is 37 to 42dB(L_{Aeq}). Most wind farm sites are in rural areas where background noise levels can easily be 20 to 25dBA when turbines are operating and so the margin above background could be up to 20dB or more*."

(Author correction: It should be noted that the ETSU night time limit is 43dB (LA90) not LAeq and the daytime limit is between 35dB and 40dB LA90)

73 The Northern Ireland Assembly report, January 2015 on the committee's inquiry into wind energy provides what is probably the most comprehensive and credible review of its kind. The key findings and conclusions relating to wind turbine noise included the recommendation that the Department should **review the use of the ETSU-97 guidelines on an urgent basis,** with a view to adopting more modern and robust guidance for measurement of wind turbine noise, with particular reference to current guidelines from the World Health Organisation.

Appendix A - Literature Summaries

A summary of each reference document is listed in chronological order. Much of the content of these summaries has been taken directly from the relevant documents.

Title: Prescription Act 1832
Platform: HM Government
Authors: HM Government
Date: 1 Aug 1832

Summary
Only relevant in view of the reference to it in Coventry v Lawrence, this Act specifies the periods over which a land owner may acquire an easement against another land owner.

Title: Rylands v Fletcher
Platform: House of Lords
Authors: House of Lords
Date: 17 July 1868

Summary
A judgement of the House of Lords which determined that if you store dangerous material on your land you can be legally responsible even if not negligent. There have been many decisions since which restrict the scope of this judgement and it is highly unlikely to be relevant in cases of wind farm noise.

Title: Guide to the evaluation of human exposure to noise from large wind turbines
Platform: National Aeronautics and Space Administration (NASA), USA
Authors: David G Stephens, Kevin P Shepherd, Harvey H Hubbard, Ferdinand W Grosveld
Date: March 1982

Summary
This document is intended for use in designing and siting future large wind turbine systems as well as for assessing the noise environment of existing wind turbine systems. Guidance for evaluating human exposure to wind turbine noise is provided and includes consideration of the source characteristics, the propagations to the receiver location and the exposure of the receiver to the noise. The criteria for evaluation of human exposure are based on comparisons of the noise at the receiver location with the human perception thresholds for wind turbine noise and noise-induced building vibrations in the presence of background noise.

The report concludes with the recommendation: "*The recommended design /siting goal is that the levels of noise and vibration at the receiver location be below the perception thresholds at the appropriate background noise conditions*".

Title: Noise induced house vibrations and human perception
Platform: Noise Control Engineering Journal Sept / Oct 1982
Author: Harvey H Hubbard
Date: September 1982

Summary
This report summarizes noise induced house responses including frequencies, mode shapes, acceleration levels and outside-to-inside noise reductions. The role of house vibrations in reactions to environmental noise is defined and some human perception criteria are reviewed.

On low frequency noise perception the report states: that there are fragmentary reports that indicate some unusual reactions to noise at very low frequencies, particularly when such noises are observed inside a structure or a vehicle. The data of Fig. 12 are representative of some of the documented cases. A number of these are cited where low frequency noise from industrial operations has propagated relatively long distances into residential areas and has resulted in complaints. In all cases the levels of the higher frequency noise portions of the spectra were judged to be well within known tolerable limits. The low frequency components (below 125 Hz) are thus believed to be most significant. It can be seen that many of the frequency-noise level combinations are below those of the well-established hearing thresholds of Refs. 31 and 32. Thus there is an indication that there are significant extra-auditory effects such as noise induced house vibrations, or that there are localized areas in the houses where the inside noise levels are considerably higher than the limited measurements, and may actually exceed the threshold of hearing.

The report concludes with: 'House buildings respond readily to noise excitations and their responses can play an important role in community reactions to noise. Walls, floors, ceilings and large windows respond mainly in the "oil canning" modes at frequencies below 100 Hz and their motions are controlled largely by the beam elements.

Title: Some individual differences in human response to infrasound
Platform: University of Waterloo and Institute for Aerospace Studies, University of Toronto
Authors: DS Nussbaum, S Reinis
Date: April 1984

Summary
The adverse responses of some individuals closely resemble motion sickness. Individual differences in the reaction to infrasound may then be explained by variability of inner-ear structure or central adaptive mechanisms.

Title: Response measurements for two building structures excited by noise from a large horizontal axis wind turbine generator
Platform: National Aeronautics and Space Administration (NASA), USA
Authors: Harvey H Hubbard, Kevin P Shepherd
Date: November 1984

Summary
The noise from large wind turbine generators may, under some conditions, cause building structures to vibrate. These structural vibrations can be observed by occupants of the buildings and thus may be a factor in community reaction. In this study window and wall acceleration measurements were made on two different building structures during excitation by noise from the, WTS-4 wind turbine generator. This paper presents data and compares the results with similar building response data from aircraft and helicopter flyover noise tests and sonic booms.

The report concluded wind turbine noise input pulses resulted in acceleration pulses for the wall and window elements of two test buildings. Response spectra suggest that natural vibration modes of the structures are excited. Responses of a house trailer were substantially greater than those for a building of sturdier construction. Peak acceleration values correlate well with similar data for houses excited by flyover noise from commercial and military airplanes and helicopters, and sonic booms from supersonic aircraft. Interior noise spectra have peaks at frequencies corresponding to structural vibration modes and room standing waves; and the levels for particular frequencies and locations can be higher than the outside levels.

Title: Acoustic noise associated with the MOD-1 wind turbine: Its source, impact and control
Platform: Solar Energy Research Institute for US Department of Energy
Authors: ND Kelley, HE McKenna, RR Hemphil, CL Etter, RL Garrelts, NC Linn
Date: February 1985

Summary
This document summarizes the results of an extensive investigation into the physical factors surrounding noise complaints related to the DOE/NASA MOD-1 wind turbine operating near Boone, North Carolina. Complaints of noise emanating from the operating MOD-l were confined to about a dozen families living within a 3-km radius of the turbine, about half of whom were annoyed frequently. In summary, the complaints centred on the following perceptions:

- The annoyance was described as an intermittent "thumping" sound accompanied by vibrations.
- A "feeling" or "presence" was described, felt rather than heard, accompanied by sensations of uneasiness and personal disturbance.
- The "sounds" were louder and more annoying inside the affected homes.

These field measurements and model results allowed us to conclude the following:

- The annoyance was real and not imagined.
- The source of the annoyance was aerodynamic and involved the passage of the turbine blades through the lee wakes of the large, 0.5-m cylindrical tower legs.
- The coherent characteristics of the radiated acoustic impulses (produced by the leg wake-blade interaction) were responsible for the annoyance of the complaining residents.
- The responsible acoustic impulses were being propagated through the air and, in some instances, were focused on the complainants' homes as a consequence of ground reflection and refraction by the atmosphere.

An investigation into the role atmospheric propagation plays in the MOD-1 annoyance has shown that surface and ground propagation are negligible in comparison with a combination of terrain reflection and atmospheric refraction. Strong focusing (25 dB or more) of the emitted MOD-1 acoustic impulses as a result of these processes can account for local, far-field enhancements (caustics).

Title: A proposed metric for assessing the potential of community annoyance from wind turbine low frequency noise emissions
Platform: Windpower 87 conference, San Francisco
Author: ND Kelley, Solar Energy Research Institute for US Department of Energy
Date: November 1987

Abstract
Given our initial experience with the low-frequency, impulsive noise emissions from the MOD-1 wind turbine and their impact on the surrounding community, the ability to assess the potential of interior low-frequency annoyance in homes located near wind turbine installations may be important. Since there are currently no universally accepted metrics or descriptors for low frequency community annoyance, we performed a limited program using volunteers to see if we could identify a method suitable for wind turbine noise applications. The results are presented in this paper. We discuss our modifications of the highest correlated predictor to include the internal dynamic pressure effects associated with the response of residential structures to low-frequency acoustic loads. Finally, we outline a proposed procedure for establishing both a low-frequency "figure of merit" for a particular wind turbine design and, using actual measurements, estimate the potential for annoyance to nearby communities.

Summary
The modern wind turbine radiates its peak sound power (energy) in the very low frequency (VLF) range, typically between I and 10 Hz. This is a direct consequence of its small rotor solidity and relatively low rotational (shaft) speed (17.5-300 rpm). Other common rotating machinery employing lifting blades (such as the large fans and blowers associated with forced-draft cooling towers and ventilation systems) generally radiate their peak sound powers at frequencies greater than 60 Hz. This higher frequency is due to a combination of high rotor solidity and much faster shaft speeds.

Experience with the low-frequency noise emissions from a single, 2-MW MOD-1 wind turbine demonstrated that, under the right circumstances, it was possible to cause annoyance within homes in the surrounding community with relatively low levels of LF-range acoustic noise. An extensive investigation of the MOD-1 situation revealed that this annoyance was the result of a coupling of the turbine's impulsive LF acoustic energy into the structures of some of the surrounding homes. This often created an annoyance environment that was frequently confined to within the home itself. The paper concludes with:

The results showed internal sound pressure levels of up to 10dB greater than external where low frequencies are present.

The ranked responses to the four annoyance categories were correlated with the four stimuli sequences by regression. Immediately obvious is the superiority of the five metrics (weightings) that pass significant low frequencies in comparison with the A-weighted scale. These results, limited as they are, seem to confirm that

- People do indeed react to a low frequency noise environment and
- A-weighted measurements are not an adequate indicator of annoyance when low frequencies are dominant.

Title: The MOD-2 Wind Turbine: Aero-acoustical noise sources, emissions and potential impact
Platform: US Department of Energy
Author: ND Kelley, Solar Energy Research Institute
Date: January 1988

Summary
This report summarizes extensive research by the staff of the Solar Energy Research Institute into characteristics of acoustic noise emissions of the DOE/NASA MOD-2 wind turbine. The results of this study have shown that the MOD-2 noise levels are well below annoyance thresholds within residential structures a kilometre or more from the turbine rotor. It was also found that the inflow turbulent structure has a major influence on the level and characteristics of the low-frequency (2-160 Hz) range acoustic emissions which, in turn, have implications for the associated structural response of the rotor assembly. The high-frequency range (A-weighted) levels were found to vary primarily with the mean hub-height wind speed. In addition, the rotor inflow turbulence characteristics at the Goodnoe Hills Site were found to be controlled almost entirely by the diurnal variation in the vertical stability of the first 100 m of the atmospheric boundary layer.

Title: Wind turbine acoustics research - bibliography with selected annotation
Platform: NASA
Authors: Harvey H Hubbard, Kevin P Shepherd
Date: January 1988

Summary
This document has been prepared as part of the US Department of Energy Wind Energy program conducted during the 1980s which was managed by the Solar Energy Research Institute. It is a selected bibliography, with some annotation, of wind turbine acoustics research papers. They are grouped together for convenience into the following sections:

- General Wind Turbine Acoustics Publications;
- Wind Turbine Noise Generation,
- Prediction and Measurements;
- Wind Turbine Noise Propagation;
- Effects of Wind Turbine Noise on People and Communities;
- Effects of Wind Turbine Noise on buildings; and
- Wind Turbine Noise Measurement Technology.

Title: Town and Country Planning Act 1990
Platform: HM Government
Authors: HM Government
Date: 24 May 1990

Summary
Part VII of the T&CP Act gives the procedure for the service of, appeal against and (if upheld) enforcement of Enforcement Notices to remedy breaches of planning control.

Title: Environmental Protection Act 1990
Platform: HM Government
Authors: HM Government
Date: 1 Nov 1990

Summary
Part III if this Act states the law relating to Statutory Nuisance and how it should be dealt with and prosecuted. For commercial wind farms, it contains a defence of “best practical means”, a defence which is noted in ETSU.

Title: Circular 11/95: The use of conditions in planning permissions
Platform: Department for Communities and Local Government (DCLG)
Authors: DCLG
Date: 20 July 1995

Summary
The relevant document at the time of the Den Brook appeal and Court of Appeal judgment. This specifies the requirements for a valid planning condition, all of which must apply for any planning condition to be valid and enforceable. The Circular also contains a number of model conditions.

The Circular was not revoked by the National Planning Policy Framework (NPPF) although paragraph 206 reiterated these requirements. The Circular has however been revoked (except for the model conditions) as a result of the Planning Practice Guidance issued in March 2014

Title: ETSU-R-97 The assessment & rating of noise from wind farms
Platform: Department of Trade & Industry, UK
Authors: Noise working group
Date: Sept 1996

Summary
This report describes the findings of a Government sponsored working group on wind turbine noise. The working group consisted of representatives of Government and the wind industry. It was realised by the late 1990s by the Government and the wind industry that in order to deploy wind power in quiet rural locations and achieve Government renewable targets, a more permissive noise assessment methodology together with higher noise limits would be required.

Despite the existing noise standard for similar industrial development, BS4142 having a successful long term record of providing effective and reasonable protection against excessive industrial noise, the Government sought to overrule BS4142 and allow higher noise levels for people that might be affected by wind power development. Importantly, ETSU-R-97 (ETSU) failed to recognise the significance of amplitude modulation, only anticipating modulation levels of up to 3dB(A) peak to trough and only close to the turbine. AM was not expected in the far field at dwellings.

Potential noise impact is assessed by the ETSU guidelines by comparing averaged background noise against predicted turbine noise for a range of wind speeds. Noise limits are set at 5dB above the averaged background noise with absolute minimum limits. These minimums are set between 35dB and 40dB LA90 during daytime and evening and 43dB LA90 for nigh time. ETSU is unusual in allowing higher noise levels at night than during the daytime. These limits may be increased to 45dB at all times if the occupier of the property has some financial interest in the wind farm.

ETSU became the formal standard for wind turbine noise assessment from 1997and has continued to be relied upon by Government and planning decision makers to the present day. Despite the science behind ETSU being heavily criticised for many years and it having been proved that it does not to provide adequate protection against noise impact, Government with support from the wind industry has resisted reviewing or replacing ETSU or the noise limits.

Title: BS4142:1997 Method for rating industrial noise affecting mixed residential and industrial areas
Platform: British Standards Institute, UK
Authors: BSI
Date: 15 Sept 1997

Summary
BS4142 was first published March 1967, with a second edition November 1990 and this third edition in September 1997. This British Standard describes the methods for determining at the outside of a building:

a) Noise levels from factories or industrial premises or fixed installations or sources of an industrial nature in commercial premises and
b) Background noise level.

The standard also describes a method for assessing whether the noise referred to in (a) is likely to give rise to complaints from people residing in the building.

BS4142 recognises that certain acoustic features can increase the likelihood of complaint over that expected from a simple comparison between the specific noise level and the background noise level. Where present at the assessment location, such features are taken into account by adding 5dB to the specific noise level to obtain the rating level.

BS4142 requires a 5dB correction if one or more of the following features occur:

- The noise contains a distinguishable discrete continuous note (whine, hiss, screech, hum etc.)
- The noise contains distinct impulses (bangs, clicks, clatter or thumps)
- The noise is irregular enough to attract attention

BS4142 assesses the likelihood of complaints by subtracting the measured background noise level from the rating level (corrected noise from the industrial source). The greater this difference the greater the likelihood of complaints:

- A difference of +10dB or more indicates that complaints are likely
- A difference of +5dB is of marginal significance.

Title: Human Rights Act 1998
Platform: HM Government
Authors: HM Government
Date: November 1998

Summary
The Act which brought the ECHR into UK law. It has aroused much criticism and the Conservative Party has given a clear indication that if they are elected to form the next government, they are likely to repeal it and replace it with a Bill of Rights. It is not the function of this exercise to question that proposal.

Title: Wilkinson v Rossendale Borough Council
Platform: High Court
Author: Mr Justice Sullivan
Date: May 2002

Summary
Not a wind farm case but one which considered the effect of an application to "vary" a planning condition under Section 73 of the TCP Act. The case determined that the application is in fact for a new permission where, if granted, reconsiders all planning conditions, not just the one in question.

Title: Effects of the wind profile at night on wind turbine sound
Platform: Journal of Sound and Vibration
Author: G.P. van den Berg
Date: 22 Sept 2003

Abstract
Since the start of the operation of a 30MW, 17 turbine wind park, residents living 500 m and more from the park have reacted strongly to the noise; residents up to 1900m distance expressed annoyance. To assess actual sound immission, long term measurements (a total of over 400 night hours in 4 months) have been performed at 400 and 1500m from the park. In the original sound assessment a fixed relation between wind speed at reference height (10 m) and hub height (98 m) had been used. However, measurements show that the wind speed at hub height at night is up to 2.6 times higher than expected, causing a higher rotational speed of the wind turbines and consequentially up to 15 dB higher sound levels, relative to the same reference wind speed in daytime. Moreover, especially at high rotational speeds the turbines produce a 'thumping', impulsive sound, increasing annoyance further. It is concluded that prediction of noise immission at night from (tall) wind turbines is underestimated when measurement data are used (implicitly) assuming a wind profile valid in daytime.

Title: Problems related to the use of the existing noise measurement standards when predicting noise from wind turbines and wind farms
Platform: Auswea 2004 Conference
Authors: Erik Sloth, Niels Christian Moller, Vestas, Ejler Kristensen, Bonus Energy and Bo Sonderfaard, Delta
Date: July 2004

Summary
This presentation was given at the Auswea 2004 conference covering problems with wind turbine noise measurements, noise prediction and noise assessment.

Title: Perception and annoyance due to wind turbine noise
Platform: Acoustical Society of America 2004
Authors: Eja Pederson, Kerstin Persson Waye
Date: December 2004

Abstract
Installed global wind power increased by 26% during 2003, with U.S and Europe accounting for 90% of the cumulative capacity. Little is known about wind turbines' impact on people living in their vicinity. The aims of this study were to evaluate the prevalence of annoyance due to wind turbine noise and to study dose–response relationships. Interrelationships between noise annoyance and sound characteristics, as well as the influence of subjective variables such as attitude and noise sensitivity, were also assessed. A cross-sectional study was performed in Sweden in 2000.

Responses were obtained through questionnaires (n=351; response rate 68.4%), and doses were calculated as A-weighted sound pressure levels for each respondent. A statistically significant dose–response relationship was found, showing higher proportion of people reporting perception and annoyance than expected from the present dose–response relationships for transportation noise. The unexpected high proportion of annoyance could be due to visual interference, influencing noise annoyance, as well as the presence of intrusive sound characteristics. The respondents' attitude to the visual impact of wind turbines on the landscape scenery was found to influence noise annoyance.

Title: Toora wind farm - Review of the environmental noise monitoring program
Platform: South Gippsland Shire Council, Victoria, Australia
Author: James Fowler
Date: 27 January 2005

Introduction
The brief for the study commissioned by South Gippsland Shire included:

- Study documents in regard to Toora WTGs, including permit conditions, documents to Council on background noise monitoring and WTG monitoring.
- Prepare review on monitoring procedures including matters as discussed earlier.
- Prepare advice regarding the whole monitoring program. Legal implications which would need to be referred to a solicitor.

Title: Low frequency noise and wind turbines
Platform: BWEA (now RenewableUK)
Authors: J Bass, A Bullmore, M Hayes, M Jiggins, G Leventhall, A McKenzie, M Trinick
Date: February 2005

Summary
This briefing sheet issued by the British Wind Energy Association (BWEA), provides information on the issue of low frequency noise and wind turbines. It concludes with:

With regard to effects of noise from wind turbines, the main effect depends on the listener's reaction to what they may hear. There are no direct health effects from noise at the level of noise generated by wind turbines. It has been repeatedly shown by measurements of wind turbine noise undertaken in the UK, Denmark, Germany and the USA over the past decade, and accepted by experienced noise professionals, that the levels of infrasonic noise and vibration radiated from modern, upwind configuration wind turbines are at a very low level; so low that they lie below the threshold of perception, even for those people who are particularly sensitive to such noise, and even on an actual wind turbine site.

In response to concerns that wind turbines emit infrasound and cause associated health problems, Dr Geoff Leventhall, Consultant in Noise Vibration and Acoustics and author of the Defra Report on Low Frequency Noise and its Effects, says: "*I can state quite categorically that there is no significant infrasound from current designs of wind turbines*."

Title: Prediction and assessment of wind turbine noise (Bulletin Method)
Platform: Institute of Acoustics: Acoustics Bulletin
Authors: Andrew Bullmore, Andy McKenzie, Bob Davis, Dick Bowdler, Geoff Leventhall, Malcolm Hayes, Mark
Date: March 2005

Summary
This article placed in the Acoustics Bulletin becoming known as the 'Article Method' or the 'Bulletin Method' attempts to address:

1. The treatment of wind shear during noise assessments.
2. The prediction of turbine noise levels at receptor locations.
3. The significance of vibration and low frequency noise from wind turbines.

These methodologies for the treatment of wind shear and turbine noise prediction have since been adopted by the IoA in the Good Practice Guide released May 2013. However, both these methodologies have been heavily criticised.

Additionally, the IoA has continued to deny that low frequency noise has any effect on wind farm neighbours. However, evidence now emerging is showing that low frequency noise is a key factor in the phenomenon known generally as amplitude modulation.

Title: Infra-sound, low frequency noise & vibration from wind turbines
Platform: All Energy 2005
Author: Andy McKenzie, HMP
Date: March 2005

Summary
The presentation concluded that:

- Infrasound was well below the established threshold for the most sensitive 5-10% of the population.
- That wind turbines produce broad band not low frequency noise.
- That vibration was well below UK criteria for 'critical working areas' at 100m from the turbine.

Title: ETSU-R-97; Why it is wrong
Platform: New Acoustics
Author: Dick Bowdler
Date: July 2005

Summary
This paper written ten years ago describes the ETSU-R-97 (ETSU) noise guidelines written some eight years previously as a '*thoroughly flawed document*'. The paper takes to task the arguments made by the Government noise working group for justifying the use of a special

set of noise guidance (ETSU) for wind turbines and for not using BS4142 as applies for all other forms of mixed industrial and residential areas.

The paper concludes with

- ETSU is so poor technically that its conclusions have to be queried. It is put together through a series of unfounded assertions and there has been no research drawn on to justify them.
- The night time level is 43dB(L_{Aeq}) and the day time level is 37 to 42dB(L_{Aeq}). Most wind farm sites are in rural areas where background noise levels can easily be 20 to 25dBA when turbines are operating and so the margin above background could be up to 20dB or more.

(INWG correction: It should be noted that the night time limit is 43dB (LA90) not LAeq and the daytime limit is between 35dB and 40dB LA90)

Now ten years later in 2015 there still has not been any meaningful research to justify the assumptions made in ETSU and the numbers of noise complaints nationally have confirmed Bowdler's claim that the noise limits are far too high for rural areas.

Title: Supplementary planning document: wind power
Platform: Huntingdonshire District Council, UK
Author: Richard Probyn
Date: February 2006

Summary
This supplementary planning document provides planning guidance and an initial indication of the relative sensitivity and capacity of different areas of Huntingdonshire to accommodate wind turbines.

Title: The measurement of low frequency noise at three UK wind farms (Final report a 3rd draft obtained following a FOI request)
Platform: UK Department of Trade and Industry (DTI)
Authors: HMP
Date: 2006

DTI Summary included:
In January 2004, an article in the national press, alleged that Low Frequency Noise (LFN) emissions from wind turbines had given rise to health effects to neighbours of three wind farms in Cumbria, North Wales & Cornwall. As a result the DTI commissioned an independent study to investigate the levels and effects of infrasound and Low Frequency Noise in dwellings neighbouring these three wind farms from which complaints had been received. Of the 126 wind farms operating in the UK, five have reported low frequency noise

problems. Therefore, such complaints are the exception rather than a general problem which exists for all wind farms. The findings of this study were:

- Infrasound associated with modern wind turbines is not a source which will result in noise levels which may be injurious to the health of a wind farm neighbour.
- Low frequency noise was measureable on a few occasions, but below the existing permitted Night Time Noise Criterion. Wind turbine noise may result in internal noise levels within a dwelling that is just above the threshold of audibility, however at all sites it was always lower than that of local traffic noise.
- That the common cause of complaint was not associated with LFN, but with the occasional audible modulation of aerodynamic noise especially at night. Data collected showed that the internal noise levels were insufficient to wake up residents at these three sites. However once awoken, this noise can result in difficulties in returning to sleep.

However, following a Freedom of Information (FOI) request, a redacted 3rd draft of the report was obtained. This showed that the original draft included:
"*To reduce the potential for such situations with future wind turbines, it is recommended that consideration be given to a revision of the night-time absolute noise criterion proposed within ETSU-R-97 and the development of an assessment methodology to take account of periods when high levels of aerodynamic modulation are found at a neighbouring receptor location*". This was subsequently removed by DTI (now DECC) officials and replaced with the more benign statement: "*To take account of periods when aerodynamic modulation is a clearly audible feature within the incident noise, it is recommended that a means to assess and apply a correction to the incident noise is developed. However, it is beyond the scope of this report to consider the issue of appropriate assessment and acoustic feature methodologies for this character within the incident noise from a wind farm/turbine*".

The 3rd draft included the statement: "*A difficulty in returning to sleep will result in tiredness the next day and all the associated descriptions of ill health which might be associated with a lack of sleep*." This was removed from the final report in response the DTI official comment "*this sentence is dangerous and could be read that windfarms cause ill-health which is not the intention. We need the report to stick to the facts that LFN is below the guidelines but that once woken by a car there may be problems getting back to sleep for those with sensitive hearing as result of the windfarm – something like that*".

Title: Research into aerodynamic modulation of wind turbine noise: Final report
Platform: University of Salford for Department for Business & Regulatory Reform
Authors: Andy Moorhouse, Malcolm Hayes, Sabine von Hunerbein, Ben Piper, Mag Adams
Date: July 2007

Summary
This report commissioned by DEFRA follows on from a 2005 report by Hayes McKenzie Partnership for the DTI in which low frequency noise from wind farms was investigated.

Their report concluded that the complaints were not caused by low frequency noise, but by amplitude modulation of aerodynamic noise (AM) from the wind turbines.

The aims of this study (also known since as the Salford report) are to ascertain the prevalence of AM on UK wind farm sites, to try to gain a better understanding of the likely causes, and to establish whether further research into AM is required. The study was carried out in four parts, a survey of local authorities with windfarms in their areas, further investigation of sites for which AM was identified as a factor, a literature review and a survey of wind turbine manufacturers.

The results showed that 27 of the 133 windfarm sites operational across the UK at the time of the survey had attracted noise complaints at some point. AM was considered to be a factor in four of these sites, and a possible factor in another eight. Regarding the four sites, analysis of meteorological data suggests that the conditions for AM would prevail between about 7% and 15% of the time. AM would not therefore be present most days, although it could occur for several days running over some periods.

The literature review indicated that, although there has been much research into the general area of aerodynamics, regarding the specific phenomenon of AM there has been little research and the causes are still the subject of debate. AM is not fully predictable at current state of the art. The survey of wind turbine manufacturers revealed that, although there was considerable interest, few claimed to have any experience of AM.

The report concluded 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.

This report has been heavily criticised for its poor methodology and its failure to identify many wind farms where complaints had occurred and for not correctly identifying the nature of noise complaints they did identify as being AM related. However, the Salford report has been widely quoted by the wind industry since 2007 to justify their argument that AM rarely occurs and where it does occur its occurrence is infrequent.

Title: Auralization and assessments of annoyance from wind turbines
Platform: Second international meeting on wind turbine noise, Lyon, France
Author: Soren Vase Legarth
Date: 20 Sept 2007

Abstract
Noise from wind turbines is of great concern for the neighbours. Both the sound level and other characteristics of the wind turbine noise are of significance for the annoyance. By applying a model for sound propagation, it is possible to auralize the sound from the wind turbines at the neighbouring residents. This approach potentially gives a more realistic presentation of the actual wind turbine noise as input to the decision-making process. In the present work, five different wind turbines were recorded and auralized at two distances

using the Nord2000 propagation model. 20 subjects rated the processed recordings on overall annoyance both with and without additional natural background noise. Relevant sound attributes like loudness, pace, tonality and swishing sound were also rated by the subjects and compared with physical metrics. As a result, a metric for swishing sound is proposed. Finally, a model based on the results from this study on annoyance of sound from wind turbines is presented.

Title: Wind turbines - low level noise sources interfering with restoration
Platform: IOP Publishing UK
Authors: Eja Pederson, Kerstin Persson Waye
Date: 11 Jan 2008

Abstract
Wind turbines generate a low level noise and would thus not be expected to cause annoyance and disturb rest. In a society where people are being exposed to an increasing noise load, moderate and low level noise sources may also be perceived as annoying and hence inhibit restoration. This article presents an analysis of two socio-acoustic studies of wind turbine noise with the emphasis on perception, annoyance and consequences for restoration. It is hypothesized that low and moderate stressors such as wind turbine noise could have an impact on health. The risk seems to be higher if restoration is, or is perceived to be, impaired and also for certain groups of individuals. The observations warrant further studies.

Title: Planning Act 2008
Platform: HM Government
Authors: HM Government
Date: 26 Nov 2008

Summary
Section 152 removes the right of anyone affected by a National Infrastructure Project to sue for damages but does create a Statutory Scheme for compensation in such cases.

Title: An estimation method of the amplitude modulation in wind turbine noise for community response assessment
Platform: Third International meeting on wind turbine noise, Aalborg, Denmark
Authors: SH Lee, KT Kim, HG Kim, SG Lee, South Korea
Date: 17 June 2009

Summary
This paper proposes a practical method to measure amplitude modulation of sound from wind turbines. A fast fourier transform was employed to find the modulation depth at each

frequency band. Tests were performed to identify a relationship between noise annoyance and modulation depth of wind turbine noise.

The paper concluded there is a correlation between noise annoyance and amplitude modulation in wind turbine noise. Not only equivalent sound level but also spectral modulation depth should be considered when assessing community response to wind turbine noise.

Title: Response to noise from modern wind farms in the Netherlands
Platform: Acoustical Society of America 2009
Authors: Eja Pederson, Frits van den Berg, Roel Bakker, Jelte Bouma
Date: August 2009

Abstract
The increasing number and size of wind farms call for more data on human response to wind turbine noise, so that a generalized dose-response relationship can be modelled and possible adverse health effects avoided. This paper reports the results of a 2007 field study in The Netherlands with 725 respondents. A dose-response relationship between calculated A-weighted sound pressure levels and reported perception and annoyance was found. Wind turbine noise was more annoying than transportation noise or industrial noise at comparable levels, possibly due to specific sound properties such as a "swishing" quality, temporal variability, and lack of night time abatement. High turbine visibility enhances negative response, and having wind turbines visible from the dwelling significantly increased the risk of annoyance. Annoyance was strongly correlated with a negative attitude toward the visual impact of wind turbines on the landscape. The study further demonstrates that people who benefit economically from wind turbines have a significantly decreased risk of annoyance, despite exposure to similar sound levels. Response to wind turbine noise was similar to that found in Sweden so the dose-response relationship should be generalizable.

Concluding Remarks
This study enlarges the basis for calculating a generalized dose-response curve for wind turbine noise usable for assessing wind turbine noise in terms of its environmental health impact, the number of people influenced by it, and, by extension, its role from a public health perspective. The study confirms that wind turbine sound is easily perceived and, compared with sound from other community sources, relatively annoying. Annoyance with wind turbine noise is related to a negative attitude toward the source and to noise sensitivity; in that respect it is similar to reactions to noise from other sources. This may be enhanced by the high visibility of the noise source, the swishing quality of the sound, its unpredictable occurrence, and the continuation of the sound at night. The study demonstrates that it is possible to model a highly needed generalized dose-response relationship for Northern Europe, and supposedly also for the rest of Europe and North America, if the different proportions of people benefiting economically from wind turbines in the different regions are taken into account. The study also shows that mitigation measures can be directed to acoustical as well as non-acoustical factors that contribute to the impact of wind farms.

Title: Case Study: Wind Turbine Noise in a small and quiet community in Finland
Platform: Third international meeting on wind turbine noise, Aalborg, Denmark
Author: Carlo Di Napoli
Date: 17 June 2009

Summary
This particular site is located at the west coast of Finland in a small community with local residents and many vacationers with summer cottages, which are located close to the sea shore. Site has just one pitch regulated 1MW wind turbine and the closest resident has a summer time vacation cottage at about 750 m distance from the turbine. Over 20 vacationers have summer cottages close to the shore line within a range from 750 m to 1.3 km from the turbine. After the turbine start up, the turbine owner received many complaints of turbine noise from the vacation residents, but not from the nearest permanent residents.

Overnight noise measurements were performed in windy conditions in a downwind location. Measurements and sound propagation modelling revealed that wind turbine noise has to be measured in a specific weather condition in order to estimate the full impact of the sound level at immission points. No specific wind turbine noise measurement or modelling rules exists in Finland (yet), which made it also difficult to perform straight forward comparisons against national noise regulations. This case also revealed the importance of correct sound level estimation for a wind turbine park in pre-engineering phase in order to minimize the developer's own risks for further complaints.

Title: Night noise guidelines for Europe
Platform: World Health Organisation
Authors: World Health Organisation
Date: 2009

Summary
Considering the scientific evidence on the thresholds of night noise exposure indicated by $L_{night,outside}$ as defined in the Environmental Noise Directive (2002/49/EC), an $L_{night,\ outside}$ of 40 dB should be the target of the night noise guideline (NNG) to protect the public, including the most vulnerable groups such as children, the chronically ill and the elderly. The WHO recommendation concludes with:

Below the level of 30 dB $L_{night,outside}$, no effects on sleep are observed except for a slight increase in the frequency of body movements during sleep due to night noise. There is no sufficient evidence that the biological effects observed at the level below 40 dB $L_{night,outside}$ are harmful to health. However, adverse health effects are observed at the level above 40 dB $L_{night,outside}$, such as self-reported sleep disturbance, environmental insomnia, and increased use of somnifacient drugs and sedatives.

Therefore, 40 dB $L_{night,outside}$ is equivalent to the LOAEL for night noise. Above 55 dB the cardiovascular effects become the major public health concern, which are likely to be less dependent on the nature of the noise. Closer examination of the precise impact will be necessary in the range between 30 dB and 55 dB as much will depend on the detailed circumstances of each case.

Also the guidance assumes it should be possible to sleep with a bedroom window slightly open (a reduction from outside to inside of 15 dB).

Title: Appeal Ref: APP/Q1153/A/06/2017162 Land to the south east of North Tawton and the south west of Bow
Platform: Planning Inspectorate Appeal Decision, UK
Author: Andrew Pykett, Inspector
Date: 11 December 2009

Summary
This relates to the Den Brook wind farm.

- The appeal was made by RES Developments Ltd against the decision of West Devon Borough Council.
- The application Ref: 8250/2005/OKE, dated 10 November 2005, was refused by notice dated 31 January 2006.
- The development proposed is nine 3-bladed horizontal axis wind turbines, electricity transformers, access tracks, crane hard-standings, control building, sub-station, met mast, temporary construction compound and met masts.
- The inquiry sat for 13 days on 23, 24, 27-31 July, 3 August, 20-23 and 26 October 2009.
- This decision supersedes that issued on 22 March 2007. That decision on the appeal was quashed by order of the Court of Appeal.

Decision
The appeal was allowed by Inspector Pykett who included a condition to control Excess Amplitude Modulation. The condition had been drafted in conjunction with Mike Stigwood but the Inspector modified it in the actual decision letter. Planning condition 20 was applied to control noise amplitude modulation to not more than 3dB peak to trough.

Title: Simplification of criminal law: public nuisance and outraging public decency
Platform: The Law Commission
Authors: The Law Commission
Date: 31 March 2010

Summary
A Consultation Paper to consider how public nuisance is an appropriate offence in a modern society. It did consider how offences of public nuisance are currently prosecuted.

Title: European Convention on Human Rights
Platform: Council of Europe
Authors: European Court of Human Rights
Date: 1 June 2010

Summary
Article 8 is relevant and states: – Right to respect for private and family life

1. Everyone has the right to respect for his private and family life, his home and his correspondence.
2. There shall be no interference by a public authority with the exercise of this right except such as is in accordance with the law and is necessary in a democratic society in the interests of national security, public safety or the economic well-being of the country, for the prevention of disorder or crime, for the protection of health or morals, or for the protection of the rights and freedoms of others.

Title: Appeal Ref: APP/H0520/A/09/2119385 Land at Cotton Farm, Offord Road, Graveley, St Neots, Cambridgeshire
Platform: Planning Inspectorate Appeal Decision, UK
Author: Martin Pike, Inspector
Date: 14 December 2010

Summary
- The appeal is made by RWE Npower Renewables Limited against the decision of Huntingdonshire District Council.
- The application Ref: 0802296FUL, dated 23 July 2008, was refused by notice dated 17 November 2009.
- The development proposed is temporary planning permission for 25 years for a wind farm comprising 8 wind turbines, substation, anemometry mast, access tracks and ancillary infrastructure.

Decision
The appeal was allowed. The Inspector noted that knowledge of EAM had not advanced much since first identified but did not accept the evidence of Mike Stigwood that this was a

common phenomenon, preferring to accept the findings of the Salford Report. The Inspector therefore refused to impose a condition in respect of EAM and stated that if it did occur, SN could be used to address the issue. He acknowledged that he had misgivings about it but said there was little other option.

Title: Wind farm noise statutory nuisance complaint methodology
Platform: DEFRA
Authors: Dani Fiumicelli, Nigel Trinder, AECOM for DEFRA, UK
Date: 6 April 2011

Summary
This report was commissioned to examine the use of Statutory Nuisance to deal with wind farm noise complaints when resolution via the Planning System is not possible or has proven to be ineffective. The report discusses aspects of wind turbine noise generation and noise features including amplitude modulation (AM) and the role of ETSU-R97 the noise assessment guidance. This report repeats the claim from the 2007 Salford report that AM is an infrequent occurrence affecting a minority of wind farm sites.

The report states that effective noise control is '*best achieved by using adequate separation of the turbine from noise sensitive receptors*'.

It also recognises that health problems '*such as persistent sleep disturbance can be classed as —injurious to health|| and therefore can fall under both the prejudicial to health limb of Statutory Nuisance, as well as the nuisance limb i.e. unreasonably materially interfering with use of a bedroom.*'

The report discusses the legal aspect of statutory nuisance including the defence of Best Practicable Means (BPM) in noise cases. The report recognises '*There are important limitations in taking Statutory Nuisance action e.g. the —BPM defence, and the difference in the standards that can be achieved via the planning and statutory nuisance routes. It is vital, therefore, that planning conditions and agreements are put in place to adequately safeguard amenity and protect the rights of the neighbouring public from nuisances. Local Authorities should satisfy themselves that any noise assessments submitted with the planning application identify all the significant likely noise impacts, the measures to be taken to mitigate and control such impacts, that proper consideration is given to issues of scientific uncertainty and monitoring of impacts after the scheme becomes operational'.*

It also recognises that '*When considered with the authorised grounds for appeal and defence against Statutory Nuisance actions, this can mean that the protection that can be secured under Statutory Nuisance is less than might normally be achievable using planning pow*ers'.

Title: Long distance amplitude modulation of wind turbine noise
Platform: Fourth international meeting on wind turbine noise, Rome
Author: Carlo Di Napoli, Finland
Date: 12 April 2011

Summary
This paper describes a noise measurement campaign in Finland, the purpose being to provide information on wind turbine noise in low background sound areas. The measurements revealed that even smaller and older turbine types can produce significant amplitude modulation detectable about 2km away from the nearest turbine. The measurements also revealed issues relating to pulsating infrasound emitted from the turbines which was detected however; this paper only presents results relating to amplitude modulation.

Two different methods of assessing AM were used to objectively measure the level of AM at different locations. AM did not decrease with distance as was expected. The highest modulation depth with higher onset rates was typically found from the downwind samples and in particular at the far field measurement points which were located normal to a turbine row axis or at points directly downwind.

Using two assessment methods of sound annoyance showed that a conservative approach to assessing wind turbine noise in complex terrain cases is needed. This may especially be the case if the area has low nocturnal background sound levels.

The infrasound results indicate that the downwind movement of the blade produces most of the broad band modulation measured.

Title: Monitoring and mitigation of low frequency noise from wind turbines to protect comprehensive test ban seismic monitoring stations
Platform: Fourth international meeting on wind turbine noise, Rome
Authors: Styles, Westwood, Toon, Buckingham, Marmo, Carruthers
Date: 12 April 2011

Summary
This title of this paper loosely describes the paper objectives. The requirement was to reduce low frequency noise and vibration in the 2 to 6 Hz band. An earlier study in 2005 concluded that micro-seismic noise is propagated through the ground from wind turbine structures, as the rotation of the blades excite modes of vibration of the tower, especially in the 4 to 5 Hz band generated by the strongly excited second bending modes of the tower and are strongly coupled into the ground. The turbine tower bending modes are described at Section 2.

Title: Measurement of amplitude modulation frequency spectrum
Platform: Fourth international meeting on wind turbine noise, Rome
Author: David McLaughlin, UK
Date: 12 April 2011

Summary
The paper starts by stating that AM in the far field is rarely observed and repeats this several times but provides no evidence to support this claim. The paper then describes the use of Fast Fourier Transform (FFT) to provide a spectral analysis of the broadband noise data. The paper speculates as to the cause of AM observed in the far field and fails to provide any helpful insight to the AM problem.

Title: Detection and quantification of amplitude modulation in wind turbine noise
Platform: Fourth international meeting on wind turbine noise, Rome
Author: J.N. McCabe, Canada
Date: 12 April 2011

Summary
The paper refers to international research that suggests there may be more annoyance associated with sound of wind turbines than with other sources of environmental noise for comparable sound levels. The amplitude modulation of the broadband sound is frequently suggested as one qualitative factor which may increase the annoyance.

In many jurisdictions including Canada there is growing attention paid to methods for quantifying the noise impact of wind turbines. Accurate measurement of sound levels at typical receptor distances is difficult, particularly in the presence of wind.

The paper describes work conceived to develop and investigate a practical approach to the detection and quantification of amplitude modulation and to investigate possible correlations between the degree of modulation and various metrics describing the wind.

When taken as a whole the data support the idea that increased periods of AM occur when the wind profile corresponds to a larger wind shear exponent. The data also indicate that a high rotor rate (rotational speed) tends to be required for high degrees of modulation and that wind direction clearly affects the degree of modulation at any given location.

Title: Measurement of swish noise. A new method
Platform: Fourth international meeting on wind turbine noise, Rome
Author: Gunnar Lundmark, Sweden
Date: 12 April 2011

Summary
The paper notes that amplitude modulated noise is characteristic for wind turbines and is considered by many to be extra annoying. It also notes that by using standard measurement methods, it is not possible to distinguish the broadband noise from the amplitude modulated noise.

Lundmark notes that reports by wind turbine manufacturers utilise integration times or at least 1 minute and this hides the swish noise. In Sweden there have been serious complaints about the swish noise but the specific sound characteristic that some people have complained about have not been analysed.

The integration time constant of the ear is quoted as being in the range of 20 to 200 milliseconds and can be approximated using sound level meters having a time constant fast response of 125msecs. The paper describes a new method for measuring the amplitude modulation (swish) noise:

1. Firstly by sampling the sound pressure level 8 times per second (time constant of 125msecs) using a hand held sound level meter.
2. Then calculate the Fast Fourier Transform (FFT) of the numeric time series to identify and quantify amplitude modulation, frequency and strength using the standard function in Excel Analysis ToolPak.

Title: Hulme v Secretary of State for Communities and Local Government and RES Developments [2011] EWCA Civ 638
Platform: Court of Appeal
Authors: Lord Justice Mummery, Lord Justice Elias, Lord Justice Patten, UK
Date: 26 May 2011

Summary
The appeal concerns the granting of planning permission to RES for a 9 turbine wind farm at Den Brook near Tawton, Devon. The appellant claimed that the condition as drafted by the Inspector did not have the same effect as that agreed at the Public Inquiry and would not, as modified, protect him and other residents throughout the duration of the planning permission. The Court held that the condition must be read along with the rest of the decision letter which made it clear that it would have this effect. While they did not, in the judgement, detail issues such as the legality of the condition, they noted that it was intended to be precautionary and mentioned Circular 11/95, at the time the relevant document that stated the considerations that are necessary for a planning condition to be valid.

The Court found against M Hulme but upheld the planning permission and declared that the relevant conditions relating to EAM are valid.

Title: Evaluating the degree of annoyance caused by impulsive noise types
Platform: Research Acoustics, Germany
Authors: Martin Atzler, Stefan Pischinger, Bernhard Lang, Stefan Heuer
Date: June 2011

Summary
Disturbing impulsive noises occurring in combustion engines have a particularly detrimental effect on the perceived quality of vehicles and are sometimes misinterpreted by customers as defects. A tool for computing objective evaluations of such disturbing noises has been developed at the Institute for Combustion Engines (VKA) at RWTH Aachen University. By using modern methods of signal analysis to break down disturbing noises into individual noise types, even better results can be obtained than when evaluations are carried out by a jury.

The method presented in this article enables objective ratings to be obtained for the impulsive disturbing noise components of stationary and transient noises of combustion engines. As an important innovation compared with the current state of the art, it separates the overall noise into the noise types of knocking, ticking, rattling and miscellaneous noise. This enables a robust evaluation to be made even if different types of disturbing noise occur at the same time.

Title: Vestas letter to Danish Minister for the Environment
Platform: Vestas
Author: Ditlev Engel
Date: 29 June 2011

Summary
This letter from the wind turbine manufacturer Vestas to the Danish government is a request to allow higher levels of low frequency noise from wind turbines that was being proposed at the time. The justification for the relaxation of LF noise limits was based on commercial considerations only.

Title: Windy Bank Ornithology Report
Platform: AESL for Banks Renewables
Authors: Alan Jones, John Olley, Nick Mason, Phil Curtis
Date: August 2011

Summary
This document is part 2 of an Ornithological report to Durham County Council to support an application for a wind farm in the County. It states at Section 6 that the developer should, after the turbines are operational, be subject to a condition to require them to monitor the wind farm for 12 months to verify predictions relating to collision monitoring. While this application has been refused permission by Durham County Council, it is perhaps a precedent for the comments by INWG that there should be monitoring of a wind farm to verify if noise predictions are correct.

Title: Wind farms and noise nuisance – another chink in the armour
Platform: Shepard and Wedderburn LLP, UK
Author: Jacqueline Cook
Date: 29 September 2011

Summary
This paper comments *on the Davis v Tinsley, Watts, Fenland Windfarms Limited, EDF Energy PLC and Fenland Green Power Co-operative Limited case* that was ongoing at that time.

Despite complying with conditions attached to planning permission for an onshore wind farm development, developers, landowners and operators may nevertheless find themselves defending an action for nuisance if the noise from the wind turbines unreasonably interferes with the use of another's land.

Nuisance actions are most likely to be brought against developers and operators of wind turbines but could also capture the owners of the land on which the turbines are built. Such actions would normally be based on the laws of statutory nuisance (where there is an actionable breach of a statutory provision) or private nuisance (a breach of common law where there is interference with the use and enjoyment of a person's land).

The report author commented that; "*The Davis case is expected to resume in Court in November 2011 following an adjournment. The outcome of this landmark case is eagerly awaited. If the claimants are successful, the judgment could impact on future wind farm developments and open the judicial floodgates for other cases on similar grounds".*

The Davis case was subsequently settled out of court and subject to a confidentiality agreement that prevents the detail of the agreement being made public.

Title: The effect of a common wind shear adjustment methodology on the assessment of wind farms when applying ETSU-R-97
Platform: MAS Environmental
Author: Mike Stigwood
Date: 27 October 2011

Summary
Research was conducted by MAS to test the assumptions of the article method and its suitability as an alternative assessment methodology to ETSU-R-97 as written.

The research found that not only is the Article (Bulletin) Method unlikely to indicate adverse noise impact at the planning stage, but once the development is operational the article method virtually removes the ability for local communities to enforce controls over reasonable turbine noise impact.

Title: National Planning Policy Framework
Platform: Department for Communities and Local Government
Authors: DCLG
Date: March 2012

Summary
This document replaces practically all the Planning Policy Guidance and Statements that previously existed. It is now the basis of Government Policy for all planning matters both in the determination of planning applications and the preparation of Local Plans. In March 2012, the Government also issued Planning Practice Guidance to assist in the interpretation of the NPPF.

Title: A critique of the IoA treatment of background noise for wind farm noise assessment
Platform: Renewable Energy Foundation (REF)
Authors: Lee Moroney, John Constable
Date: April 2012

Summary
This information note examines the revision to the ETSU-R-97 method of deriving noise conditions for wind farm planning permissions from background noise measurements, as proposed in an article in the *Acoustics Bulletin* of the Institute of Acoustics (IoA). We have used actual wind speed data to model the impact of the revision on noise conditions and likelihood of noise complaints from neighbours.

The revision is designed to correct for site-specific wind shear that was erroneously assumed to be constant between two heights in the ETSU-R-97 guidance. The impact of this assumption is shown graphically in Appendix 1. However, in this note we show that the

Acoustics Bulletin revision increases the uncertainty of the background noise curves and reduces confidence in the reliability of noise conditions based on them.

We show that the revised methodology can produce different noise conditions depending on the dates chosen for the baseline background noise survey, thus yielding differences in permitted wind farm noise levels of as much as 5dB for the same site. Consequently, use of the methodology can lead to the situation where predicted noise levels from turbines at a given proximity to dwellings are deemed acceptable, whereas measurements taken two weeks later would give the opposite result.

Title: Mechanisms of amplitude modulation in wind turbine noise
Platform: Acoustics 2012, Nantes
Authors: M Smith, AJ Bullmore, MM Cand, R Davis
Date: April 2012

Summary
The noise produced by wind turbines is inherently time varying. This amplitude modulation is normally due to the directivity of the dominant trailing edge noise sources combined with the changing position and orientation of the rotating blades. In some circumstances the level and character of the amplitude modulation is altered and this paper outlines results from a RenewableUK funded research programme into the possible causes. Besides the variability of the normal trailing edge noise mechanism, other factors investigated include the possibility of blade stall or increased levels of inflow turbulence under some wind conditions combined with various propagation factors such as the effect of wind gradients and atmospheric absorption.

Title: The perception and effect of wind farm noise at two Victorian wind farms
Platform: Noise Measurement Services QLD Australia
Author: Bob Thorne, Australia
Date: June 2012, reissued June 2014

Summary
This Report is part of a research program commenced in 2003 – 2005 into the human perception of low amplitude intrusive noise. The objective of this report is to respond to a request from a number of families living or working near wind farms in Victoria for an independent impartial wind farm noise assessment and is a follow-up to the 2009 - 2010 reports for Mr and Mrs N. Dean with respect to the Waubra wind farm. At the time concerns about wind farm noise were raised by local residents and are recorded in evidence before planning hearings in 2010 and the 2011 Senate Inquiry into the social and economic impact of rural wind farms.

The current study consists of formal objective measurement tools for quality of life, sleep disturbance, noise sensitivity, environmental amenity and sound character analysis; as well

as standard measures for sound levels, sound quality and (special) audible characteristics including amplitude modulation and tonality. The confidential acoustical, attitudinal survey data and human perception analysis is summarised in this Report following professional peer-review.

Two wind farm locales (Waubra, Cape Bridgewater) and one 'green-fields' location (Berrybank) were surveyed. Persons affected live between 700 metres to a distance of around 3500 metres from the turbines, with an 'average' of 1400 metres. Residents participating in this study record considerable stress and identifiable adverse health effects due to wind farm noise.

Outcomes

- Sound from the Waubra wind farm, when measured at residence 2 (Lobbs Road), exceeds the night-time criteria and is therefore assessed as being non-compliant on a frequent and regular basis with or without the special audible characteristics penalty applied under NZS6808.
- Based on the results of the study it can be argued that, when exposed to wind farm noise and wind turbine generated air pressure variations, some will more likely than not be so affected that there is serious harm (also termed 'significant adverse effect') to health. By 'serious harm' it is meant harm that is more than mere annoyance and that can be quantified in terms of reported illness, sleep disturbance or other physical effect. A measure of serious harm is if the exposed individual is adversely affected to the extent that he or she is obliged to remove themselves from the exposure in order to mitigate the harm.
- The technical outcome of the report is to emphasise the need for, and practicality of, the 2km setback that the Minister has implemented for new wind farms.
- It is recommended that the 2 km setback be implemented at Waubra, Cape Bridgewater and other existing wind farms.

Title: Assessing aerodynamic amplitude modulation from wind turbine noise
Platform: Joint Baltic-Nordic Acoustics Meeting, Denmark
Author: Carlo Di Napoli, Finland
Date: 18 June 2012

Summary
This paper describes noise measurement results from a single wind turbine, which has revealed deficiencies when assessing amplitude modulation on wind turbine noise. The current assessment method for wind turbine noise guarantees according to the IEC 61400-11:2002 standard does not provide sufficient information nor measurement methods regarding the modulation.

Since amplitude modulation may significantly increase the perception as well as annoyance of wind turbine noise, new near field measurement methods are required to ensure, that sufficient information from modulated noise and possible annoyance corrections from a single turbine installation are presented. When planning a new wind farm with new type of

wind turbines, the guarantee test certificates are typically the only official noise measurement documentation available, which consultants and environmental impact assessment authors often refer.

Additionally, the report author mentions that the WHO has repeatedly emphasized the importance of measuring maximum values of noise fluctuations, rather than averages. Thus, any measured or predicted noise levels should be accompanied by maximum levels, as sensitivity to the peaks of modulating noise waves are likely to better predict annoyance.

The immission point was located 470 meters away from the turbine base in an open yard. The one-floor dwelling (a summer holiday cottage) situated about 15 meters behind the measurement point. A simultaneous noise measurement was performed close to the turbine ("near field measurement") according to the IEC rules by using a hard ground board and protective wind screens. Although simultaneous wind speed measurements from the nacelle were not received, the wind had strong gusts with pauses in between each gust. As the wind arrived first to the turbine, the sound was the first indication of the wind gust. The same wind gust then arrived to the immission point location about 50 seconds later creating stronger background sounds. Such a cyclic variation of wind speed and thus background sounds was typical for many measurement periods under downwind conditions.

Modulation depths of broad band sound at the immission point were 8-9 dB while at the same time in the near field location it was not more than 5-6 dB. If the turbines sound power level was calculated by using one minute LAeq results and basic sound propagation model used with a spherical sound source, the deviation to the measured maximum sound pressure levels at immission point would be about 10-12 dB and slightly less with LAFmax near field results. The question of course is why there is such a high deviation from the maximum sound power level results and even greater deviation, if official guaranteed sound power levels are used?

From Figure 3 it can be clearly seen that the modulation impulsivity increases as one goes further away from the turbine. This phenomenon has been reported in some occasions with multiple turbines, but not previously from a single machine.

Title: Alaska wind farm Appeal Ref: APP/B1225/A/11/2161905
Platform: Planning Inspectorate
Author: Paul Jackson
Date: 10 July 2012
Summary
An appeal that was 'allowed' for a wind farm of 4 turbines 125 meters high. EAM was argued but the Inspector determined that it was very rare and in this case unlikely to amount to a "serious objection". The Inspector did not address any other potential remedies should EAM occur.

Title: Wind Turbine Noise Impact Assessment: Where ETSU is Silent
Platform: Various
Authors: Richard Cox, David Unwin and Trevor Sherman, UK
Date: 10 July 2012

Key Findings
The authors claim that failure to comply with the intent of ETSU by developers facilitated by the lack of detailed guidance in ETSU has occurred in all the wind farm noise assessments they reviewed.

- There has been a failure to use suitable microphone wind screens which include secondary wind screens. Measured background noise values are therefore higher than the true values as they include wind noise contamination at the microphone. The consequence of these artificially high measured levels of noise is that the noise limits that apply for the life of the wind farm are calculated to be higher than they should be. The artificially high noise levels have provided justification for reduced separation distances between turbines and residential areas. The failure to use secondary wind screens has probably resulted in measurement errors of greater than 10dB (corresponding to a doubling or more of allowed noise loudness).
- There has been a failure adequately to consider the effects of wind shear during wind farm noise assessments. High levels of wind shear at intermediate wind speeds significantly increase noise intrusion particularly during the night. Either very low levels of wind shear have been factored into the developer's assessments or the effects of wind shear have been totally ignored. However, wind shear was found to be high at the sites in Northamptonshire where wind data was made available to the report authors.
- There has been a failure correctly to analyse the measured background noise data when plotting the average noise curve through the data points. This has resulted in errors, usually in the developer's favour allowing higher levels of turbine noise at wind speeds when complaints are most likely.
- There has been a failure correctly to apply or test the standard turbine noise prediction calculation model resulting in under prediction of turbine noise levels.
- There has been a failure to allow for measurement tolerances and assessment uncertainties arising at each stage of the noise assessment. Excluding wind screen errors, it is estimated that an accumulation of assessment uncertainties of greater than around +/-10dB can occur (resulting in a doubling or halving of noise loudness).
- There has been a failure to address adequately excess amplitude modulation, (EAM) the highly intrusive noise occurring when the normal turbine 'swish' noise changes to a banging or thumping noise. The report authors found that the Salford report into EAM was carried out in a less than rigorous way for identifying EAM and noise complaints.

These failures of guidance have continued throughout the period since 1997 when Government policy on wind farms closely followed the advice provided by two acoustic consultancies, Hayes McKenzie Partnership and Hoare Lea Acoustics.

Title: Variations of sound from wind turbines during different weather conditions
Platform: Inter noise New York 2012
Authors: Conny Larson, Olof Ohlund
Date: August 2012

Abstract
Long-term measurements of sound from wind turbines show variations of the order of 6 – 14 dBA at some distance from the source. The meteorological conditions change over the day and the year and vary a lot depending of the terrain conditions. The meteorological parameters govern both the wind turbine sound level and the sound propagation conditions. In an extensive measurement program, with economical support from the Swedish Energy Agency, long-time measurements of meteorological effects on sound propagation from wind turbines are performed at three sites in Sweden. The measurements are performed during 1-2 years. Sound propagation is studied in a 1) forest area, 2) over a water bay and 3) over heterogeneous terrain. The first two sites are located in the southern part of Sweden and the third is located in the northern part of Sweden. The aim of the project is to improve the knowledge about sound propagation from wind turbines and especially over varying terrain and different weather conditions. The hub height of the studied wind turbines varies from 80 - 138 m. The result shall be improved sound propagation models, updated measuring requirements, validation of modelled sound levels and methods for deriving meteorological input data for a sound propagation model. In this paper preliminary results from the first 10 months are presented.

Conclusions
Sound from wind turbines is strongly dependent on the meteorological situation. The effect increases with distance. For 12 wind turbines at 1 - 2 km a meteorological variation of 6 - 14 dBA were found depending on ground conditions and refraction. For 2 wind turbines at 400 - 600 m the first analyse during these 10 months the meteorological effect could not be separated during these with from the directivity of the source.

The lowest sound levels are found for negative sound speed gradients (upward bending sound waves) when the sound wave touches the ground and large ground attenuation occur. It shows the strong coupling between refraction and ground attenuation. The ground attenuation and refraction are closely linked and could hardly be separated. Lower sound levels are found during the winter with snow on the ground, especially after snowfall when the snow is porous and the tree branches are covered by snow.

Amplitude modulated sound from wind turbines is an effect of both meteorology and acoustics and is observed during roughly 30 % of the time at 400 m and 10 % of the time at 1 km from the closest turbine. AM sound is influenced by conditions in the propagation path and interference pattern can occur. It is most common in the evening, night and morning when the turbulence intensity is low

Title: The nature of nuisance
Platform: Infrastructure Planning Commission
Author: Peter Jennings's representation for Brechfa Forest application
Date: September 2012

Summary
Representations of Peter Jennings, Barrister to the Infrastructure Planning commission determining the Brechfa Forest application. He gave a number of reasons why SN was not a suitable alternative to a planning condition but this was not accepted by the Commission

Title: Characterisation of noise in homes affected by wind turbine noise
Platform: Australian Acoustical Society
Authors: Benjamin Nobbs, Con J Coolan, Danielle J Mereau
Date: November 2012

Abstract
A growing need for low carbon energy production necessitates the use of renewable resources such as wind power. However, residents living near wind farms often state that annoyance due to wind farm noise is a serious problem that affects their wellbeing. This paper describes a new methodology for recording noise and annoyance within residents' homes affected by wind turbine noise. The technique records time-series noise measurements allowing complete analysis of the signal using a variety of post processing techniques. Preliminary results from the system in a single home near a wind farm are presented including overall sound pressure level with A, C and Z weighting, narrow band frequency spectrum and amplitude modulation depth correlated with resident rated annoyance level. This information provides insight into the nature of noise in homes close to wind farms.

Summary and Conclusion
This paper has described a new methodology for recording noise and annoyance within residents' homes affected by wind turbine noise. The technique records time-series recordings that allow complete analysis of the signal using a variety of post processing techniques. While being used to characterise wind turbine noise in this study, the system can be used to record noise and annoyance in residents' homes affected by other forms of environmental noise.

Measurements taken in a single resident's home near a wind farm show an increase in the overall mean Z (unweighted) and C weighted sound level with Annoyance rating. No increase was, however, observed in the mean A weighted sound level and this is due to the majority of the acoustic energy being contained in the lower frequencies. In particular, the energy levels within the 10-30 Hz band were observed to increase with Annoyance rating. Additionally, significant amplitude modulation was detected in the noise signals.

It should be noted that the results presented in this paper are the preliminary results of a much larger study to investigate the character of wind turbine noise within homes. There is

a need for a much more comprehensive data set measured in a large number of homes to draw more definite conclusions about the nature of noise in residences close to wind farms.

Future measurements with the system will incorporate use of a microphone capable of measuring below 1 Hz to capture noise over a larger frequency range than is reported in this study. Additionally, it is hoped that wind farm operational data can be obtained to correlate power production, wind condition and rotor motion with residents' noise measurements.

Title: Brechfa Forest West wind farm examining authority's report of findings and conclusions and recommendation to the Secretary of State for Energy and Climate Change
Platform: The Planning Inspectorate
Author: Bob Macey
Date: 12 December 2012

Summary
The Report recommends that Consent be granted for the Brechfa Forest proposed wind farm. The Examining Authority considered that an EAM condition was not appropriate in the absence of clear evidence that EAM would occur and recommended that Statutory Nuisance would be appropriate if it did occur. He did however note that Statutory Nuisance does not provide an ideal remedy but was the most appropriate way of dealing with it.

Title: A Cooperative Measurement Survey and Analysis of Low Frequency and Infrasound at the Shirley Wind Farm in Brown County, Wisconsin (Wisconsin report)
Platform: Clean Wisconsin for Wisconsin Public Service Commission, USA
Authors: Channel Islands Acoustics, Camarillo, CA Principal: Dr. Bruce Walker; Hessler Associates, Inc., Haymarket, VA Principals: George F. and David M. Hessler: Rand Acoustics, Brunswick, ME Principal: Robert Rand: Schomer and Associates, Inc., Champaign, IL Principal: Dr. Paul Schomer
Date: 24 December 2012

Introduction and remarks
Clean Wisconsin is a non-profit environmental advocacy organization that works to protect Wisconsin's air and water and to promote clean energy. As such, the organization is generally supportive of wind projects. Clean Wisconsin was retained by the Wisconsin Public Service Commission (PSC) to provide an independent review of a proposed wind farm called the Highlands Project to be located in St. Croix County, WI (WI PSC Docket 2535-CE-100). Clean Wisconsin in turn retained Hessler Associates, Inc. (HAI) to provide technical assistance.

During the course of the hearings, attorneys representing groups opposed to the Highlands project, presented witnesses that lived near or within the Shirley Wind project in Brown County, WI. The Shirley wind project is made up of eight Nordex100 wind turbines that is one of the turbine models being considered for the Highlands projects. These witnesses

testified that they and their children have suffered severe adverse health effects to the point that they have abandoned their homes at Shirley. They attribute their problems to arrival of the wind turbines. David Hessler, while testifying for Clean Wisconsin, suggested a sound measurement survey be made at the Shirley project to investigate low frequency noise (LFN) and infrasound (0-20 Hz) in particular.

Partial funding was authorized by the PSC to conduct a survey at Shirley and permission for home entry was granted by the three homeowners. The proposed test plan called for the wind farm owner, Duke Power, to cooperate fully in supplying operational data and by turning off the units for short intervals so the true ON/OFF impact of turbine emissions could be documented. Duke Power declined this request due to the cost burden of lost generation, and the homeowners withdrew their permission at the last moment because no invited experts on their behalf were available to attend the survey.

Clean Wisconsin, their consultants and attorneys for other groups all cooperated and persisted and the survey was rescheduled for December 4 thru 7, 2012. Four acoustical consulting firms would cooperate and jointly conduct and/or observe the survey. Channel Islands Acoustics (ChIA) has derived modest income while Hessler Associates has derived significant income from wind turbine development projects. Rand Acoustics is almost exclusively retained by opponents of wind projects. Schomer and Associates have worked about equally for both proponents and opponents of wind turbine projects. However, all of the firms are pro-wind if proper siting limits for noise are considered in the project design. The measurement survey was conducted on schedule.

This report is organized to include four separate reports, Appendices A to D where each firm submitted on their own letterhead a report summarizing their findings. Based on this body of work, a consensus is formed where possible to report or opine on the following:

- Measured LFN and infrasound documentation
- Observations of the five investigators on the perception of LFN and infrasound both outside and inside the three residences.
- Observations of the five investigators on any health effects suffered during and after the 3 to 4 day exposure.
- Recommendations with two choices to the PSC for the proposed Highlands project
- Recommendations to the PSC for the existing Shirley project

The report concludes with the remark; '*Since the problem may be devoid of audible noise, we also recommend a test as described by Schomer in Appendix D to develop a "Threshold of Perception" for wind turbine emissions*'.

Summaries and observations (from the separate consultant's reports)

Channel Island Acoustics
Overview
Channel Islands Acoustics (ChIA) was requested by Hessler Associates to assist in defining low and infrasonic frequency (approximately 0.5 – 100 Hz) sounds at abandoned residences in the environs of Shirley Wind Park near DePere, WI. ChIA has been developing a

measurement system that combines extended range microphones and recording equipment with mixed time domain and frequency domain signal processing in an effort to quantify sound levels and waveform properties of very low frequency periodic signals radiated by large wind turbines.

Remarks
The apparent and tentative result indicates that at the second residence, located approximately 1,280 ft. from the nearest turbine, blade-passage induced infrasound was correlated between outdoor and indoor locations and peak amplitudes of periodic waves composed of blade harmonics 0.7 to 5.6 Hz on the order 76 dB were detected both indoors and outdoors. Well correlated broadband low frequency noise at this nearest residence was also detected, with one-third octave band sound pressure levels approximately 50 dB in the frequency range 16-25 Hz. Both of these sounds are below normal hearing threshold; residents report being intensely affected without audibility.

At the other two residences, located approximately 3,300 and 7,100 ft. from the nearest turbine, respectively, high levels of infrasound were detected indoors but the correlation with outdoor acoustic signals was not clear except at the 3,300 ft. residence, where the broadband noise in the 20 Hz range was moderately correlated and produce one-third octave band level approximately 40 dB, which is well below normal hearing threshold. At the 7,100 ft. residence, outdoor-to-indoor correlation was low except during motor vehicle passages or in particular a helicopter overflight. Again, residents report being intensely affected despite inaudibility and to be aware of turbine operation when the turbines are not visible.

Hessler Associates, Inc.
Conclusions
Walker of Hessler Associates showed unequivocally that low level infrasonic sound emissions from the wind turbines were detectable during near full load operation with specialized instrumentation inside of residence R2 as a series of peaks associated with harmonics of the blade passing frequency. The long-term response of the inhabitants at R2 has been severely adverse for the wife and child while the husband has experienced no ill effects, which illustrates the complexity of the issue. The family moved out of the area to solve the problem.

The industry response to claims of excessive low frequency noise from wind turbines has always been that the levels are so far below the threshold of hearing that they are insignificant. The figure shown in the paper plots the exterior sound level measured around 2 a.m. on a night at R2 during full load operation compared to the threshold of hearing. In the region of spectrum where the blade passing frequency and its harmonics occur, from about 0.5 to 4 Hz, the levels are so extremely low, even neglecting the very real possibility that these levels are elevated due to self-generated pseudo noise, that one may deduce that these tones will never be audible. What apparently is needed is a new Threshold of Perception.

The study also showed that a wind turbine is indeed a unique source with ultra-low frequency energy. In general, enough was learned by these investigators, all with quite

different past experiences, that it can be mutually agreed that infrasound from wind turbines is an important issue that needs to be resolved in a more conclusive manner by appropriate study, as recommended in the cover report.

Rand Acoustics

Introduction

This report presents information on an investigation of infrasonic and low frequency noise performed at the Shirley Wind facility in Wisconsin December 4-7, 2012. Three homes were investigated that had been abandoned by the owners due to negative health effects experienced since the Shirley Wind facility had started up. The health effects were reported to make life unbearable at the homes and had affected work and school performance. It was understood that once relocated far away from the facility, the owners and families recovered their health; yet revisiting the homes and roads near the facility provoked a resurfacing of the adverse health effects. The owners had documented their experiences in affidavits prior to the investigation.

Conclusions

Nauseogenicity is a factor at Shirley. Acceleration of the inner ear is suggested due to extremely low-frequency pulsations at the rotation and blade pass rates that occur in or near the frequencies of highest potential for nauseogenicity and, are coupled strongly into the homes now abandoned. More research at Shirley is recommended to understand nauseogenicity from wind turbine operations, to properly design and site large industrial wind turbines (over 1 MW) near residential areas to prevent the severe health effects. More work is needed to establish what infrasonic levels are consistent with relief for the neighbours.

Medical research and measurement is urgently needed to be field coordinated along with infrasonic acoustic and vibration testing. The correlations to nauseogenicity at the 2.5MW power rating and size suggest worsening effects as larger, slower-rotating wind turbines are sited near people.

Schomer and Associates, Inc.

Observations

Four of the five researchers; George Hessler, David Hessler, Bruce Walker, and Paul Schomer met with affected residents of Shirley and discussed the problems they had that were precipitated by the wind turbines. This discussion produced several notable points not previously known by this researcher:

1. At most locations where these health problems occurred, the wind turbines were generally not audible. That is, these health problems are devoid of noise problems and concomitant noise annoyance issues. The wind turbines could only be heard distinctly at one of the 3 residences examined and they could not even be heard indoors at this one residence during high wind conditions.
2. The residents could sense when the turbines turned on and off; this was independent of hearing the turbines.
3. The residents reported "bad spots" in their homes but pointed out that these locations were as likely to be "bad" because of the time they spent at those locations, as because of

the "acoustic" (inaudible) environment. The residents certainly did not report large changes from one part of their residences to another.
4. The residents reported little or no change to the effects based on any directional factors. Effects were unchanged by the orientation of the rotor with respect to the house; the house could be upwind, downwind, or crosswind of the source.
5. Residents of the nearest house reported that their baby son, now 2 years old, would wake up 4 times a night screaming. This totally stopped upon their leaving the vicinity of the wind turbines, and he now sleeps 8 hours and awakens happy.

Implications of these observations:
1. The fact that these residents largely report wind turbines as inaudible, and the reported effects on a baby seem to rule out the illness being caused by extreme annoyance as some have suggested.

2. The lack of change with orientation of the turbine with respect to the house and the lack of change with position in the house suggest that we are dealing with very low frequencies; frequencies where the wind turbine size is a fraction of the wavelength--about 3 Hz or lower.

3. Currently the wind turbine industry presents only A-weighted octave band data down to 31 Hz. They have stated that the wind turbines do not produce low frequency sound energies. The measurements at Shirley have clearly shown that low frequency infrasound is clearly present and relevant. A-weighting is totally inadequate and inappropriate for description of this infrasound. In point of fact, the A-weighting, and also the C and Z-weightings for a Type 1 sound level meter have a lower tolerance limit of -4.5 dB in the 16 Hz one-third-octave band, a tolerance of minus infinity in the 12.5 Hz and 10 Hz one-third-octave bands, and are totally undefined below the 10 Hz one-third-octave band. Thus, the International Electro-technical Commission (IEC) standard needs to include both infrasonic measurements and a standard for the instrument by which they are measured.

Title: Numerical modelling of wind turbine aerodynamic noise in the time domain
Platform: Acoustical Society of America
Authors: Seunghoon Lee, Seungmin Lee, Soogab Lee, Seoul National University, Republic of Korea
Date: 8 January 2013

Abstract
Aerodynamic noise from a wind turbine is numerically modelled in the time domain. An analytic trailing edge noise model is used to determine the unsteady pressure on the blade surface. The far-field noise due to the unsteady pressure is calculated using the acoustic analogy theory. By using a strip theory approach, the two-dimensional noise model is applied to rotating wind turbine blades.

The numerical results indicate that, although the operating and atmospheric conditions are identical, the acoustical characteristics of wind turbine noise can be quite different with respect to the distance and direction from the wind turbine.

Introduction

Although aerodynamic noise from modern wind turbines is low compared to other community noise sources, wind turbine noise can annoy residents near wind farms. One of the reasons for this annoyance is that wind turbines generate a periodic swishing sound at the blade passing frequency. This is known as the amplitude modulation of wind turbine noise. In the vicinity of a wind turbine, this swishing sound is heard due to convective amplification and trailing edge noise directivity.

However, van den Berg reported that sometimes at night, a periodic thumping sound was perceived at distances of more than 1 km from wind turbines and that this thumping sound had a more impulsive characteristic compared to the swishing sound. He maintained that a stable atmospheric condition at night is the main cause of the thumping sound. Oerlemans and Schepers calculated the swish amplitude of wind turbine noise using a semi-empirical model. They claimed that in the crosswind direction, wind turbine noise retains the amplitude modulation even at long distances. However, it is still not known why the perceived sounds are different and how they differ depending on observer locations.

In this study, in order to compare the acoustical characteristics of wind turbine noise depending on the observer location, the aerodynamic noise from a wind turbine is numerically modelled in the time domain. Because the time domain simulation directly provides the acoustic pressure of the wind turbine noise, we can actually hear the predicted acoustic signals. This helps us to better understand the acoustical characteristics of the wind turbine noise with respect to the distance and direction from the wind turbine. In Section 2, a numerical procedure for the modelling of wind turbine noise is described. Section 3 presents the calculated acoustic signals and their sound pressure levels at a number of locations. Using these results, the characteristics of the amplitude modulation of wind turbine noise are discussed in Sec. 4.

Discussion

The acoustical characteristics of wind turbine noise are quite different with respect to the distance and direction from the wind turbine, although the operating and atmospheric conditions are identical. In the vicinity of a wind turbine, typical swishing sounds are perceived from all azimuthal directions. On the other hand, at long distances from a wind turbine, low-frequency amplitude-modulated sounds are heard in particular directions. Moreover, in contrast to the swishing sounds, these low-frequency sounds are heard only at the moments when the sound pressure level is sufficiently high, e.g., when the blades pass the black contours shown in Fig. 3. This effect may make the wind turbine noise seem more impulsive at long distances despite the fact that its overall sound pressure level is low.

Van den Berg suggested that the thumping sound occurs due to excessive vertical wind shear at night. However, the results from this study indicate that even when a uniform wind is blowing into the rotor disk, different types of noise can be heard depending on the observer location. This implies that the main cause of the thumping sound could be the

convective amplification and the trailing edge noise directivity rather than the strong wind shear.

Nevertheless, the strong wind shear can increase the strength of the amplitude modulation in wind turbine noise. At long distances in the directions where the blade passes downward, the amplitude-modulated sound occurs when the blades are at the top of the rotor disk, as shown in Fig. 3. Hence, if the vertical wind shear is strong, the effective angle of attack at the top of the rotor disk will increase, as will the sound level of the amplitude-modulated sound in these directions. Furthermore, in the downwind directions, sound rays are bent toward the ground in a strong wind shear. This effect will also raise the level of the amplitude-modulated sound in the downwind directions.

Summary
This paper models wind turbine noise with the aim of better understanding how wind turbine noise characteristics vary with respect to distance and direction from the wind turbine. It is noted by the author that the modelled noise does not account for ground reflections or refraction caused by temperature or wind gradients. The results confirm previous findings that whilst sound pressure level is greatest in the (upwind and) downwind direction, modulation is greatest in crosswind directions. As distance increases from the turbine modulation was found to change in spectral content (becoming lower frequency amplitude modulation sounds) and also reducing significantly in decibel level, disappearing in the upwind and downwind directions. At different distances and angles from the turbine different areas of the rotor disk are responsible for the noise. This has implications for the mitigation of AM. Where some claim that by altering the blade pitch of turbines the impact of AM can be mitigated, the findings of Lee et al suggest that this may alleviate AM at the original location but shift the adverse AM to a different location.

Title: Letter to Darlington BC - EAM planning condition
Platform: Parsons Brinckerhoff
Author: Richard Perkins
Date: 28 Jan 2013

Summary
Letter of Advice dated 28 January 2013 by Richard Perkins of Parson Brinckerhoff to Darlington Borough Council where he advised that "*As a matter of principle, the Statutory Nuisance regime is not there to pick up problems that should be dealt with by the Planning system, and as the Defra report notes, whilst it is theoretically possible to take nuisance action, it would be a significant "challenge" for a Local Authority to take this action due to the technical and legal challenges it would present. For that reason, local residents may not feel that there were sufficient safeguards in place if EAM were to occur in the absence of a planning condition*." Although he then went on to suggest that if there were a problem, there should be swift use of the SN powers by local authorities.

Title: The Bad Science behind the wind turbine noise guidelines
Platform: Various
Authors: R Cox and Prof D Unwin with contributions by D Bingham and Dr R Greenough, UK
Date: March 2013

Summary
This presentation report was prepared for a meeting with officials at the Department of Energy and Climate Change (DECC) during early 2013. The meeting was subsequently delayed until October 2013. The author's meeting objectives were to engage with DECC officials at a technical level, to demonstrate the fundamental scientific weakness of the draft Good Practice Guide proposed by the Institute of Acoustics and to stress the need for transparency to ensure that subsequent noise assessment guidelines are based on solid scientific principles and is evidence based. The report summary included the following recommendations:

- The current guidance (ETSU and draft Good Practice Guide) is unreliable and fails to protect against noise nuisance
- Until proper science based guidance can be put in place the minimum separation distance for a typical 120m high turbine should be 2km from homes.
- There should be simultaneous publication of the Institute of Acoustics new guidelines and a technical annex discussing those consultation responses not adopted in the new guidance including the scientific justification.
- To stop commissioning noise studies from the wind industry supply chain on a 'best value' basis and consider independent academic options instead.
- Commission an urgent independent review of the health effects of wind turbine noise.

Title: The Brechfa Forest West wind farm Order 2013
Platform: Infrastructure Planning
Authors: DECC
Date: 13 March 2013

Summary
The Consent Order to give permission for this wind farm

Title: A good practice guide to the application of ETSU-R97 for the assessment and rating of wind turbine noise
Platform: Institute of Acoustics
Authors: IoA Noise Working Group: Richard Perkins, Matthew Cand, Robert Davis, Chris Jordan, Malcolm Hayes
Date: 1 May 2013

Summary
This Good Practice Guide (GPG) was produced by the Institute of Acoustics (IoA) via its Noise Working Group (NWG) in response to a request from the Department of Energy and Climate Change (DECC). The guide claims to present current good practice in the application of the

ETSU-R-97 assessment methodology for all wind turbine developments above 50 kW, reflecting the original principles within ETSU-R-97, and the results of research carried out and experience gained since ETSU-R-97 was published.

The noise limits in ETSU-R-97 have not been examined as these are claimed to be a matter for Government. Subsequent to the guide being issued, a series of Supplementary Guidance Notes (SGNs) have been issued. Additionally, the consultation and subsequent GPG excluded noise amplitude modulation (AM), considered by many to be the most intrusive and annoying feature of wind turbine noise. It has a very short paragraph about Excess AM to say that current practice is not to impose a condition.

The GPG has since been widely criticised for the way the consultation was handled and especially for the science claimed to underpin the GPG. All scientific argument at odds with the NWG was ignored and no scientific justification was ever made. A major shortcoming with the GPG is that there are many statements that are not properly referenced so you cannot refer to the original research upon which the arguments and recommendations are made. This is most unscientific and prevents any independent review of the evidence upon which the GPG was apparently based.

Additionally, the composition of the NWG has also been widely criticised for its bias towards and close association with the wind power industry.

Title: Assessment of RES revised condition 20 for evaluating excessive amplitude modulation
Platform: Various
Author: M.A. Swinbanks, MAS Research Ltd, UK
Date: May 2013

Summary
This report examines the revised planning condition 20 for application at the Den Brook wind farm as proposed by RES, the wind farm developer. The report executive summary summarises the report as:

- The characteristics and consequences of the RES Revised Condition 20 are examined. RES procedure amounts to identifying and estimating the mean-square amplitude of the wind turbine Blade-Passing Frequency (BPF) present in fixed 1-minute segments of modulation time record (1/8-second dBA Leq). The procedure then converts this mean-square amplitude to a nominal Peak-to-Trough amplitude. A breach of the Condition occurs if the resultant value exceeds 4dB.

- It is found that this particular procedure significantly underestimates the true Peak-to-Trough amplitude of wind-turbine Amplitude Modulation; in one specific example, the result is in error by almost a factor of 2.

- Three independent effects have been identified which lead to such underestimate. First, the use of a narrow Blackman-Harris time-window on the initial analysis time-segment can exclude significant regions of amplitude modulation, since this particular window concentrates only on the central portion of the segment. Even minor changes in timing can yield different results.

- Secondly, the estimated amplitude of the BPF component is based on mean-square sideband integration, which fails to account for the relative phase of the sideband contributions. Local amplitudes determined by taking full account of both amplitude and phase can be over 25% higher.

- Finally, Amplitude Modulation is not purely sinusoidal but is usually sharply peaked, indicating the presence of significant higher harmonic contributions. Failure to take these additional components into account gives rise to further underestimate of the true amplitude.

RES have consistently emphasized the possibility of False Positives arising from application of the Original Condition 20. It can be argued that their concern relates primarily to circumstances which are readily identified, and would not even be considered appropriate for assessment. RES fail to mention that their revised procedure introduces an immediate likelihood of False Negatives, whereby obvious instances of severe Amplitude Modulation are underestimated, and consequently considered to be not in breach of their Revised Condition. They further exacerbate this situation by recommending that the original 3dB threshold should be raised to 4dB.

In conclusion, it is apparent that the overall RES procedure as proposed would provide inaccurate and completely inadequate protection for neighbouring communities.

Title: Common Barn decision: Land at Church Farm, Rectory Lane, Southoe, Cambridge
Ref: APP/H0520/A/12/2188648
Platform: The Planning Inspectorate
Author: Philip Major
Date: 11 July 2013

Summary
The appeal was allowed for a wind farm and the Inspector commented on the rarity of EAM in practice and that there were other legal remedies. He did not mention SN but this is the clear implication of his comments

Title: Wind farm noise assessments: ETSU-R-97 and the three legged stool
Platform: Science in Parliament, Vol 70 No 3
Authors: David Unwin, Richard Cox, UK
Date: July 2013

Summary
This paper provides an explanation of the noise assessment methodology identifying the three key issues affecting the assessment and how the official noise guidance known as ETSU-R-97 fails to provide adequate protection for people who live near wind turbines.

These three assessment legs being:

- The measurement of the background noise under various conditions.
- A prediction of the turbine noise using manufacturer's turbine data and a noise propagation and prediction model
- A comparison of predicted noise against background noise derived noise limits to determine compliance with noise limits.

The paper discusses some of the important scientific failings underpinning ETSU-R-97

Title: Discussion of Den Brook wind farm conditions 20 and 21
Platform: West Devon Borough Council
Authors: RA Davis, MG Smith, University of Southampton ISVR Consulting, UK
Date: July 2013

Summary
This report was provided by ISVR for West Devon Borough Council. The report claims that the original condition 20 does not provide a robust means of identifying the presence of amplitude modulated wind turbine noise due to the identification of false positives and that such a condition would be unsound until a dose-response relationship for wind turbine noise has been derived and validated.

Title: RES comments on Dr Swinbank's report of May 2013
Platform: West Devon Borough Council
Authors: J Bass, Daniel Leahy, RES, UK
Date: July 2013

Summary
This email response to West Devon Borough Council to Dr Swinbank's report argues around the detail of the FFT (Fast Fourier Transform) applied to the proposed RES scheme.

Title: RES comments on Den Brook wind farm conditions 20 and 21
Platform: West Devon Borough Council
Author: Rachel Ruffle, RES, UK
Date: 13 Aug 2013

Summary
This letter from RES to West Devon Borough Council sets out RES's position prior to meeting with WDBC.

Title: Cotton Farm wind turbines: Phase 1 noise limit compliance assessment
Platform: Hayes McKenzie Partnership for BayWa r.e. Ltd
Author: Andy McKenzie
Date: 20 Aug 2013

Summary
Prior to the operation of the Cotton Farm wind turbines, Hayes McKenzie were commissioned by BayWa r.e. UK Ltd (BayWa), formerly a business unit in RENERCO Renewable Energy Concepts AG, to advise on noise-related aspects of the wind farm. The commission included advising on and managing a voluntary noise monitoring programme that was set up in response to local residents' concerns regarding potential noise emissions from the wind farm. The aim of the monitoring programme was to demonstrate compliance with the noise limits set out in planning conditions imposed on the site (the "limits").

Measurements have been carried out around the Cotton Farm wind farm site since the commencement of full operations in February 2013, to evaluate compliance or otherwise with noise limits in the planning conditions imposed on the site. During this time a number of the turbines have been operating in a curtailed mode to increase the margins by which the limits were predicted to be met and to allow data measured on site to be used to evaluate whether limits would continue to be met once curtailment was lifted on these turbines.

The report concluded with: "*The results of the measurements show that, for the wind conditions for which data is available, the noise limits are met for worst-case conditions of downwind propagation from the site to the receiver locations in the curtailed mode. The margins by which the limits are met demonstrate that all turbines can now be run uncurtailed and that the limits will continue to be met, given the predicted operational differences between curtailed and uncurtailed modes. This will be demonstrated in practice by continuing the measurements at certain locations with the turbines running un-curtailed*".

Title: Amplitude modulation and complaints about wind turbine noise
Platform: 5th International Conference on Wind Turbine Noise, Denver USA
Authors: Joachim Gabriel, Thomas Neumann, Gundula Hűbner, Johannes Pohl, Germany
Date: 28 August 2013

Summary
The subject of the project is a wind farm of nine 2MW wind turbines (WT) in Northern Germany at a distance of approximately 1,500 m from a village in a flat rural landscape. The calculated sound pressure levels at houses in the village based on the WT manufacturer's data predicts sound pressure levels below 33 dB(A).

At this wind farm it is not the loudness of the broadband WT noise causing complaints, nor the tonality or impulsiveness according to the standardised definition of impulsivity. Residents complain about sound identified as different from the natural background noise even if the loudness of this special sound is very low and hardly perceptible. Amplitude modulated aerodynamic noise turned out to be the common ground of complaints documented within this research project about acceptance of noise from wind turbines. The assessment method combined interviews with residents of a wind farm with physical measurements. Audio recorders had been handed out to residents to record annoying noise situations by themselves, as it is difficult to perform a temporary measurement just at the time of annoyance and complaints about WT noise.

Available data did not allow the definition of a certain critical operational mode or weather condition for AM, but daytime patterns occurred.

An AM assessment tool for the quantification of AM perception has been developed and applied to the sound recordings. An improved version of the AM assessment tool featuring long term data analysis will help to identify AM critical operational conditions.

Title: Assessment of wind turbine noise in immission areas
Platform: 5th International Conference on Wind Turbine Noise, Denver USA
Authors: Hideki Tachibana, Hiroo Yano, Chiba Institute of Technology and Akinori Fukushima NEWS Environmental Design Inc, Japan
Date: 28 August 2013

Summary
A synthetic study program on wind turbine noise titled "Research on the evaluation of human impact of low frequency noise from wind turbine generators" has been performed over the three years from the 2010 fiscal year sponsored by the Ministry of the Environment, Japan. In this study program, field measurements and social surveys in the immission areas around 34 wind farms across Japan and laboratory experiments on the psycho-acoustical effects of wind turbine noise have been performed. Among them, the methods of measurement and analysis of wind turbine noise are discussed in this paper. It includes a prototype of wide-range sound level meter, wind-screen to prevent the wind-

noise at the microphone, practical method of on-site measurement, statistical assessment method of amplitude modulation sound, measurement method of residual noise and indicators for the assessment of wind turbine noise.

Conclusions

To summarize the results obtained in the study program for WTN by putting emphasis on noise measurement and analysis:

(1) In the field measurements, the effect of wind should be reduced as far as possible by using wind-screen with sufficient wind shielding effect. As a system, we devised a double windscreen set.

(2) The measurement points should be located on the side facing to wind turbine(s) in the yard of the residence under investigation. The microphone should be positioned near the ground so that the effect of wind could be reduced.

(3) Since the operation of wind turbine(s) varies according to the change of natural wind condition, a measurement should be conducted for a long term; at least five days.

(4) Since WTN tends to increase annoyance and cause sleep disturbance in the night-time, the noise assessment should be made mainly for this time interval.

(5) As the main noise indicator, time-averaged A-weighted SPL should be adopted in principle. At the same time, 1/3 octave band SPLs should be analysed to examine the contents of tonal components.

(6) In the reference time interval, the recordings for ten minutes in every hour during the time when the wind turbines are under the rated operation condition. As the representative values for the time interval, the energy-mean of the SPL values in every ten minutes should be calculated for the reference time interval.

(7) As a practical method of assessing WTN, 90% percent A-weighted SPL (LA,90,T) or 95% percent levels (LA,95,T) may be measured. In these cases, LAeq,T can be approximated by equation (1) . In the measurement of residual noise without WTN, LA,90,T or LA,95,T should be measured. The difference between these two indicators can be approximated by 0.5 dB.

(8) In the analysis, background noises such as road vehicle noise, aircraft noise and various creatures' and insects' sounds should be eliminated by paying careful attention. In cases where the insects' sounds are dominating (in summer and autumn), high-cut filtering with 1.25 kHz cut-off frequency should be applied to eliminate high frequency components which is apt to be dominant in the assessment of A-weighted SPL.

(9) Amplitude modulation can increase annoyance of WTN and it should be assessed. As a method for this aim, we contrived a method using the difference between the A-weighted SPL obtained by FAST time-weighting and that by the SLOW time-weighting, and calculating the width of the 90 percent range of the level difference as a measure indicating the amplitude modulation depth. In almost all cases, amplitude modulation is contained in WTN, and therefore the effect of this component should be considered when setting any noise limit for WTN.

(10) In the study program, the effect of tonal components contained in WTNs has not been sufficiently investigated. Regarding this problem, the validity and applicability of ISO 1996-2 should further be examined by psycho-acoustical experiments.

Title: Audible amplitude modulation – results of field measurements and investigations compared to psychoacoustic assessment and theoretical research
Platform: 5th International Conference on Wind Turbine Noise, Denver USA
Authors: Mike Stigwood, Sarah Large, Duncan Stigwood, UK
Date: 28 Aug 2013

Summary
In the UK the cause of amplitude modulation (AM) and the ability to predict its occurrence is considered abstruse by many. Few have experienced or measured AM and yet conclusions are frequently made asserting that it is rare and that any action to counter its effects is limited by minimal knowledge surrounding its nature and cause. This paper aims to advance current knowledge and opinion of AM. Methods used to successfully investigate AM are confirmed. AM should be measured during evening (after sunset), night time or early morning periods. Meteorological effects, such as atmospheric stability, which lead to downward refraction resulting from changes in the sound speed gradient alter the character and level of AM measured. AM is generated by all wind turbines including single turbines. Propagation conditions, mostly affected by meteorology and the occurrence of localised heightened noise zones determine locations that will be affected. Measurements from eleven wind farms have been presented and discussed in relation to current research and theory. Findings confirm that AM occurrence is frequent and can readily be identified in the field by measuring under suitable conditions and using appropriate equipment and settings. Audible features of AM including frequency content and periodicity vary both within and between wind farms. Noise character can differ considerably within a short time period. The constant change in AM character increases attention and cognitive appraisal and reappraisal, inhibiting acclimatisation to the sound. It is advised that those responsible for approving and enforcing wind energy development improve their understanding of the character and impact of AM. This can be achieved by attending a listening room experience which has been trialled and is discussed in this paper.

Title: Study on the amplitude modulation of wind turbine noise: part 1 –physical investigation
Platform: inter.noise 2013, Innsbruck, Austria
Authors: Akinori Fukushima, Kazuhiro Yamamoto, Hideo Uchida, Shinichi Sueoka, Japan
Date: 15 Sept 2013

Abstract
Amplitude modulation (AM) sound, so called swish sound, is generally contained in wind turbine noise (WTN) and it causes serious annoyance in the areas around wind farms. Therefore, the methods to assess the characteristics of this kind of sound should be investigated in both viewpoints, physically and psycho-acoustically. Regarding the former problem, a practical method to evaluate the magnitude of the AM using common acoustic measurement instrumentation is proposed in this paper. That is, the sound pressure level difference between the levels measured by using FAST and SLOW dynamic characteristics of a sound level meter is calculated for the measurement time interval under investigation and

then the cumulative distribution function of the level difference is calculated. From the result, the value of 90% range is obtained as an indicator for assessing the AM. Statistical data evaluated by using this indicator for AM sounds contained in actual WTNs were obtained through the field measurements performed nationwide across Japan.

Conclusions
In the assessment of WTN, the magnitude of AM is an important factor as well as the time-averaged sound pressure level. Thus, a method for the assessment of the extent of AM in WTN was contrived and an indicator has been proposed in this paper. As a result of investigation using 81 measurement results obtained at 18 wind farm sites in Japan according to this assessment method, sensible AM sounds were found in about three-quarters of the WTs.

Title: Advice on monitoring wind turbine noise impact
Platform: University of Salford
Authors: Sabine von Hünerbein, Robert Oldfield, Andy Moorhouse
Date: 27 Sep 2013

Summary
This report provides independent advice to the Steering Group of the project "LIT/0389/Wind Farm Impacts Research" that is examining the noise, visual and shadow flicker impacts impact of selected wind farms in Scotland and comparing it with the impacts predicted in their planning submissions and the experience of local residents.

Objectives
- Set the proposed and alternative approaches to noise monitoring in the context of what the scientific community accepts to be best practice
- Identify what, from a science perspective, could be additionally concluded by undertaking further monitoring:
  a) With cooperation from wind farm operators to shut down operations for background noise monitoring and
  b) Without wind farm operator cooperation and without information on background noise levels.

Possible objections
The conclusions of wind farm noise impact derived from any proposed method of noise measurement might be open to the following frequently voiced challenges.

a) Wind reference not suitable
   - inaccurate measurements
   - site not representative for either whole wind farm or residential dwelling
   - over-/under-prediction of wind shear
b) Background noise measurement inaccurate
c) Instrumentation issues affecting measurement accuracy: o

  - Wind noise in microphones due to insufficient wind shields or inappropriate high pass filter contaminate low frequency measurements
  - Microphones not capable of accurately measuring low noise floor
- d) Inappropriate data analysis: o
  - Regression or bin averaging methods for determining sound levels
  - Data rejection procedures
- e) Measurements too short to be representative and provide sufficient impact assessment.
- f) Low frequency signatures, infrasound not considered.
- g) Insufficient trust in data and management information provided by turbine operators.

The paper notes: "It is worth pointing out that some of the objections might be pre-empted by the data provision procedure suggested by SAS of detailed project documentation and the public release of all available evidence and project data".

Title: A summary of the bad science behind the wind turbine noise guidelines
Platform: DECC meeting Oct 2014, UK
Authors: David Unwin and Richard Cox
Date: 9 Oct 13

Summary
This presentation material is a summary of the presentation material prepared during March 2013 titled 'The Bad Science behind the Wind Turbine Noise Guidelines' by Cox, Unwin, Bingham and Greenough and updated following the release of the Good Practice Guide. This was presented to Secretary of State Ed Davey MP in October 2013. The following concerned were made clear by Cox and Unwin during their meeting with the Secretary of State:

- IoA Noise Working Group (NWG) members taken from the wind industry - Conflict of interest?
- No statisticians, meteorologists, academics or health professionals included in the NWG, Why?
- Several consultation responses that we are aware of were not published. Why?
- No credible independent peer review process
- Any criticism at odds with the IoA NWG views has been ignored. A summary report showing why consultation responses were not included has not been issued as promised by R Perkins to C Heaton-Harris MP – Why?
- The GPG Supplementary Notes (the all-important small print) have not been issued – Why?
- NWG have failed to demonstrate that a 'grown-up conversation' has taken place with the wider scientific community and that the outcome is demonstrably based on sound science

Title: Evidence of failure of wind farm guidance to protect well being
Platform: DECC meeting Oct 2014, UK
Author: Mike Stigwood
Date: 9 Oct 2013

Summary
This two page summary sheet was presented to Secretary of State Ed Davey MP at a meeting in October 2013.

1. All the wind farms causing complaints that we have so far investigated are considered to comply with ETSU-R-97 except one case which is marginally over the limit.
2. A large number of wind farms are causing noise complaints and obvious evidence of harm to well-being such as sleep disturbance (more than 75 we know of and likely to double) = ETSU-R-97 fails to protect.
3. ETSU-R-97 is incapable of controlling / preventing adverse effects or being modified to achieve that purpose.
4. Proportionally wind farms causing problems is higher than any noise source investigated in my career, including music venues, metals recycling sites and transport noise. Reason = sleep disturbance and stark contrast in noise character.
5. Well-being of a significant minority of communities are being jeopardised for the policies. Potentially between 80-160 wind farms causing problems and 1000's homes affected.
6. Research shows Excess Amplitude Modulation (EAM) = main problem and caused by **all** large wind farms. It is common and not rare as suggested by UK Government policy. Wider international acceptance.
7. Government proposals for community support are divisive, causing more damage and dividing communities.
8. Reliance by UK Government on experts of known persuasion (who are reliant on industry and derive major income with pointless compliance tests that do not fail) is the reason for the problem. The same problem arises with the Institute of Acoustics who are dominated by acousticians reliant on industry and who selected a working group dominated by individuals of known persuasion.
9. Findings are due for release in 2014 with supporting evidence.

Title: Waterloo wind farm environmental noise study
Platform: Environmental Protection Authority, South Australia
Authors: EPA South Australia
Date: November 2013

Conclusion
This report presents results of noise monitoring program performed at six sites in the vicinity to Waterloo Wind Farm over approximately two months, at distances ranging between 1.3 and 7.6 km, covering a broad range of directions. Measurements of noise inside and outside of houses were undertaken at five sites. Additional monitoring

equipment was deployed at two houses (Township and North sites) to acquire data in infrasound frequency range both inside and outside of the houses.

No evidence was found for the presence of excessive infrasound within the infrasound frequency range. The blade pass frequency component, which falls within the infrasound frequency range, was found to be below the perception threshold by significant margin, and typical levels were consistent with results of other relevant studies. G-weighted levels were also found to be below the perception threshold.

Analysis of acoustic data and audio records measured at the Township and East sites did not show evidence for noise that may have been associated with wind farm operations. Wind farm noise was found to be audible at very low levels at the other sites, with a slight degree of modulation; but rarely dominated the noise environment during the monitoring period. Where it could be identified, wind farm noise was generally only discernible with substantial amplification of audio records. A 'rumbling' character could be identified in amplified audio records at three residences (North East, West and South East sites), typically under downwind conditions.

The data showed that operation of the wind farm may have contributed to the low frequency content of noise under some operating and environmental conditions during the period, resulting in increases of relevant low frequency noise descriptors. As with the rumbling effect, the low frequency content was not discernible subjectively when replaying audio records at actual levels, but could be detected with amplification. Analysis of data for the sites showed that high level of low frequency noise is typical for some of the sites, most likely due to natural background or ambient noise sources, for which low frequency descriptors were found to be comparable with those from the wind farm, or at times even higher.

The noise diaries were essential to the study in focusing the acoustic analyses on events and descriptions recorded by the community. In particular, the identification of the rumbling effect and other noise characters associated with the wind farms was facilitated by diary returns. However, it is noted that in analysing audio records acquired during the study, amplification was generally necessary to hear these effects; and where detectable, noise levels recorded during the study complied with the conditions of the development approval and the baseline criterion of 40dB(A).

Nevertheless, it is possible that people who have a higher sensitivity to the lower frequencies in particular may detect these characteristics, and they may cause increased annoyance for those who have been aware of them for a prolonged period. Noise impact from the wind farm, where detectable, was found to comply with the conditions of the development approval and the baseline criterion of 40dB(A).

Title: Rebuttal to the noise proof of evidence of Dr Matthew Cand
Platform: Shipdham Appeal APP/F2605/A/12/2185306
Author: Dr Lee Hoare on behalf of Residents of Daffy Green
Date: November 2013

Summary
The rebuttal points reinforce the fact that the straightforward noise problems at this site have not and cannot be addressed by the appellants. These issues can be summarised as follows :

- The extensive evidence of actual measurements proves that the noise predictions are not robust. Whether this is due to erroneous assumptions of the validity of the turbine source sound power levels used, or the ground reflection factor, or some other factor, is irrelevant when the outcome means more noise than predicted at neighbouring dwellings.
- Although the IoA guidance purports not to have increased wind turbine noise limits from the ETSU limits, the evidence based on actual wind shear data measured at Shipdham demonstrates the opposite; the proposed IoA-style noise condition methodology increases turbine noise limits as wind shear increases, as turbine noise increases and as masking background noise decreases.
- The candidate turbine used for the noise assessment is not typical, it is not conservative in terms of noise output and nor is it sensible in terms of electricity generation capacity factors.
- The wind industry has accepted that we are correct on the likelihood that there will be elevated levels of amplitude modulation at the site and that an AM condition is necessary. Our evidence shows that the noise will be particularly intrusive and annoying because of the beating character of turbine AM noise. Applying the necessary condition to prevent excessive AM noise will reduce the potential energy generation possible for the proposal.

Title: Automated detection and analysis of amplitude modulation at a residence and wind turbine
Platform: Australian Acoustical Society (paper peer reviewed)
Authors: Jonathan Cooper, Tom Evans: Resonate Acoustics, Adelaide, Australia
Date: 17 Nov 2013

Abstract
A small degree of amplitude modulation is a normal feature of wind turbine noise but most assessment guidelines for wind farm noise state that, where excessive amplitude modulation occurs, an additional penalty should be applied to the measured noise. Excessive amplitude modulation is typically defined as a situation where the peak to trough levels (either overall or in particular frequency bands) exceed a nominated level. The assessment of amplitude modulation outdoors at receptor locations near wind farms over a wide range of wind conditions can be difficult due to the need to undertake unattended measurements in an environment where background noise regularly interferes with the measurements. This paper describes a methodology for the assessment of amplitude

modulation over an extended period at a residence, and the specific techniques used to identify amplitude modulation resulting from the wind farm. The methodology has been employed at an operational wind farm and the results at both a residence and wind turbine assessed to identify conditions which contribute to modulation judged to be 'excessive' using the modulation test provided in New Zealand Standard 6808:2010.

Conclusion
This paper has provided a summary of the development of an algorithm for the assessment of amplitude modulation against the requirements of Appendix B of NZS 6808:2010. Additionally, the findings of an assessment at a residence have been provided, along with the results of an analysis of modulation at an adjacent turbine.

On the balance of the available data at the residence it would appear that the ambient noise level at the residence is a more important factor in the detection of excessive amplitude than the influence of wind shear. Periods judged to be 'excessive' modulation using the 6 dB third octave test in NZS 6808:2010 occurred at the residence under periods of both low and high wind shear. Measurements at the turbine suggested a negligible influence from wind shear on the generation of amplitude modulation at the source. Review of modulation at the source also indicated no significant increase in modulation from turbulence, which occurs when the turbine is operating in the wake of another.

The lack of increase in modulation at the source during periods of wind shear suggests the modulation at the site might be best described as 'normal' wind turbine noise modulation with a 'swish' character, rather than 'excessive' modulation with a 'thumping' nature. This finding was supported by a review of audio at both the residence and turbine, which did not find any obvious change in the character of the sound.

Further work is required to determine whether the 6 dB criterion level for modulation depth of third octave noise provides a suitable test of 'excessive' modulation, and to determine a dose response against which the level of increased annoyance can be determined. This 6 dB criterion was regularly exceeded close to the turbine when measuring at high wind speeds to the side of the turbine. The findings at this residence suggest this criterion may also be occasionally exceeded at residential distances during periods of 'normal' modulation.

Title: Wind turbine amplitude modulation: research to improve understanding as to its cause and effect
Platform: RenewableUK
Authors: RenewableUK
Date: 16 Dec 2013

Summary
The ReUK report was launched with accompanying press releases and the following introduction: "*The wind energy industry today publishes detailed scientific research into the identification, occurrence and resolution of an acoustic characteristic known as Other Amplitude Modulation (OAM). This work, led by RenewableUK is the largest study of its kind*

to date". The findings claim to represent a significant advancement in the scientific understanding of the acoustic characteristics associated with OAM, including its causes and mitigations. The report consists of six documents:

1. **Brief summary – Wind turbine amplitude modulation**
   A 2 page document dated 16 December 2013
2. **Summary of research into amplitude modulation of aerodynamic noise from wind turbines**
   A 17 page document dated 11 December 2013
3. **Review of RenewableUK's research into amplitude modulation**
   An 8 page document dated 11 December 2013
4. **Wind turbine amplitude modulation**
   A 513 page document dated December 2013
5. **Template planning condition on amplitude modulation**
   A 16 page document dated December 2013
6. **The development of a penalty scheme for amplitude modulated wind farm noise**
   A 10 page document dated December 2013

Report Conclusions

The report concludes: "*The authors of the work package reports constituting the study have been objective in drawing their conclusions and recommendations from the evidence and information presented; and a high degree of confidence in the information presented is warranted. The new evidence and information presented in the work package reports making up the study significantly increase the understanding of the causes and impacts of amplitude modulation (AM*)".

The detail of the interrelated work package reports is important and should be consulted in depth for the fullest picture of the outcomes of the study. However, key outcomes from the study include the following:

- Normal AM (NAM) is a fundamental characteristic of wind turbine noise and its causal mechanisms are well understood.
- Other AM (OAM) is defined in the study as AM whose characteristics cannot be described by the normal source generation mechanisms of NAM.
- However, OAM is not simply intensified NAM, and has different causal mechanisms to NAM.
- NAM can occur with modulation depths as high as approximately 5 dBA23 in close proximity to a turbine.
- OAM tends to have modulation depths of approximately 5 dBA24 or higher in the far field. The occurrence of OAM is dependent on a number of interacting factors. However, the study reports the primary cause of OAM as being "transient stall" i.e. separation of the air flow from the upper surface of the turbine blade
- Based on the evidence available, the study recognises that even at those wind farm sites where OAM has been reported to be an issue, its occurrence may be relatively infrequent
- The study finds that it is not feasible to reliably predict the likelihood of OAM occurring at a particular site.

- The dominant descriptor of the human subjective response to wind turbine noise is the overall noise level e.g. LAeq,*T*, not the depth of modulation.
- When comparing modulated and un-modulated sounds of the same level, modulated sounds have been found to be slightly more annoying to some people, however, there is no specific level at which the onset of annoyance occurs
- The influence of modulation on the impact of wind turbine noise decreases as the overall level of turbine noise increases.
- Measuring (O)AM is not straightforward, but the study examines various methods and provides a validated and robust method for objectively and automatically measuring (O)AM.
- Because of the causal mechanism identified, minimising the onset of stall will reduce the likelihood of OAM occurring
- Should OAM arise from a scheme, turbine management systems can be used to control the individual turbines responsible so that the impacts are mitigated under the particular conditions that give rise to the phenomenon on a case by case basis

Title: Template planning condition on amplitude modulation
Platform: RenewableUK
Authors: RenewableUK (J Bass of RES)
Date: 16 Dec 2013

Summary
This document is a part of the RenewableUK report into wind turbine amplitude modulation and provides the detail of a proposed planning condition to control AM.

At page 3 the condition requires that: '*The rating level at each integer wind speed is the arithmetic sum of the wind farm noise level as determined from the best-fit curve described in Guidance Note 2 of these Guidance Notes and any tonal penalty applied in accordance with Guidance Note 3* ***and any amplitude modulation penalty applied in accordance with Guidance Note 4****.*' The penalty curve is provided at page 5 and applies a penalty of 3dB for a 3db level of AM rising to 5dB for a 10dB or greater level of AM.

Title: Amplitude modulation of sound from wind turbines under various meteorological conditions
Platform: Acoustical Society of America
Authors: Conny Larsson and Olof Ohlund, Uppsala University, Sweden
Date: January 2014

Abstract
Wind turbine (WT) sound annoys some people even though the sound levels are relatively low. This could be because of the amplitude modulated "swishing" characteristic of the turbine sound, which is not taken into account by standard procedures for measuring average sound levels. Studies of sound immission from WTs were conducted continually

between 19 August 2011 and 19 August 2012 at two sites in Sweden. A method for quantifying the degree and strength of amplitude modulation (AM) is introduced here. The method reveals that AM at the immission points occur under specific meteorological conditions. For WT sound immission, the wind direction and sound speed gradient are crucial for the occurrence of AM. Interference between two or more WTs could probably enhance AM. The mechanisms by which WT sound is amplitude modulated are not fully understood.

Conclusions

Studying AM is very complex due the many factors that govern sound propagation from WTs. For an ideal analysis of how AM is produced and transmitted, emitted sound power, wind direction, temperature gradients, wind gradients, and turbulence would need to be known three dimensionally in small time steps. This is impossible to measure in the field, so simplifications must be made. Furthermore, the interaction of sound from several WTs complicates the analysis.

Higher prevalence of AM is detected when the sun is close to or under the horizon, which corresponds well with when temperature inversions occurs on clear nights. A temperature inversion near the ground changes the angle of incidence of the sound waves and affects the ground attenuation. The reflected sound waves are normally less damped if the sound comes more from the zenith than parallel to the ground. At the Dragaliden site when AM was present, a typical pattern was approximately 15 s of distinct AM followed by a minute of steadier sound levels.

Analysing approximately 30 h of AM measurements recorded simultaneously at both an emission and an immission point shows that enhanced AM at an immission point could not be explained by enhanced AM at the emission point. It is instead an effect of interference between sound from several WTs or of different ray paths of the sound from one turbine. However, this last possibility requires further testing.

The AM detection method works well and does not react to passing cars, birds, or airplanes. During strong masking, the WT signal is lost using the detection method; the sound will of course not be experienced as amplitude modulated, but the signal may still be present in the background noise. Larsson and Ohlun conclude from their measurements that amplitude modulated sound from WTs is more common under certain meteorological conditions and is observable approximately 20%–30% of the operational time, depending on the distance from the turbines. In future studies, it would be interesting to investigate WT sound annoyance coupled to conditions with and without AM present.

Title: A critique of the RenewableUK report on wind turbine amplitude modulation, what it tells us and what it doesn't
Platform: Various including the IoA Conference 20 March 2014, UK
Author: Richard Cox, UK
Date: 22 Jan 2014

Summary
This 43 page document summarises the RenewableUK report, at over 500 pages in length. The critique report conclusions taken from the report are:

- The ReUK report has highlighted aspects of turbine noise previously denied by the wind industry and includes an admission that the AM problem is 'too large to ignore'.
- The claims that AM is rare and infrequent have not been substantiated since no survey was carried out; however, evidence elsewhere shows it to be widespread.
- The report claims are not supported by the evidence from the study and indicates a disconnect between ReUK who commissioned the study and the authors who carried it out.
- The claimed root cause of OAM being blade stall is unproven and admitted to as such by the report authors. As a result the proposed mitigation strategy, even if it was available would fail to work.

Title: Land at Dunsland Cross, Branis Corner, Devon Ref: APP/W1145/A/13/2194484
Platform: The Planning Inspectorate
Author: Neil Pope
Date: 30 January 2014

Summary
This Appeal was allowed for 3 wind turbines. It was agreed at the Inquiry that there was a higher than average risk of EAM and a condition was imposed to cover this. Whether or not it is adequate to protect residents is another matter.

Title: Turncole Farm Ref: APP/X1545/A/12/2174982
Platform: DCLG Appeal decision
Authors: Secretary of State
Date: 13 Feb 2014

Summary
The appeal was recovered by the SoS who allowed it for 7 turbines. In view of new research, he decided to impose a condition to control AM. The condition however is limited to the developer submitting a scheme to the LPA for approval.

Title: Coventry v Lawrence [2014] 1 AC 822
Platform: The Supreme Court
Authors: Lords Neuberger, Mance, Clarke, Sumption, Carnwath
Date: 26 Feb 2014

Summary
A judgement of the Supreme Court which may have significant implications for nuisance cases in the future. It is not a wind farm case but does deal with noise as a nuisance. Many issues such as the ability to acquire a right to commit a noise nuisance and "coming to the nuisance" may need new approaches in the light of this judgment. It is not clear however how it will affect ETSU R 97.

Title: Use of planning conditions
Platform: Department for Communities and Local Government
Authors: DCLG
Date: 6 March 2014

Summary
This Guidance effectively revokes Circular 11/95 which relates to the use of planning conditions except for the model conditions contained in that Circular.

Title: The Efficacy of the RenewableUK (RUK) Condition in controlling wind farm amplitude modulation (AM) noise
Platform: Renewable Energy Foundation (REF)
Authors: Lee Moroney, John Constable, UK
Date: 19 Mar 2014

Summary
After testing the proposed RUK planning condition REF concluded:

- The proposed RUK AM condition would not be breached by recorded wind farm noise data with high levels of AM measured at Askam, a site widely recognised to be producing severe AM problems, and at Swaffham, from data where the AM is clear and significant in magnitude. By comparison, data from both the Askam and Swaffham sites would be in breach of the Den Brook AM condition.
- The authors conclude from these facts that the RUK AM condition is manifestly inferior to the Den Brook condition and does not offer to wind farm neighbours any realistic or significant protection against AM disturbance.
- The RUK AM condition is too complex and computationally intensive to provide a reasonably accessible and transparent methodology for assessing excessive AM noise. Even acoustic professionals will struggle with this method, and Local Authority Environmental Health Officers are extremely unlikely to have either the resources or the training to undertake such compliance tests. This is unacceptable,

particularly when more effective alternatives, such as the Den Brook method, suffer no such defects.

- The RUK condition method results in an understated value of the true peak-to trough levels of the AM noise. This is obviously unacceptable.
- The RUK AM condition is limited to a maximum penalty of 5dB linked to overall noise levels, so where there is 5dB headroom – which is often the case at night-time when ETSU-R-97 wind farm noise limits are higher, background noise levels lower and AM more likely to be a nuisance – there is no sanction against AM of any level or duration.
- It is unreasonable to treat the annoyance arising from the beating noise character of wind farm AM noise as an adjunct to the total sound levels rather than as a distinct problem in its own right. Applying a correction to the measured sound levels will not address the issue of noise complaints arising from excess AM noise; it should be treated as a standalone problem. This is because annoyance is not linked to overall noise level, but to its modulation even at low noise levels. It is AM that has to be removed not just compensated for in a way which is demonstrably ineffective.

Title: The Cotton Farm research project long term study – initial findings and other MAS research
Platform: IoA Conference 20 March 2014
Author: Mike Stigwood, MAS, UK
Date: 20 Mar 2014

Summary
This presentation included:

- An argument that BS4142 – 1997 provides a good mechanism for assessing EAM.
- External EAM measurements do not reflect internal EAM
- ETSU fails to address AM arising from large wind turbines
- Provided initial findings from one year of continuous monitoring at the Cotton Farm site
- The proposed RUK AM condition was tested and found to allow even the worst cases of AM

The presentation concludes with:

- All wind turbines cause AM.
- AM occurs in heightened noise zones (HNZ)
- Meter location & site observations critical.
- HNZ vary with wind direction, synchronicity and meteorology (especially wind shear)
- Some locations regularly experience higher AM than others.
- Crosswind AM exhibiting large peak to trough values can arise at significant distances in excess of 400m.
- Upwind AM can be as bad as downwind AM when within a reasonable proximity of the wind farm

Title: A critique of the RenewableUK report on wind turbine amplitude modulation
Platform: IoA Conference 20 March 2014, UK
Author: Richard Cox
Date: 20 March 2014

Summary
This presentation made at the IoA conference during March 2014 provided a critique of the RUK report into AM including the proposed AM planning condition and then the implication for noise assessments and planning approvals including the failings of ETSU.

Abstract
On 16 December 2013 RenewableUK (ReUK) finally released their report resulting from a study commenced during 2010 into a feature of wind turbine noise known as amplitude modulation (AM). The report was accompanied by a press release on the ReUK web site and a closely coordinated news article in the Guardian newspaper.

In the report ReUK now acknowledge that AM is a problem "*too large to ignore"* and as a result of their study claim that AM is now largely understood. However, ReUK claim that the occurrence of excess AM is rare and infrequent and where it does occur, a mitigation scheme can be implemented.

This paper examines the claims made by ReUK demonstrating that these claims are not supported by the evidence provided within the report or elsewhere.

Additionally, an updated summary of the main shortcomings of the ETSU wind turbine noise assessment methodology will be discussed including the implications of the ReUK AM report recommendations.

Title: Amplitude modulation case study at the Leonards Hill wind farm, Victoria, Australia
Platform: IoA AM Conference, Cardiff 20 March 2014
Author: W Les Huson, Australia
Date: 29 April 2014

Abstract
Results of two channel simultaneous audio recordings outdoors in the free field and inside a bedroom are presented from the Leonards Hill wind farm that has two Repower 2MW MM82 wind turbines.

The analysis demonstrates the dynamic effects of amplitude modulation on attenuation of sound between the two measurement locations and shows how outdoor to indoor attenuation is compromised at particular room resonant modes.

Different measurement approaches are discussed with the conclusion that a 10Hz sampling rate of sound level is insufficient to accurately determine peak to trough amplitude modulations.

Infrasound measurements are also presented to show that amplitude modulation is also observable below 20Hz and that low frequency infrasound may also be considered to be amplitude modulation.

Conclusions
The data recorded and analysed so far suggest that data sample rates greater that 100ms would be advantageous to better quantify AM. An Impulse response is recommended for sound level recording. PSD averaging should include peak spectrum values although more work in this area of analysis is required, that should also include the envelope of AM and AM repetition rate change of blade swish from multiple wind turbines. AM is observed in the infrasound frequency range and should not be discounted.

Some of the questions yet to be answered for planning authorities and regulators are:

- What amplitude modulation should be deemed acceptable?
- Is there a simple compliance method available using spectrum analysis of amplitude modulated levels (perhaps the RenewableUK OAM with modifications)?
- How do we address the beating between multiple turbine amplitude modulations?
- Should an extra penalty apply to an envelope of amplitude modulation or rate of change of amplitude modulation frequency caused by multiple turbines?
- Should we consider the full acoustic spectrum below 20Hz and can infrasound pressure variations below 7 Hz themselves be considered to be amplitude modulation?
- Is it appropriate to low pass filter A-weighted measurements below 1kHz for AM?
- Should AM be specified in 1/3 octave bands?

Title: Appraisal of the proposed scheme for condition 21
Platform: ISVR Consulting to West Devon Borough Council, UK
Authors: Malcolm Smith, Bob Davis
Date: 29 April 2014

Summary
ISVR acting as consultants to West Devon Borough Council appraised the RES proposed condition 21 for the Den Brook wind farm planning consent. The purpose of condition 21 is to determine whether amplitude modulated wind turbine noise is present. The intent being that the assessment of whether the AM is excessive is then carried out using condition 20.

This assessment was based on data acquired at the Cotton Farm wind farm. The overall conclusions were:

- The procedure proposed by RES for implementing condition 20 is technically robust and can be reasonable adopted in accordance with condition 21

- The threshold value defined in stage 4f of the procedure should be set at 2.5dB, not 4dB as currently proposed by RES.
- The measurements may be made in terms of $L_{Aeq,100ms}$ or $L_{Aeq,125ms}$.

Title: Written scheme relating to condition 21 Den Brook wind farm implementation of condition 20 for the identification of greater than expected amplitude modulation
Platform: RES to West Devon Borough Council, UK
Authors: RES (J Bass)
Date: 8 May 2014

Summary
This document provides the RES revised proposed planning condition 21 for the Den Brook wind farm.

Title: Assessment of proposed Den Brook condition 21 scheme for the implementation of condition 20 (amplitude modulation of wind turbine noise)
Platform: ISVR Consulting for West Devon Borough Council, UK
Authors: RA Davis, MG Smith
Date: May 2014

Summary
RES have proposed a scheme to satisfy condition 21 of the Den Brook wind farm planning permission. The scheme is intended to define a procedure for implementing condition 20, which sets limits on the permissible levels of amplitude modulation of wind turbine noise.

ISVR Consulting were commissioned by West Devon Borough Council to advise on the technical aspects of the scheme. The scheme as first proposed has been subjected to validation tests. These tests show that the scheme provides a necessary and robust preliminary 'filter' to enable noise data containing amplitude-modulated wind turbine noise to be identified and to be evaluated using condition 20.

The proposed condition is considered to be technically fit-for-purpose and can reasonably be accepted by the Council for the purpose of discharging condition 21.

Title: Discharge of Conditions Decision - Land adjacent to Den Brook
Platform: West Devon Borough Council, UK
Authors: WDBC
Date: 21 May 2014

Summary
The summary of this decision is: *"In respect to the details of the greater than expected amplitude modulation scheme received by ourselves on 08/05/2014, I can confirm that these are considered acceptable. Providing that the development above is carried out in accordance with the details submitted, then condition 21 of the above planning permission can be discharged".*

Title: Indoor noise survey: Knockglass farm
Platform: L Huson & Associates Pty Ltd, Australia
Authors: W Les Huson
Date: May 2014

Summary
L Huson & Associates Pty Ltd has completed sound level measurements indoors at Knockglass Farm in Scotland from 7 April 2014 to 9 April 2014.

Amplitude modulation at rotor speeds typical of 2.3 MW wind turbines (17.4 rpm) have been observed inside a bedroom of Knockglass Farm in the early morning of 8 April 2014 at peak to trough levels exceeding 20 dB(A).

The report author suspects that the major source of the amplitude modulation is the Neilston Community Wind Farm located approximately 1000 m SE of Knockglass Farm from which a repetitive transient has been observed corresponding to shaft rotational speed.

Overall infrasound pressure levels in the frequency range 0.05 Hz to 2 Hz have been observed that are inversely proportional to amplitude modulation levels.

Title: Clocaenog Forest wind farm Examining Authorities Report
Platform: The Planning Inspectorate
Author: Wendy Burden
Date: 12 June 2014

Summary
The Examining Authority issued this Report following an examination that ran from 12 September 2013 to 12 March 2014. The Examining Authority addressed the issue of EAM and whether SN was an appropriate remedy. She noted at paragraph 4.149 that SN had been determined to be a suitable remedy in the Brechfa Forrest examination. She also noted at paragraph 4.150 that the situation has developed since then.

At paragraph 4.151, she said:
"The impact of noise on the occupiers of properties is a planning issue, and mitigation through the imposition of requirements is recognised as necessary and appropriate. The pursuit of a statutory nuisance claim can be lengthy and cumbersome in comparison with the enforcement of a condition or requirement.
With a project of the scale of CFWF, it is acknowledged that there would be significant impacts on those who live in the vicinity of the site. The application of the precautionary principle, in order to alleviate the risk of causing further harm both to those residents and to a larger number of people would in my view be reasonable and appropriate. I return to consider what if any requirement it would be appropriate to impose in order to provide protection against the possibility of other AM in Section 7 of the report."

In addressing the case for Compulsory Acquisition, the Ex A considered the impact of the Human Rights Act 1997 and Article 8 of the European Convention of Human Rights and article 1 of the First Protocol.

At paragraphs 6.18 and 6.19, she stated:
"In the event that compulsory acquisition rights are granted, Article 1 of the First Protocol and Article 8 of the Human Rights Act are engaged. However, the interference with private rights of way is necessary to the construction of the project. Interference would be for a prescribed period and compensation would be available for any loss experienced. This is a very large scale project for which there is significant support in national policy. The limited interference with private rights in order to construct the project would be both proportionate and justified in the public interest.
Those whose rights would be affected have been properly notified by the applicant of the development 366, and there has been adequate opportunity during the six months of the examination for those parties to express their views. I held a hearing on compulsory acquisition on 29 January 2014 but no objections were put forward. All those affected have therefore had the opportunity for a fair and public hearing in accordance with Article 6 of the Human Rights Act"

It should be noted that these comments are made in connection with any compulsory purchase required under the scheme. They are not made in relation to the operation of the scheme and enjoyment of private property

At paragraph 8.32 and 8.42 in her recommendation, she states
"However, I identify three dwellings which would be at risk of a particularly harmful level of visual impact. When combined with the changes to the noise environment, there is a risk that those dwellings would become unattractive places in which to live. This level of harm to residential amenity would not be in the public interest, and must weigh against the project [paras 4.204 to 4.239]."

And at paragraph 8.46-47:
"Nevertheless, there is the wider public interest to be weighed against the risk of harm to the residential amenity of the three properties. In this case it is a difficult and finely balanced judgement to be made. EN-1 identifies the need to address the impacts of climate change as

urgent. The CFWF accords with national, regional and local policy in all other respects and would make a significant contribution to meeting that need, and the presumption in favour of the development established in EN-1 carries great weight [paras 8.3 and 8.4].
With the weight of national policy in favour of the project, I find that the wider public interest marginally outweighs the risk of harm to residential amenity. In these circumstances the interference with the human rights of the occupants of the three properties would be proportionate and justified in the public interest"

This reference to HR considers it in a different way from that mentioned above which deals only with compulsory purchase. It is made without quoting Article 8. The issue is whether "proportionality" is relevant in Article 8 cases.

Title: Report on the examination into the Allerdale local plan part one
Platform: The Planning Inspectorate
Authors: Susan Holland
Date: 1 July 2014

Summary
A report by the Inspector who conducted an Examination in Public into the proposed Allerdale Local Plan. The proposed Plan included provisions for a separation distance between wind turbines exceeding 25 meters and housing. The Inspector noted that there are concerns about the effectiveness of ETSU and held that a proposed Policy for a separation distance was sound.

Title: Between Michael Hulme and West Devon Borough Council and RES Developments - Witness Statement
Platform: High Court
Author: Michael Stigwood
Date: 29 July 2014

Summary
This document is the witness statement of Michael Stigwood responding to the proposed condition 21 of the planning consent for the Den Brook wind farm.

Title: Land at Saxby Wolds, near Barton-upon-Humber, North Lincolnshire Ref: APP/Y2003/A/12/2180725
Platform: DCLG Appeal decision
Author: Secretary of State
Date: 31 July 2014

Summary
A planning appeal recovered by the Secretary of State who agreed with the recommendation of the Inspector to dismiss the appeal. However the Inspector criticised the Council for adapting a proposed condition that did not comply with ETSU that the Government considered "fit for purpose"

Title: AM working group – options document
Platform: Institute of acoustics good practice guide to wind turbine noise assessment
Author: Richard Perkins
Date: 1 Aug 2014

Summary
This document released on the IoA web site provides detail of the IoA working group study into amplitude modulation. It documents the working group membership, meeting schedule, goals, success criteria, work plans and the terms of reference.

Title: Letter to Ed Davey, Secretary of State DECC from the Institute of Acoustics
Platform: Institute of Acoustics
Author: William Egan, President of IoA
Date: 7 Aug 2014

Summary
This letter requests DECC to:

- Accept and confirm the Supplementary Guidance Notes which sit alongside the Good Practice Guide.
- To consider a penalty scheme for wind turbine amplitude modulation by conducting an independent research project.

Additionally the letter warned the Secretary of State, "*The incidence of AM is reported to be increasing the number of complaints from onshore wind farms and a number of nuisance cases are understood to be currently being progresses through the courts. Without a Government steer on the matter of AM, it is likely that Judges may accept a lower threshold of acceptance than current Government support for onshore may suggest, which could restrict the roll-out of onshore wind in the UK*".

Title: Low-frequency sound affects active micromechanics in the human inner ear
Platform: Royal Society Open Science
Authors: Kathrin Kugler, LutzWiegrebe, Benedikt Grothe, Manfred Kössl, Robert Gürkov, Eike Krause and Markus Drexl, Germany
Date: 18 Aug 2014

Summary:
Noise-induced hearing loss is one of the most common auditory pathologies, resulting from overstimulation of the human cochlea, an exquisitely sensitive micromechanical device. At very low frequencies (less than 250 Hz), however, the sensitivity of human hearing, and therefore the perceived loudness is poor. The perceived loudness is mediated by the inner hair cells of the cochlea which are driven very inadequately at low frequencies. To assess the impact of low-frequency (LF) sound, we exploited a by-product of the active amplification of sound outer hair cells (OHCs) perform, so-called spontaneous otoacoustic emissions. These are faint sounds produced by the inner ear that can be used to detect changes of cochlear physiology. We show that a short exposure to perceptually unobtrusive, LF sounds significantly affects OHCs: a 90 s, 80 dB(A) LF sound induced slow, concordant and positively correlated frequency and level oscillations of spontaneous otoacoustic emissions that lasted for about 2 min after LF sound offset. LF sounds, contrary to their unobtrusive perception, strongly stimulate the human cochlea and affect amplification processes in the most sensitive and important frequency range of human hearing.

Title: Between Michael Hulme and West Devon Borough Council and RES UK & Ireland – Witness Statement
Platform: High Court
Author: Robert Davis
Date: 8 Sept 2014

Summary
This document is the witness statement of Robert Davis responding to the issues raised by Michael Stigwood relating to the evaluation of condition 21 of the planning consent for the Den Brook wind farm.

Title: Between Michael Hulme and West Devon Borough Council and RES UK & Ireland – Witness Statement
Platform: High Court
Author: Jeremy Bass
Date: 10 Sept 2014

Summary
This document is the witness statement of Jeremy Bass responding to the issues raised by Michael Stigwood relating to the evaluation of condition 21 of the planning consent for the Den Brook wind farm.

Title: Decision letter: Clocaenog Forest wind farm
Platform: DECC Planning decision
Author: Secretary of State
Date: 12 Sept 2014

Summary
In this letter, the SoS gives consent for the development. He notes the noise problems likely to be caused in particular to 3 properties. At paragraph 4.14, after considering the Ex A's comments on Human Rights, he states:

"The Secretary of State agrees that the arguments in this case and in respect of this particular issue are finely balanced. He agrees with the ExA's view that it is not possible to mitigate the impacts of the wind farm on the three properties in question. He considers the matter has been considered appropriately during the examination of the application and that residential amenity is not an issue of sufficient magnitude to justify the withholding of consent given the benefits of the Development. In these circumstances he considers that the interference with human rights of the occupants of the three properties would be proportionate and justified in the public interest."

Apart from the reference to "interference with HR" in paragraph 8.47 of her Report, this does not appear to be consistent with the comments of the Ex A, who considered HR in the context of compulsory purchase, not in the context of enjoyment of the property.

Title: Land at Wood Farm, Church Lane, Shipdham Ref: APP/F2605/A/12/2185306
Platform: DCLG Appeal decision
Author: Secretary of State
Date: 25 Sept 2014

Summary
Another appeal recovered by the SoS. The decision is more recent than Dunsland and Turncole. It was dismissed for other reasons but in relation to EAM the letter says "*"The Secretary of State has taken account of the Inspector's remarks at IR365-367 and agrees*

that the matter of noise-related amenity is addressed through the use of ETSU-R-97. He further agreed with the Inspector's conclusions at IR373 that if excess amplitude modulation were to arise, that statutory nuisance procedure as a means of dealing with excess amplitude modulation is preferable to assigning a planning condition."

Title: Between Michael Hulme and West Devon Borough Council and RES Development – Witness Statement
Platform: High Court
Author: Michael Anthony Stigwood
Date: 29 Sep 2014

Summary
This document is the witness statement of Michael Stigwood responding to the evidence of Robert Davis and Jeremy Bass relating to the evaluation of condition 21 of the planning consent for the Den Brook wind farm.

Title: Starbold decision: Land between Bishops Itchington, Gaydon and Knightcote Ref: APP/J3720/A/13/2193579
Platform: DCLG Appeal decision
Author: Secretary of State
Date: 1 October 2014

Summary
The appeal was recovered by the Secretary of State and was dismissed on other grounds. The Inspector did consider EAM conditions proposed by the LPA but said they did not meet policy tests. He stated "*In such circumstances, I am not convinced that the SC proposed by the LPA would pass the tests of precision and reasonableness as set out in PPG. In the absence of a specific condition, a resident affected by EAM would rely on the statutory nuisance regime. Whilst I have noted the concerns raised by the lpa in the implementation of this regime, in the absence of any other appropriate mechanism, it remains the current process by which noise problems can be mitigated.*" The SoS agreed that this would be the appropriate approach.

Title: Measuring wind turbine coherent infrasound
Platform: Dept of Physics and Astronomy, University of Waterloo, ON, Canada
Authors: John Vanderkooy, Richard Mann,
Date: 2 Oct 2014

Abstract
To extract the optimum coherent infrasound signal from a wind turbine whose rotation is not precisely periodic, we use an optical telescope fitted with a photodetector to obtain

reference blade passage periods, recording these together with the microphone infrasound signal. Signal processing of the quasi-periodic microphone signal is then used to obtain periodic data, which are analysed by an appropriate length DFT to extract optimum values for the fundamental and harmonics of the coherent signal. The general procedure is similar to order domain analysis for rotating machines and is thoroughly explained and illustrated with measurements and analysis from a number of different wind farms. If several turbines are measured by a single microphone with blade passage periods obtained from several separate reference tracks, it may be possible to retrieve separate useful coherent signals from multiple turbines by appropriate processing.

Conclusion
Our paper shows how the coherent part of the infrasound from a single WT can be extracted from a microphone signal by using a blade passage reference track from the turbine under study.

Our analysis reveals a characteristic infrasonic pulse. We conjecture that the pulse from a single WT is caused by the interaction of the blades against the pylon, while the rather more complex background signal relates to the radiation of the Tyler-Sofrin spinning modes.

The random component of the infrasonic signal exceeds the coherent part, and this random component is related to wind noise, which appears to be similar whether one is near or far from a wind farm.

Our paper avoids the issue of health effects from WT infrasound. Information on both sides of the controversy abounds in the literature.

Title: AM working group – terms of reference
Platform: Institute of acoustics good practice guide to wind turbine noise assessment
Author: Richard Perkins
Date: 21 Oct 2014

Summary
This updated document released on the IoA web site provides detail of the IoA working group study into amplitude modulation. It documents the roles and responsibilities and working arrangements.

Title: AM working group – options document
Platform: Institute of acoustics good practice guide to wind turbine noise assessment
Author: Richard Perkins
Date: 21 Oct 2014

Summary
This updated document released on the IoA web site provides detail of the IoA working group study into amplitude modulation. It documents the working group membership, schedule of meetings, goals, work plans and success criteria.

Title: BS4142:2014 Methods for rating and assessing industrial and commercial sound
Platform: British Standards Institution
Authors: BSI
Date: October 2014

Summary
The British Standard (BS) distinguishes between sound and noise, defining sound as can be measured by a sound meter or other measuring system. Noise is related to the human response and is routinely described as unwanted sound, or sound that is considered undesirable or disruptive.

At Section 1 the BS describes the scope of the standard including sound from fixed installations which comprise mechanical and electrical plant and equipment. It is applicable for outdoor locations for the purposes of investigating complaints and assessing sound from proposed new, modified or additional source(s) of sound of an industrial and/or commercial nature. The standard is not intended to be applied for sound sources falling within the scope of other standards or guidance or the assessment of low frequency noise.

Section 7 discusses how to determine the specific sound level free of other influences contributing to the ambient sound.

At Section 8.1 the BS discusses how to determine the background sound level. It contains a warning of the care needed when measuring low background sound levels that are less than 10bB above the noise floor of the measuring system. NB this is regularly the case for wind farm assessment - i.e. background noise levels in the region of 18-20dB(A), which roughly corresponds to the noise floor of most type 1 sound level meters, are frequently measured in rural locations.

At Section 9 the BS describes how to determine the Rating level and corrections to be applied in the event of tonal or impulsive characteristics of the specific sound. Also corrections can be applied in the event of intermittency and other sound characteristics.

- For tonality, this can be converted to a penalty of 2 dB for a tone which is just perceptible at the noise receptor, 4 dB where it is clearly perceptible and 6 dB where it is highly perceptible.

- For impulsivity, this can be converted to a penalty of 3 dB for impulsivity which is just perceptible at the noise receptor, 6 dB where it is clearly perceptible and 9 dB where it is highly perceptible.
- For intermittency, where it is readily distinctive against the residual acoustic environment, a penalty of 3 dB can be applied.
- For other sound characteristics where the specific sound features characteristics that are neither tonal nor impulsive, though otherwise are readily distinctive against the residual acoustic environment, a penalty of 3 dB can be applied.

The BS notes that where tonal and impulsive characteristics are present in the specific sound within the same reference period then these two corrections can both be taken into account. If one feature is dominant then it might be appropriate to apply a single correction. Where both features are likely to affect perception and response, the corrections ought normally to be added in a linear fashion.

At Section 10 the BS requires consideration of the level of uncertainty in the data and to report the level and potential effects of uncertainty. This is dealt with in some considerable detail.

Section 11 of the BS considers the assessment of the impact of the specific sound. An initial estimate is obtained of the impact of the specific sound by subtracting the measured background sound level from the rating level , and typically, the greater this difference, the greater the magnitude of the impact.

- A difference of around +10 dB or more is likely to be an indication of a significant adverse impact, depending on the context.
- A difference of around +5 dB is likely to be an indication of an adverse impact, depending on the context.
- Where the rating level does not exceed the background sound level, this is an indication of the specific sound source having a low impact, depending on the context

Title: Judgement – Hulme v West Devon Borough Council
Platform: High Court
Author: Mr Justice Supperstone
Date: 7 Nov 2014

Summary
The judicial review was refused.

Title: Letter to the Institute of Acoustics from Secretary of State, DECC
Platform: Department of Energy & Climate Change (DECC)
Author: Ed Davey MP
Date: 16 Nov 2014

Summary
This letter being a reply to the letter dated 7 August from W Egan, President of the Institute of Acoustics. In this letter DECC agrees to commission research on an appropriate penalty scheme for amplitude modulation as requested by the Institute of Acoustics.

Title: Initial findings of the Cotton Farm wind farm long term community noise monitoring project
Platform: Inter-noise 2014, Melbourne, Australia
Authors: Mike Stigwood, Duncan Stigwood, Sarah Large, MAS Environmental, UK
Date: 16 Nov 2014

Abstract
This paper provides early results of a long term study of community impact from wind farm noise and uses of the data obtained. A continuously recorded database of noise collected under different meteorological conditions has allowed detailed analysis of particular characteristics such as amplitude modulation and also the reliability of assessment methodologies for predicting and quantifying impact.

Surprising outcomes are explored including upwind impact. In 2012 the local community contracted MAS Environmental to establish a permanent monitoring station to record and publish data online located 600m from the nearest turbine to correlate the impact upon the community and provide an extensive database. This paper maps the evolution of the project. Online data enables a wider study of the effect of meteorological change on noise immission in a flat eastern area of the UK. Anyone can independently observe and listen to the audible elements of the noise that people complain about. This tool aids understanding as well as predicting times of likely adverse impact.

The database has enabled testing of proposed controls, particularly in relation to audible amplitude modulation and demonstrated the recent Renewables UK proposed control mechanism fails. Data obtained challenges claims of blade stall as the primary cause of far field AM and wind farm noise prediction methodologies.

Title: The noise characteristics of 'compliant' wind farms that adversely affect its neighbours

Platform: Inter-noise 2014, Melbourne, Australia
Authors: Sarah Large, Mike Stigwood, MAS Environmental, UK
Date: 16 Nov 2014

Abstract

In the UK many wind farms generate complaints of noise despite complying with control limits. Problems relate to reliance on the LA90 index, failure to consider or apply ratings on the context of the sound characteristics and actual human responses due to complex characteristics. In general in the UK low frequency and very low frequency sound effects are either ignored or denied. The complex interrelationship of features within this noise and difficulties in quantifying and qualifying noise impact and inappropriate comparison with other sources of noise renders the effects difficult to investigate or quantify with contradictory outcomes possible using the same data sets. Claim and counterclaim of health and adverse effects complicate the analysis. This paper explores some of the interrelating characteristics of wind farm noise measured and observed in the field that appear to influence complaints made by communities. Cumulative effects occurring in environments normally dominated by natural sounds and both audible and inaudible elements remain alien sounds which are not habituated to. It appears that sensitisation arises. The physical reason for the failure to appropriately identify modulating noise effects and in particular low frequency modulating noise problems are explored.

Conclusions

Wind farm noise character is largely neglected at the planning stage. This appears to be exacerbated by inappropriate comparisons with noise sources that have a similar noise level but an entirely different noise character. Noise limits rarely account for noise character and where they do assessment is typically limited to application of a maximum 5-6dB penalty to the existing noise limits. In cases where noise complaints have been received from wind farm noise there are distinctive intrusive character features in the noise, but the noise is found to be compliant with decibel limits. This is demonstrated in the examples provided and is evidence that the current approach to assessing impact is ineffective.

The four examples provided show that wind farm noise character can be unique to each development and highly variable within each development. Different assessment metrics result in contradictory outcomes of acceptability at each site. Whilst one aspect of noise character might be well characterised by a modulation index another noise characteristic might be better defined by a prominence rating, other characteristics, such as rhythm, are ignored by all assessment parameters.

The analysis and comparison of assessment methods for each of the four examples confirms that a single assessment parameter does not reflect impact. The worst metric of assessment for noise character is that of a penalty applied to a noise limit, as currently proposed in the UK. Even where multiple assessment parameters are adopted significant character features can still be neglected. The ability of noise measurements to accurately reflect the perception of the listener, including within the dwelling, is further questioned.

It is concluded that assessment of character in wind farm noise is in need of serious review by the acoustics community. The current methods adopted to assess noise impact fail those affected and suggest compliance where significant adverse impacts exist. The above analysis suggests that metrics assessing amplitude modulation in isolation will help to provide an indication of intrusive noise character but still neglect many important characteristics. It is noted that the above examples focus only on short extracts of wind farm noise. Long term exposure to noise is likely to heighten perception and annoyance of specific characteristics. Studies investigating how multiple character features interrelate to judgement of impact and the longitudinal impact of noise with character are recommended.

Title: Special noise character in noise from wind farms
Platform: Inter-noise 2014, Melbourne, Australia
Authors: Valeri Lenchine, Jonathan Song, SA Environmental Protection Authority, Australia
Date: 16 Nov 2014

Summary
A particular noise character, which can be described as “rumbling”, has been detected at a few monitoring sites situated around a wind farm area under a range of downwind conditions. The rumbling was only discernible to a typical listener when replayed at amplified audio records, actual noise levels were low, approximately 30dB(A) or less. Analysis of shutdown and adjacent periods at one of the monitoring sites indicated a direct link between operation of the wind farm and this particular noise character. This effect is most commonly recorded at the monitoring sites under downwind conditions. It is most prominent when the local background noise was low, notably at low local wind speeds but high hub height wind speeds.

Conventional methods of rumbling assessment are based on the concept of low frequency spectral imbalance. Methods of assessment based on this concept cannot always be applicable to rumbling evaluation because of very low SPLs associated with rumbling from wind farms. Analysis of the filtered audio records indicated that the rumbling is also linked to the noise level variations.

Spectral analysis showed that the effect could have been linked to a prominency of 50Hz component when parameter *P* exceeded 10dB. The component was not that prominent at other monitoring locations and noise there did not exhibit the rumbling character. The rumbling was not combined with tonal perception of the noise and is most likely caused by a combination of the temporal fluctuations and the imbalanced low frequency spectrum. As a part of simplified approach to detecting potential rumbling from wind farms, the predicted noise levels can be further analysed in accordance with the method suggested in work (12). It was found that using this method, the times when the rumbling in audio records could be heard produced positive results. The QAI calculated during these times were shown to be less than 20dB which is considered Neutral (no rumbling should be detected).

In spite of the fact that the overall noise levels met regulatory requirements, it is possible that people who have a higher sensitivity to the lower frequencies in particular may detect

these characteristics, which may cause increased annoyance for those who have been aware of it for a prolonged period. Also, due to the very low A-weighted noise levels that were recorded during these events, it may be possible that listeners are more sensitive to frequencies between 30-50Hz. The wind farm manufacturers may have to consider potential for low frequency impact of wind turbines and presence of prominent components at the design stage. It can help to avoid presence of the characters in the wind farm noise and improve perception of the noise by sensitive listeners.

Title: Correlation of amplitude modulation to inflow characteristics
Platform: Inter-noise 2014, Melbourne, Australia
Authors: Helge Aa. Madsen, Franck Bertagnolio, Andreas Fischer, Christian Bak, Denmark
Date: 16 Nov 2014

Abstract
Amplitude modulation (AM) of noise from wind turbines and its more extreme version named “other amplitude modulation” OAM have been investigated intensively during the last few years due to the additional annoyance impact this type of noise has compared to broad band noise. In a recent published research by RenewableUK the hypothesis has been that one of the causes of OAM is transient stall on the blade due to non-uniform inflow such as shear. Part of the RenewableUK research work was a contribution by DTU on analysis of data from the DANAERO MW experiment from 2009. In the DANAERO experiment a new 38.8m test blade for a 2MW NM80 turbine was manufactured and equipped with a massive instrumentation comprising flush mounted surface microphones, pressure taps and five hole pitot tubes. The correlation of the spectra from the surface microphones and the measured inflow angle (IA) confirmed the strong increase in the noise source for high IA. As only few 10min data sets were measured in the DANAERO project a data set with measured inflow angle from 2003 on the same turbine has been used to explore the statistical properties of AM and OAM based on assumed correlation to IA.

Conclusions
The analysis of the spectra from flush mounted surface microphones on a 2MW turbine conducted in the DANAERO experiment shows a strong increase at low frequencies when the AoA reaches 12-13^{o} where trailing edge stall initiates. For the turbine operating in a strong wind shear a modulation of the surface spectra for frequencies below 200Hz is 14dB. This is expected to generate AM or OAM in the far field.

The statistics based on an analysis of about 2000 10min time series of measured AoA on the same turbine over a period of three weeks has shown that transient stall over part of a rotor revolution is likely to occur and in particular during wake operation. The meandering of the velocity deficit in the wake can cause abrupt changes in wind speed over the rotor disc and for a variable speed turbine the rotor might not be able to accelerate fast enough to avoid transient stall for a few revolutions. This intermittent occurrence corresponds well to the reported typical characteristic of OAM and the mechanism might explain many of the occurrences of OAM.

Title: Noise and low frequency noise from wind turbines
Platform: Inter-noise 2014, Melbourne, Australia
Author: Bo Søndergaard, Denmark
Date: 16 Nov 2014

Conclusions
The purpose of this review is to investigate if the new Danish regulation on low frequency noise has had any impact on the emitted low frequency noise and the low frequency noise at the neighbours or not. The wind farm examples do not give a clear answer. It gives the impression, that the situation has not changed and the amount of low frequency noise at the residents is the same as for wind farms with smaller and/or older wind turbines.

Looking at the sound power levels and sound power spectra gives more information. Analysis of the sound power spectra shows that after 2010 the relative amount of noise in the frequency range from 100 to 400 Hz is reduced significantly. This includes the important part of the low frequency range from 100 Hz to 160 Hz. Whether this is because of the Danish regulation is impossible to say, but it is likely that the regulations have increased the focus on this in the design phase. It is the experience of Grontmij, that the low frequency tones, which were a significant part of low frequency noise in (1), (2), (3), (4) and (5) are reduced for series produced wind turbines.

In general the analysis shows that the development of low frequency noise with size does not follow the conclusions from the analyses in (3), (4) and (5). The analysis show that on average the amount of low frequency noise is the same for large and small wind turbines, relative to the total noise level and that the amount of low frequency noise for new large wind turbines is less than for old large wind turbines, relative to the total noise level.

The analysis is based on a larger number of measurement reports than previous analyses and experiences from post construction documentation. The results can change if the dataset is increased further, but the conclusions are in line with the conclusions in (1) and (2), where the results were influenced by prototype wind turbines. There is a large variation in sound power levels and sound power spectra within each group of wind turbines used in the analysis and it is important to check the details for each wind farm project. It is also important to follow the development into the next generation of wind turbines where new technologies are likely to be introduced.

The comparison between wind turbines with different types of regulation shows that the development with wind speed of the low frequency part of the sound power level LWA,LF follows the general development of the sound power level LWA. This means that for a modern pitch-RPM regulated wind turbine the low frequency noise does not increase above 8 m/s. For stall and active stall regulated wind turbines the low frequency part of the noise increases above 8 m/s but at a lower rate the noise in general. These conclusions are expected to be valid when no significant tones are present in the low frequency part of the spectrum.

Title: Outcome of systematic research on wind turbine noise in Japan
Platform: Inter-noise 2014, Melbourne, Australia
Author: Hideki Tachibana, Japan
Date: 16 Nov 2014

Abstract
In Japan, serious complaints about wind turbine noise have arisen from nearby residents since the commencement of large-scale construction of wind generation plants in about 2000. Regarding this new type of environmental noise problem, scientific knowledge is insufficient and no standard methods for measuring and assessing the noise have been established in Japan. To improve this situation, a research project entitled "Research on the evaluation of human impact of low frequency noise from wind turbine generators" has been conducted over the three years from fiscal year 2010, funded by a grant from the Ministry of the Environment, Japan. This project consisted of three main subjects: (1) physical research on wind turbine noise by field measurement, (2) a social survey on the response of nearby residents, and (3) auditory experiments on the human response to noises containing low frequency components. In this paper, the outcome of the research project is reviewed and standard methods for measuring and assessing the wind turbine noise are discussed.

Conclusions
As a result of the systematic research on WTN in Japan conducted to obtain fundamental material to produce guidelines of noise impact assessment of wind power plants, the following findings have been obtained.

Acoustical characteristics of WTN: From the measurement results obtained at 164 points in the residential areas around 29 wind farms, it was found that WTN generally has a spectrum characteristic of about - 4 dB/octave in band spectrum and the components in the infrasound frequency region were much below the hearing thresholds. This fact was examined through a laboratory experiment conducted as part of this research project (6). These indicate that WTN is not a problem in the infrasound frequency region. However, most of the frequency components in audible frequency range are above the hearing thresholds. This means that WTN should be discussed as an "audible" environmental noise.

Noise effects: All the measurement results of WTN in the immission areas obtained in this study were between 25 dB to 50 dB at most in terms of *L*Aeq. Although these levels are not so high compared with other community noises, they are audible, especially at night, and might cause serious annoyance and sleep disturbance in residential areas which are generally very quiet rural districts. Legislative and administrative measures (noise limits or guidelines) should be prepared by considering these points.

Noise indicator: WTN can be assessed by the A-weighted SPL as a primary indicator, similarly to general environmental noises. Since WTN is relatively low level in general, it is rather difficult to accurately measure *L*Aeq being influenced by various background noises. In this respect, it is preferable to measure the percentile level like *L*A90 or *L*A95 from which *L*Aeq can be approximated statistically.

Amplitude modulation: Amplitude modulation generated by the rotation of the blades of wind turbine is inevitable in WTN, and is apt to increase residents' annoyance. Therefore, the effect of AM sound should be considered when preparing noise limit or guideline for WTN. To objectively assess the extent of amplitude modulation, a simple statistical method was proposed in this research project.

Tonal components: In the measurement results of this study, tonal components were observed in some cases, especially in the areas near some types of wind turbines. Tonality is also a serious factor to increase annoyance of WTN (19, 20) and the effect should be considered as an additional penalty when any tonal components are included in WTN (18). The method for objectively assessing the tonality is specified in IEC 61400-11: 2012 and is also being discussed at ISO/TC43. The effectiveness of these assessment methods are also being investigated in Japan.

Measurement points: For some physical and practical reasons as mentioned in 2.2, the measurement points should be located outside of buildings in principle. In the measurement, the microphone should be covered with wind-screen with a high wind-shielding effect and be placed close to the ground in order to prevent the wind-induced noise as far as possible.

Residual noise: In the WTN problem, the audibility of the noise when the environment is quiet is serious. Therefore, the environmental condition without WTN should be assessed by the residual noise which is an ambient noise excluding every specific noise such as road traffic noise, aircraft noise, and the sounds of various creatures. To that end, 90 or 95 percentile level should be measured and used in the assessment of the environmental condition.

Title: The relevance of the precautionary principle to wind farm noise planning
Platform: Inter-noise 2014, Melbourne, Australia
Author: Bob Thorne, Australia
Date: 16 Nov 2014

Abstract

Wind farms consist of clusters of industrial wind turbines which, when placed in rural areas, are associated with intrusive and unwanted sound. Wind turbine noise has characteristics sufficiently different from other, more extensively studied, noise sources to suggest that standard industrial noise standards are not appropriate for measurement and assessment purposes. A seven year study is reported and, although limited in population size, it is clear that there are definite adverse health effects related to wind farm noise. Time-aggregated noise metrics have limited utility in assessing individual human health and well-being, and a cluster of metrics are needed to describe and estimate potential effects on individuals and communities. Sleep deprivation is a widely reported occurrence by people in the vicinity of a wind farm. At this time (2014), however, the quantity and quality of research are insufficient to effectively describe the relationship between wind turbine noise and health, and until such time that a definitive relationship is obtained, legislation should apply the

precautionary principle and conservative criteria when assessing proposed wind farm developments.

Conclusions
The precautionary principle seeks to "prevent degradation of the environment if there are threats of serious or irreversible environmental damage". This study and published anecdotal and observational information indicates that serious damage or harm does exist and is measurable in economic and health related terms. Even though this study is limited in population size, there is ample evidence that, until such time as a definitive noise/health relationship has been obtained for wind turbine noise, the precautionary principle should be used in wind farm noise planning.

Consequently, this means that the potential adverse effects from the threat/risk of the development to the environment must be taken into account in weighing up the balance between the benefits and costs of the development. In the absence of the precautionary principle this process may not occur. The difficult question then becomes: is there a balance and if so, where does the balance lie?

Title: The results of an acoustic testing program, Cape Bridgewater wind farm
Platform: The Acoustic Group for Energy Pacific, Australia
Author: Steven Cooper, The Acoustic Group, Australia
Date: 26 Nov 2014

Summary
This study appears to be the first of its kind in Australia to be a joint exercise between a wind farm operator and residents, and therefore provides information not normally available in a one sided acoustic assessment of a wind farm.

The study found that the resident's observations identified "sensation" as the major form of disturbance from the wind farm. The observations from the residents with respect to sleep disturbance indicate that for the rural setting of Cape Bridgewater, where the ambient noise levels at night inside dwellings are typically below 15 dB(A) (in the absence of any activity in the household), then the concept of a 30 dB(A) Leq threshold level identified in the New Zealand Standard (that in the main is based on road traffic noise) would appear to be an inappropriate threshold for the assessment of internal noise levels associated with wind farms.

It was confirmed that there is a unique signature attributed to wind farms that involves a peak at the blade pass frequency and the first five harmonics of that frequency. This unique infrasound pattern has been labelled by the author as the 'wind turbine signature'. This signature is present when the turbines are operating but does not occur with the wind farm shut down. When the turbines are operating there is a distinct frequency generated at 31.5 Hz that exhibits side bands on either side of that frequency at multiples of the blade pass frequency. This pattern confirms the presence of an amplitude modulated signal which is not present when the turbines are not operating. The study confirmed that the infrasound

obtained in a wind farm affected environment is different to that in the natural environment.

Monitoring in proximity to the towers found a significant variation in noise levels from the tower structure including the typical 'aircraft that never lands' signal often quoted by residents. The noise appeared to change with loading on the turbine.

Monitoring of vibration near the towers indicates surges associated with wind gusts where a significant increase above the ambient vibration was recorded. The vibration surges described by some residents as disturbances during shutdown could be attributed to wind gusts exciting resonances of the blades/towers and requires further investigation.

Title: Health effects related to wind turbine noise exposure: a systematic review
Platform: PLOS one
Authors: Jesper Hvass Schmidt, Mads Klokker, Denmark
Date: 4 Dec 2014

Abstract
Background: Wind turbine noise exposure and suspected health-related effects thereof have attracted substantial attention. Various symptoms such as sleep related problems, headache, tinnitus and vertigo have been described by subjects suspected of having been exposed to wind turbine noise.
Objective: This review was conducted systematically with the purpose of identifying any reported associations between wind turbine noise exposure and suspected health-related effects.
Data Sources: A search of the scientific literature concerning the health-related effects of wind turbine noise was conducted on PubMed, Web of Science, Google Scholar and various other Internet sources.
Study Eligibility Criteria: All studies investigating suspected health-related outcomes associated with wind turbine noise exposure were included.
Results: Wind turbines emit noise, including low-frequency noise, which decreases incrementally with increases in distance from the wind turbines. Likewise, evidence of a dose-response relationship between wind turbine noise linked to noise annoyance, sleep disturbance and possibly even psychological distress was present in the literature. Currently, there is no further existing statistically-significant evidence indicating any association between wind turbine noise exposure and tinnitus, hearing loss, vertigo or headache.
Limitations: Selection bias and information bias of differing magnitudes were found to be present in all current studies investigating wind turbine noise exposure and adverse health effects. Only articles published in English, German or Scandinavian languages were reviewed.
Conclusions: Exposure to wind turbines does seem to increase the risk of annoyance and self-reported sleep disturbance in a dose-response relationship. There appears, though, to be a tolerable level of around LAeq of 35 dB. Of the many other claimed health effects of wind turbine noise exposure reported in the literature, however, no conclusive evidence

could be found. Future studies should focus on investigations aimed at objectively demonstrating whether or not measureable health-related outcomes can be proven to fluctuate depending on exposure to wind turbines.

Title: Institute of acoustics statement in respect of wind farm noise assessment
Platform: Institute of Acoustics
Authors: IOA
Date: 19 Dec 2014

Summary
The institute of acoustics issued this document on their web site as an apparent response to recent criticism with regards to the ethics surrounding the IOA noise working group and their close connections to the wind power industry. This document provides a clarification by the IOA regarding their position with respect to ETSU-R-97, the IOA Bulletin Method, the IOA Good Practice Guide, Amplitude Modulation and the IOA AM Working Group.

Incredibly, in countering criticism of the IoA NWG, the IoA Bulletin Method and the IoA Good Practice Guide, the IoA has claimed that, since their methodologies have been debated at planning inquiries and accepted by Planning Inspectors, they must be scientifically correct. This in effect turns around the accepted practice of science being debated and decided by the experts and Planning Inspectors normally accepting expert, and in theory unbiased, opinion from experts. Here the IoA are using the Planning Inspectorate to decide the science.

Title: Letter from R Rand to S Cooper: Cape Bridgewater study
Platform: Rand Acoustics, CO, USA
Authors: Robert Rand
Date: 21 Jan 2015

Summary
The letter commenting on the Cape Bridgewater study states: " *Congratulations on this superlative work investigating the neighbor reports and correlating (unintended) adverse effects of the facility. The scope and detail of your report is sure to assist acoustic investigators, planners, utilities, and the public to understand without any further doubt or dismissal what wind turbine neighbors have been saying for years, as you so clearly sum up, ("What we found was that previously they were complaining about the noise, but it wasn't really the noise, it was sensations.")*

The report's establishing of tonal energy at the blade pass and harmonics along with higher frequencies with sidebands as the wind turbine signature, puts to rest any further tendency by acoustic professionals to rely on constant-percentage bands to attempt to assess neighbor impacts from wind turbine signals.

The correlation of sensation level to WTS tone level in the infrasonic and audible bands brings wind turbine acoustics right to the door of medical science. Medical tests in the homes, long overdue, can now be correlated directly to WTS. May the medical testing in homes begin without further delay."

Title: Letter from S Ambrose to S Cooper: Cape Bridgewater study
Platform: SE Ambrose & Associates, ME, USA
Author: Stephen Ambrose
Date: 22 Jan 2015

Summary
The letter commenting on the Cape Bridgewater study starts with: "*Congratulations, I commend you for pursuing scientific truth by investigating the human response to large wind-turbines in the acoustic environment. Your correlation of human response journal entries with scientific waveform analysis clearly shows hearing is not limited to audible sounds. Research continues to reveal that the ear has multiple functions and capabilities. This study merits recognition by acoustic and public health professionals for more research*."

It goes on with: "*Your study goes far beyond the 1980s Neil Kelley et al. studies that identified operating wind-turbines can produce airborne transmissions that humans detect as "sensations". Bray/James research showed that one-third octave band filters could not measure the low-frequency peaks produced wind-turbines. Neighbors' complaints were ignored by the majority. Acoustic experts failed to understand the limitations of their instruments and analysis methods*".

Title: Report on the committee's inquiry into wind energy
Platform: Northern Ireland Assembly
Authors: Committee for the environment: Anna Lo, Pam Cameron, Cathal Boylan, Colum Eastwood, Sandra Overend, Alban Maginness, Ian McCrea, Barry McElduff, Ian Milne, Lord Morrow, Peter Weir
Date: 29 Jan 2015

Introduction
The Northern Ireland Assembly is the devolved legislature for Northern Ireland. The committee was established to advise and assist the Minister of the Environment. The committee undertakes a scrutiny, policy development and consultation role with respect to the Department of the Environment and plays a key role in the consideration and development of legislation. The Committee Chairperson is Ms Anna Lo.

The Committee for the Environment initially agreed on 10 October 2013 to carry out a short review of wind energy issues after hearing from a range of stakeholders. The Committee

subsequently agreed that it would not complete this review, but that it would instead carry out a full inquiry into this topic. The terms of reference covered 3 areas:

- Strategy and planning guidance
- Perceived impact of wind turbine noise and separation distances
- Extent of engagement by wind energy providers with local communities.

The committee's report consists of 2,658 pages arranged into 7 volumes.

Summary
The key findings and conclusions relating to wind turbine noise are:

- The Committee recommends that the Department should review the use of the ETSU-97 guidelines on an urgent basis, with a view to adopting more modern and robust guidance for measurement of wind turbine noise, with particular reference to current guidelines from the World Health Organisation.
- The Committee recommends that the Department should bear responsibility for ensuring that arrangements be put in place for on-going long-term monitoring of wind turbine noise.
- The Committee recommends that the Department, working with local universities, should commission independent research to measure and determine the impact of low-frequency noise on those residents living in close proximity to individual turbines and wind farms in Northern Ireland.
- The issue of the separation distance of wind turbines from dwellings was carefully considered by the Committee. Although it appears that this distance relates more to visual amenity than to restriction of the noise impact, the Committee has recommended that the Department should specify a minimum separation distance, rather than simply advising that 500m will generally apply, as is currently the situation.

Title: Evidence on wind farms and human health
Platform: Australian Government
Authors: National Health and Medical Research Council
Date: Feb 2015

Summary

- Examining whether wind farm emissions may affect human health is complex, as both the character of the emissions and individual perceptions of them are highly variable.
- After careful consideration and deliberation of the body of evidence, NHMRC concludes that there is currently no consistent evidence that wind farms cause adverse health effects in humans.
- Given the poor quality of current direct evidence and the concern expressed by some members of the community, high quality research into possible health effects of wind farms, particularly within 1,500 metres (m), is warranted.

The statement ends with: '*NHMRC urges authorities with responsibility for regulating wind farms to undertake appropriate planning, in consultation with communities, and be cognisant of evidence emerging from research. Although it is unlikely that there are significant health effects at a distance of more than 1,500 m from wind farms, concern has been expressed by people living near wind farms about perceived impacts on their health. NHMRC recommends that any person experiencing health problems consult their General Practitioner.*

Given these reported experiences and the limited reliable evidence, NHMRC considers that further, higher quality, research is warranted. NHMRC will issue a Targeted Call for Research into wind farms and human health to encourage Australia's best researchers to undertake independent, high quality research investigating possible health effects and their causes, particularly within 1,500 m from a wind farm'.

Title: Appeal Ref: APP/H0520/A/13/2207023 Land to the west of Bicton industrial estate between the villages of Kimbolton and Stow Longa, Cambridgeshire
Platform: Department for Communities and Local Government
Authors: Secretary of State
Date: 11 Feb 2015

Summary
The SoS considered the report by Planning Inspector Paul Griffiths into the refusal by Huntingdon District Council to refuse planning permission for three wind turbines and associated infrastructure.

The main issues were the harmful impacts on heritage assets, harm to the landscape and the impact on the living condition of local residents.

Decision
The appeal was dismissed and planning permission refused.

Title: Letter to Chris Heaton-Harris MP from Ed Davey MP Secretary of State
Platform: Department of Energy & Climate Change
Author: Edward Davey MP, Secretary of State
Date: 12 Feb 2015

Summary
An acknowledgement by the Secretary of State for Energy and Climate Change that a planning condition is now required to control amplitude modulation.

Title: Infrasound measurements of Falmouth wind turbines Wind #1 and Wind #2
Platform: Noise Control Engineering LLC MA USA
Authors: Michael Bahtiarian, Allan Beaudry
Date: 27 February 2015

Summary
Noise Control Engineering, LLC (NCE) was retained by Senie & Associates P.C. to evaluate the acoustic impact at the home of Neil and Betsy Andersen at 211 Blacksmith Shop Road, East Falmouth, Massachusetts. The goal of the evaluation was to determine if the three nearby wind turbines were detectable within the interior of the home. These wind turbines are all Vestas, model V82 at 1.65 megawatts. Two wind turbines are owned by the Town of Falmouth; known as "Wind #1" and "Wind #2". The third turbine is privately owned by Notus Clean Energy and referred to as the "Notus" turbine. Wind #1 is the closest to the Andersen home at a nominal distance of 1,385 feet. The other two wind turbines are more than double that distance.

Soon after the first wind turbine was operational, complaints were filed by the Andersens and other neighbours. In the following years, evaluations of audible sound were performed by various organizations including NCE, consultants for the Town, consultants for Notus, and even the Massachusetts Department of Environmental Protection (MADEP). Various results were reported with some evaluations showing compliance and some showing non-compliance.

The study reported herein differed in a number of ways from previous evaluations performed by NCE and others. The major difference is that the primary measurements reported here is infrasound. Briefly, infrasound is sound pressure levels with frequency below 20 hertz which is generally considered an inaudible frequency range. Another difference is that measurements were taken both inside and outside the home. All previous tests were performed at exterior locations due to the fact that State regulations and local ordinance were only applicable at outdoor locations.

The methods used herein allowed for the collection of infrasonic sound pressure levels within the inside of the Andersen residence. Inspection of this data shows that there is a readily identifiable acoustic signature that is attributable to the Wind #1 Turbine, and to slightly lessor extent the Wind #2 turbine both inside and outside the Andersen home. These results are similar to results from other international researchers with references given in the report.

Based on our experience, NCE can unequivocally state that the infrasonic signature captured inside the Andersen residence with the wind turbines operational is 100% attributable to one or both of the Town's Wind Turbines. To put the conclusions more commonly, this study finds that the wind turbine(s) produce acoustic emissions which are "acoustically trespassing" into the Andersen home.

Title: R (Catt) v Commissioner of Police of the Metropolis and another
Platform: The Supreme Court
Authors: Lord Neuberger, Lady Hale, Lord Mance, Lord Sumption, Lord Toulson
Date: 4 March 2015

Summary
Although not a case relating to enjoyment of property, it does deal with article 8 of the ECHR and the issue of "proportionality" and how it controls the way public officials exercise their powers. The issue here is whether the SoS for Energy and Climate Change did act in a proportionate way in his decision letter regarding Clocaenog Forest wind farm when saying that potential nuisance to certain residents did not prevent his decision to grant development consent without any mitigating factors being made to protect them.

Title: Invitation to tender for the review of the evidence on effects and response to amplitude modulation
Platform: Department of Energy & Climate Change
Authors: DECC
Date: 26 March 2015

Summary
Invitation to Tender for a review of the evidence on the effects and response to amplitude modulation (AM) from wind turbines, with recommendations on how excessive AM might be controlled through the use of a planning condition.
Tender Reference Number: 970/01/2015
Deadline for Tender Responses: Noon on Tuesday 21 April 2015

The Department of Energy and Climate Change ("DECC") wishes to commission a review of the evidence on the effects of and response to amplitude modulation (AM) from wind turbines, with a view to recommending how excessive AM might be controlled through the use of a planning condition.

Title: Health-based Audible Noise Guidelines Account for Infrasound and Low Frequency Noise Produced by Wind Turbines
Platform: 6th International Conference on Wind Turbine Noise, Glasgow
Authors: Robert G. Berger, Payam Ashtiani, Christopher A. Ollson, Melissa Whitfield Aslund, Lindsay C. McCallum, Geoff Leventhall, Loren D. Knopper
Date: 20 April 2015

Summary
This paper produced jointly by Geoff Leventhall and Canadian acoustics and health companies Aercoustics Engineering and Intrinsik Environmental Sciences would appear to be a wind industry attempt to downplay the significance of wind turbine infrasound and low

frequency noise. This paper bases its conclusion of an 'evidence of absence' on their own 'absence of evidence'.

Title: Time-Dependent Interference: The Mechanism Causing Amplitude Modulation Noise?
Platform: 6th International Conference on Wind Turbine Noise, Glasgow
Author: Stuart Bradley
Date: 20 April 2015

Summary
Sound from an elevated source, such as a turbine blade, generally reaches a listener via a direct path and via a path or paths which have reflected from the surface. Depending on the heights of the sound source and listener, and the distance between them, the sound from these multiple paths can combine constructively or destructively because of the phase differences. This leads to an intensity pattern which has maxima and minima surrounding the source.

Trailing edge noise from a turbine blade comprises sources which are not at fixed positions, but instead move periodically up and down. Corresponding to this sinusoidal vertical motion of the sound source, the intensity pattern on the ground moves in and out. At any one listener location, there is therefore a fluctuating intensity. A simple straight-line ray model shows that this mechanism explains the observed characteristics of wind turbine amplitude modulation noise.

This mechanism does not depend on intermittent stall, although increased source intensity obviously leads to increased modulation noise. Downward refraction also enhances the effect. Furthermore, there are three blades, each with their own source angular distribution (the source pattern for an ascending blade is different from that of a descending blade). Results from a more complex model, "time-dependent interference", which includes these effects, are described.

Title: Measurements demonstrating mitigation of far-field AM from wind turbines
Platform: 6th International Conference on Wind Turbine Noise, Glasgow
Authors: Matthew Cand, Andrew Bullmore
Date: 20 April 2015

Summary
This paper by Cand and Bullmore of Hoare Lea Acoustics is an attempt to justify their previous claims in the RenewableUK AM study that AM or OAM as they describe it, is caused by transient blade stall. This paper describes mitigation tests carried out at two unnamed wind farm sites.

The failure to identify the test sites prevents any verification with local residents of whether AM has been reduced. Also the lack of details regarding the 'kit' applied at test location 1 or the turbine operating data for both sites prevents any third party verification of the paper's claims. It will be apparent to most informed observers that operating the turbine in a less aggressive manner by reducing blade pitch will reduce noise but will also reduce power generated. The claim that their findings demonstrate that OAM is caused primarily by transient blade stall is unproven.

Title: Addressing the Issue of Amplitude Modulation: A Developer's Perspective
Platform: 6th International Conference on Wind Turbine Noise, Glasgow
Authors: Matthew Cassidy, Jeremy Bass
Date: 20 April 2015

Summary
This paper describes what appears to be the identical situation at location 2 in the Cand paper at the same conference. Figure 6 in this paper is the same as Figure 6 in the other Cand paper. As with the other Cand paper the identity of the wind farm is not revealed so preventing verification of the claims made in the paper.

Figure 5 shows how the angle of attack affects the coefficient of lift and hence power generation. Changing the operating point down the curve from the optimum (yellow star) reduces power generation and sound emission. However, this will reduce the operator's income so there will always be reluctance by operators to move the operating point away from the optimum for power generation.

At Section 5.2 the paper indicates that there is a 50% difference in energy loss between shutting down the turbines to mitigate against AM compared to the mitigation strategy described. This indicates that even this mitigation strategy is expensive for the operator.

Title: Reduction of tonalities in wind turbines by means of active vibration absorbers
Platform: 6th International Conference on Wind Turbine Noise, Glasgow
Authors: Jürgen Engelhardt, Sebastian Katz, Steffen Pankoke
Date: 20 April 2015

Summary
This paper describes the retrofitting of an active damping device (ADD) to wind turbine structures to reduce vibrations. Specific details of where the ADD is fitted are not provided but it can be assumed from Figure 2.3 that these devices are fitted to the turbine tower.

The source of the vibrations is also not made clear although gearbox vibration from approximately 80Hz to several hundred Hertz as one possible source of excitation is mentioned. However, once excited the tower could not vibrate at these frequencies as tower and blade natural frequencies would be much lower.

Title: Tonal noise from wind turbines
Platform: 6th International Conference on Wind Turbine Noise, Glasgow
Authors: Tom Evans, Jonathan Cooper
Date: 20 April 2015

Summary
Wind turbine noise is composed of aerodynamic noise produced by the blades rotating through the air and mechanical noise associated with components such as the gearbox and generator. Currently more focus is afforded to aerodynamic noise as this typically dominates the noise emission from a turbine, but mechanical noise requires consideration particularly as it can result in low frequency tonal emissions. This paper presents an analysis of noise emissions from several different makes of wind turbines that exhibit tonality when measured at the turbine in the frequency range from 50 to 200 Hz. In each case, the tone emitted by the turbine was found to modulate at the blade pass frequency and was often more prominent under upwind and crosswind conditions. Furthermore, the tones could also be detected as audible at residences at relatively large distances from the wind farm.

This paper presents the findings of detailed tonality assessments conducted on seven different wind turbines from three manufacturers. In each case, the turbine was found to emit an audible low frequency tone in the range of 50 to 200 Hz. The tones were typically modulated at blade pass frequency and predominantly occurred under wind speeds and directions not tested under the current IEC 61400-11 Standard. These tones were also detected at residences at up to three kilometres from the wind farm and, while the audibility was not always at a high level, the modulating nature of the tone may have the potential to result in annoyance for some residents.

Title: Indoor Simulation of Wind Turbine Amplitude Modulated Noise
Platform: 6th International Conference on Wind Turbine Noise, Glasgow
Authors: Felipe A. Fernandez, Ricardo A. Burdisso
Date: 20 April 2015

Summary
Wind energy is the world's fastest-growing renewable energy source and, thus, the number of people exposed to wind farm noise pollution is increasing. Due to its broadband amplitude modulated characteristic, wind turbine noise (WTN) is more annoying than others common community/industrial sources. As higher frequencies are attenuated by air absorption and building transmission, the noise from modern large wind farms is mainly below 1000 and 500 Hz for outdoor and indoor conditions, respectively. Many WTN complains are for indoors and during night time when background levels are lower. As recently reported, indoor noise has the potential to cause sleeping disorders. Human annoyance response studies to amplitude modulated WTN have been mainly focused on the outdoor case were an abundance of measured data exits. This is not the case for indoor

where it is much harder to gather data. Thus, there is a need to understand the transmission of WTN into dwellings and develop indoor annoyance metrics. In this work, the transmission of WTN into residential type structures is investigated. Using a wind turbine outdoors noise recording and structures with different properties/configuration, a series of computer simulations for indoor noise predictions were made. These indoor results were assessed using several metrics conventionally used for WTN, e.g. spectral content, modulation depth, and overall levels. In general, the indoor noise levels are higher and the average modulation depth is similar as compared to outdoors recording. In addition, there is a significant change in the spectral shape. These results could potentially explain WTN indoor annoyance.

Title: Detection of Amplitude Modulation in Southern Ontario Wind Farms
Platform: 6th International Conference on Wind Turbine Noise, Glasgow
Authors: Duncan Halstead, Adam Suban-Loewen, Payam Ashtiani
Date: 20 April 2015

Summary
This paper details the results of an automated detection algorithm based on the method developed for the RenewableUK study on Amplitude Modulation (AM) in wind turbines. The algorithm was used to evaluate the possible presence of AM in five different wind farms of varying size and turbine model in Southern Ontario, Canada. Measurement locations were at nearby residences, roughly 500m to 800m from the nearest turbines. The data available for analysis represents over 7000 hours of sound recordings, acquired between the months of March and December 2014.

The ability of the algorithm to successfully detect AM was verified by listening to the recordings where the algorithm detected AM. The algorithm was found to be generally successful in detecting amplitude modulation, and with a few adjustments, was able to filter out the influence of ambient amplitude modulations from insects and small fauna. The algorithm, however, is still susceptible to amplitude modulation from ambient sources that modulate at mid-frequencies.

The analysis also found that while wind turbine AM was readily detectable, the rate of occurrence of AM at a particular measurement location was, at maximum, less than 0.25% of the total measurement time.

This very low detection rate must be highly suspect and a strong indicator that the RenewableUK detection algorithm is failing to detect most of the EAM that is known to occur at a much higher percentage of the total time.

Title: Stationary wind turbine infrasound emissions and propagation loss measurements
Platform: 6th International Conference on Wind Turbine Noise, Glasgow
Author: W Les Huson, Australia
Date: 20 April 2015

Summary
Microbarometers have been used to quantify the infrasonic emissions (0.05Hz to 20Hz) from five wind farms in Victoria, Australia. The wind farms measured include; Macarthur wind farm (140 turbines type Vestas V112 3MW); Cape Bridgewater (29 turbines type MM82 2MW); Leonards Hill (2 turbines type MM82 2MW); Mount Mercer (64 turbines type MM92 2MW), and; Waubra (128 turbines 3 types of Acciona Windpower 2MW).

Upwind indoor measurements at the Macarthur wind farm during an unplanned shutdown from full power and subsequent start up to 30% load has shown that stationary turbines subject to high winds emit infrasound pressure below 8 Hz at levels similar to the infrasound emissions at blade pass frequencies and harmonics.

The stationary V112 turbine infrasound emissions are caused primarily by blade and tower resonances excited by the wind. It is apparent from the mismatch of resonances and blade pass frequency components that Vestas have carefully designed this unit to minimise fatigue of the wind turbine.

Short range (up to 2km) measurements from the Leonards Hill wind farm have shown the determination of attenuation rate with distance to be problematic due to interference between the two turbines. A model to explain the unexpected attenuation results at Leonards Hill has demonstrated that the commonly observed amplitude modulation of blade pass tones is the result of changing phase between turbine rotor speed and changes in wind speed.

Long range measurements from two different wind farms over a distance of 80km have shown that infrasound below 6Hz has a propagation loss approximating 3dB per doubling of distance.

Title: Constraints imposed by and limitations of IEC 61672 for measurements of wind farm sound emissions
Platform: 6th International Conference on Wind Turbine Noise, Glasgow
Author: W Les Huson, Australia
Date: 20 April 2015

Summary
It is not uncommon for predicted and post-construction sound levels from wind farms to show compliance with margins of less than 2dB(A). With such small compliance margins there is a need to consider uncertainties in the instruments taking the measurements. IEC 61672 is a commonly used instrumentation standard for sound level meters to ensure consistent results between different manufacturers. Whilst this and similar older versions

of the standard provide some comfort regarding repeatability, they are not necessarily appropriate when trying to push the envelopes of sound level meter use.

Huson is aware of numerous wind farm assessments, made in accordance with the ETSU-R-97 methodology, where data has been used in preparing trend lines from background and post-construction operating conditions that is outside the range of measurement for which the sound level monitoring equipment is compliant with IEC 61672. Such charts are presented as examples of good practice in the IoA Good Practice Guide. He knows of no ETSU-R-97 type assessment where account has been made for such non-compliant data that is outside the measurement range of the instruments. The IoA Supplemental Guideline Note 1 Data Collection needs to be amended to address these issues.

A correction methodology to extend the noise floor of instruments has been presented; however, this method would not be compliant with IEC 61672 and is not rigorous.

It is recognised that the time and frequency weightings described in IEC 61672 are conventional and do not represent the characteristics of the human ear. The IoA Good Practice Guide and its Supplementary Notes should provide guidance on appropriate time constants and short L_{eq} sample rates that better define emissions from wind turbines.

Guidance is required on the temporal weighting of the loudness of time-varying sounds as it relates to amplitude modulation and the uncertainty associated with different short L_{eq} sample rates to better define amplitude peak and trough determinations (AM).

It is recommended that future research into AM record time histories utilising currently available sound level meters with sample rates of around 10ms as short L_{eq} (not time weighted with Fast response). Such equipment is also compliant with IEC 61672.
Z-weighting can provide large differences in readings between different sound level meters if the source contains infrasound typically found in wind turbine noise emissions at frequencies below 6 Hz. It would be a mistake to assume that dB(Z) results are accurate because there is compliance with IEC 61672.

IEC 61672 currently does not include the standardisation of instruments suitable for the measurement of infrasound. Such a standard would prove useful considering the amount of planned research in this area.

Title: Observation of vibration velocity at many parts of wind turbine and relational analysis with propagated sound to surroundings
Platform: 6th International Conference on Wind Turbine Noise, Glasgow
Authors: Teruo Iwase Niigata, Hideo Uchida, Hiroyasu Kurono, Yasuaki Okada, Koichi Yoshihisa
Date: 20 April 2015

Summary
The report authors had carried out many kinds of trial to understand characteristics of wind turbine noise. In this study, they also newly tried measurements of the excited vibration on many parts of wind turbine such as outside surface of nacelle for storing power generation system and tall tower by using a laser Doppler vibration meter. Observation and analysis of the natural frequencies of blade vibration at rotation stopping state were done.

Investigations on the noise in surroundings of wind turbine were also done. They tried the FFT analyses on them with high resolution to obtain detailed frequency characteristics. Then, relational analyses between vibration velocity and noise propagated to surroundings were added to ordinal spectral analyses only for the propagated wind turbine noise to make origins of tonal components clear. It first could be understood that both sharp spectra at near 1 Hz as slightly lower on a blade and higher on a tower were appeared in the analysed results. In analysed results of the vibration velocity and propagated sound in the normal operation continued state, a lot of sharp spectral peaks with exceeding of 10dB from each base level of vibration and noise were recognized in the broad frequency range from very low to several hundreds of Hz's.

It also could be understood that there were high coherencies between vibration velocity and wind turbine noise at frequencies with high spectral peaks. And certain values of coherency as exceeding 0.3 or up to 0.6 were remained even for the case of noise received at distance of about 200m from a wind turbine.

For sound source modelling, these results clearly show the existences of both sound sources in the wind turbine noise. One is aerodynamic sound with broadness and low frequency prominent components caused by rotating blades in the strong wind flow and another one is remarkable discrete frequency components originated in the vibration on power generation mechanical system. Together they propagate to far surroundings. For some applications to reduce wind turbine noise and to make audible simulation for evaluating effects of the noise, such a modelling with two kinds of sound origin or hypothesis based on the experimental studies as we made will be effective.

Title: Compliance isn't everything
Platform: 6th International Conference on Wind Turbine Noise, Glasgow
Authors: Sarah Large, Mike Stigwood
Date: 20 April 2015

Summary
Wind farm noise complaints are prevalent in the UK. Few cases make headlines and those that do are typically larger wind turbine or offshore developments. In the last few years complaints from smaller wind turbines (rated power in the region of 50kW or less) have increased. Complaints typically focus on the character of the noise rather than the decibel level or volume.

At the planning stage (in the UK) applications that are shown to meet a simplified noise limit of 35dB LA90 up to wind speeds of 10m/s are commonly approved without question of adverse noise impact. It is widely assumed that noise levels below this threshold will not cause disturbance and turbine manufacturer's information on noise can also often be misleading.

This paper examines noise impact from smaller wind turbines which, due to their size and the number of people potentially affected, are often neglected. Case studies are provided that follow turbines approved at planning that have been erected, tested and found to comply with noise limits but which have caused or continue to cause noise complaints. It investigates the character of noise generated by smaller wind turbines and questions whether the methodology currently used is providing adequate protection to wind turbine neighbours.

Title: On the overlap region between wind turbine infrasound and infrasound from other sources and its relation to criteria
Platform: 6th International Conference on Wind Turbine Noise, Glasgow
Author: Geoff Leventhall
Date: 20 April 2015

Summary
A bylaw has been introduced in the town of Plympton-Wyoming, Ontario, with the intention of restricting levels of wind turbine infrasound (0.1Hz to 20Hz). Blade pass tones greater than 50dB are specified as an indication of excessive infrasound. These tones normally have a fundamental frequency of around 1Hz, where the hearing threshold is not well known, but is probably about 130dB. Restricting an average level to 80dB below median hearing threshold is an unusual requirement. Blade pass tones have normally disappeared from the wind turbine spectrum by 10Hz, or lower. The threshold at 10Hz is nearly 100dB Natural infrasound covers a frequency range from about 0.001Hz to 10Hz, but some occurrences produce higher frequencies of short duration. It was decided to look at the overlap region between wind turbine infrasound and other infrasound in order to help assess the scientific basis of the Plympton-Wyoming bylaw. The paper claims there is no evidence to support the bylaw.

Title: Wind Turbines – A Changed Environment
Platform: 6th International Conference on Wind Turbine Noise, Glasgow
Author: William K.G. Palmer
Date: 20 April 2015

Summary
This paper gives examples of the sound from wind turbines in the outdoor environment, and in the indoor environment. These are compared to other sounds occurring in the environment, such as road traffic or overhead aircraft, and to the sounds produced in a typical municipal library and by a typical refrigerator. In summary, the paper shows that wind turbines do alter the acoustic environment, both outside homes and inside homes presenting a greater difference at low frequencies than other sound sources normally met.

The charts in this document show the sound from wind turbines is indeed rich in low frequency, exceeding the low frequency contribution received from the wind in the environment, of a helicopter flying directly overhead, of refrigerators, or libraries, and of most highway traffic. The charts show that the sound from wind turbines shows tonal characteristics. The charts also show that inside homes, room conditions cause a greater variation across a room than in the outdoor environment, and result in intensity increases at room mode frequencies, a function of the room size, and exciting source.

What the charts cannot show is the duration of the wind turbine sound, which can continue for hours at a time, particularly at night, when meteorological conditions favour higher wind turbine output, and be significantly greater than other sound sources in the environment. Neither do the charts properly identify the cyclical nature of the sound, rising and falling repeatedly, which makes them particularly recognizable. These durations and repetitive patterns (amplitude modulation) are apparent from the audio recordings that form the basis for this document though, which were made in a rigorous manner.

It is suggested that the information displayed in these charts provides a firm argument that use of A-weighting and of considering only octaves from 63 Hz to 8000 Hz does not provide an adequate regulatory environment for wind turbines.

Title: Cotton Farm Wind Farm – Long term community noise monitoring project – 2 years on
Platform: 6th International Conference on Wind Turbine Noise, Glasgow
Authors: Mike Stigwood, Sarah Large, Duncan Stigwood
Date: 20 April 2015

Summary
In 2013 MAS Environmental, under a contract with the local community, established a permanent monitoring station to record and publish data online, located 600m from the nearest turbine, to correlate the impact upon the community and provide an extensive

database. This database enables a wider study of the effect of a number of variables in the noise immission on the communities affected. The database has enabled testing of proposed controls, particularly in relation to audible amplitude modulation. Previous papers in 2014 on this project have described its background and the early results of the data collected, especially in relation to the occurrence of the special characteristic amplitude modulation.

This paper includes further evaluation of the now extensive database collected over nearly 2 years and how noise features correlate with community response / complaints, including analysis of some of the prominent characteristics recognized as a feature of the community noise as created by this wind farm and how they impact.

The data has also been used to test the appropriateness and reliability both of some commonly applied and also emerging principles and methods for Amplitude Modulation (AM) noise control used for wind farms. It identifies issues relating to uncertainty, error and reliability / repeatability. In this paper particular focus is placed on the analysis of automated or semi-automated Fast Fourier Transform procedures and whether they can adequately detect and quantify AM. This part of the long term study focuses on the parameters and procedures used to identify AM noise. Analysis of the inability of noise controls to reflect true impact in relation to Cotton Farm wind Farm data is also explored.

What the new analysis of Cotton Farm WF data shows

The quickest and most effective means of analysing the special characteristic AM within WTN is firstly through manual assessor checks. This provides a quick method of excluding unusable data that is not subject to the flaws in automated algorithms.

- Algorithms and procedures designed to automatically filter WTN datasets to exclude periods affected by extraneous noise but not exclude AM and based on FFT analysis of the BPF, have a high failure rate.
- FFT procedures are yet to be shown to provide efficient algorithms for this type of highly variable sound energy and can miss periods of impact, be falsely triggered by extraneous noise or simply fail to reflect impact. The main procedure developed by ReUK was found to permit highly intrusive, erratic and unreasonable noise.
- FFT derived procedures in a modified form to those currently presented by RES can be used as an extra evaluation tool to assist analysis of noise but only after initially filtering periods excessively corrupted by extraneous or absent AM.
- FFT procedures are unhelpful when dealing with sound data containing erratically varying AM and erratically varying extraneous noise sources. There are also problems identifying AM where there are other character features such as tonality or lower frequency noise.
- Impact from WTN containing special characteristics can best be assessed applying context procedures comparing against actual levels of background masking noise which are present during the periods of impact. This is best evaluated by comparing the periods before, during and after turbine switch off tests.
- Application of special character penalties to threshold limits such as contained in ETSU-R-97 does not reflect impact and fails to reduce excess levels of adverse noise.

- The revised standard BS4142 2014 has addressed concerns which led to its exclusion when ETSU-R-97 was written and now includes extended analysis of special characteristics in noise. This renders it suitable to WTN containing AM. Comparative tests show it is better suited at determining impact than ETSU-R-97 derived methods which are formulated on the absence of any significant character content.
- Many commonly held views over frequency and duration of AM, when it occurs and how it should be rated, require revisiting. In particular the cumulative effect of AM and other characteristics of the wind turbine noise need to be considered and not just modulation depth.

Title: Direct Experience of Low Frequency Noise and Infrasound within a Windfarm Community
Platform: 6th International Conference on Wind Turbine Noise, Glasgow
Author: M.A.Swinbanks
Date: 20 April 2015

Summary
It has been shown that upwind-rotor turbines can indeed sometimes give rise to impulsive low-frequency infrasound – a characteristic commonly attributed only to old-fashioned downwind rotor configurations. But perception of wind turbine low frequency noise and infrasound can be quickly suppressed by the effects of wind-induced airflow over the ears, with the result that incorrect conclusions can easily result from observations made when exposed to outside breezy conditions. The effects within a residence are much more readily perceptible, and cannot be ignored. An account has been given of an occurrence of severe direct health effects experienced by the author, and considered to be due entirely to wind-turbine infrasound, yet manifest under superficially benign conditions where no such adverse effects were anticipated.

Title: Discussion Document - Methods for Rating Amplitude Modulation in Wind Turbine Noise
Platform: Institute of Acoustics AM noise working group
Authors: Irvine, Bass, Cand, Coles, Davis, Leventhall, Levet, Miller, Sexton, Shelton
Date: 23 April 2015

Summary
This discussion document has been produced specifically to promote discussion of the relevant issues during the consultation on a metric for amplitude modulation (AM) from wind turbines, and as such does not necessarily represent the final AM metric that will be chosen, nor should it be treated as such until the final document is published in due course.

The Working Group has not addressed the question of what level of AM in wind turbine noise (when measured by any specific metric) is likely to result in adverse community response, or how that response should be evaluated. The psycho-acoustic aspects of AM will be the subject of further studies by others. However, sources of information on

subjective response to amplitude modulated noise are referenced in this document to assist in further work.

This Consultation Draft presents the Working Group's preliminary observations and conclusions on methods of measurement and rating AM. Three methods for rating AM are proposed for consultation. Comments, observations and criticisms from interested parties are welcomed. This document should be read in conjunction with the "IOA AMWG Consultation Questionnaire" which includes a questionnaire style response. The closing date for the receipt of comments was 30th June 2015.

Title: IoA Consultation questionnaire for "Methods for rating amplitude modulation in wind turbine noise"
Platform: Institute of Acoustics AM noise working group
Authors: Irvine, Bass, Cand, Coles, Davis, Leventhall, Levet, Miller, Sexton, Shelton
Date: 23 April 2015

Summary
This document is written to initiate the discussion and asks a number of specific questions but feedback is encouraged on all aspects of the document, whether positive or negative, and it is not necessary to limit the response to the questions in this document.

Title: Monitoring of Greater Than Expected Amplitude Modulation (GTE-AM) from the Proposed Den Brook Wind Farm
Platform: Den Brook Judicial Review Group
Authors: Mike Hulme
Date: 26 May 2015

Summary
In this document the Den Brook Judicial Review Group (DBJRG) have issued to RES, the developer this pre-action protocol for Notice of Intent to install 24/7 noise monitoring at the Den Brook wind farm.

Title: Select Committee on Wind Turbines – Interim report
Platform: Commonwealth of Australia
Authors: Senators John Madigan, Bob Day, Chris Back, Matthew Canavan, David Leyonhjelm, Anne Urquhart
Date: June 2015

Summary
The terms of reference of the Select Committee were the application of regulatory governance and economic impact of wind turbines, with particular reference to:

(a) The effect on household power prices, particularly households which receive no Benefit from rooftop solar panels, and the merits of consumer subsidies for Operators;

(b) How effective the Clean Energy Regulator is in performing its legislative Responsibilities and whether there is a need to broaden those responsibilities;
(c) The role and capacity of the National Health and Medical Research Council in Providing guidance to state and territory authorities;
(d) The implementation of planning processes in relation to wind farms, including the level of information available to prospective wind farm hosts;
(e) The adequacy of monitoring and compliance governance of wind farms;
(f) The application and integrity of national wind farm guidelines;
(g) The effect that wind towers have on fauna and aerial operations around turbines, including firefighting and crop management;
(h) The energy and emission input and output equations from whole-of-life operation of wind turbines; and
(i) any related matter.

The recommendations of the Committee relating to noise taken from the report include:

Recommendation 1
1.5 The committee recommends the Commonwealth Government create an Independent Expert Scientific Committee on Industrial Sound responsible for providing research and advice to the Minister for the Environment on the impact on human health of audible noise (including low frequency) and infrasound from wind turbines. The IESC should be established under the Renewable Energy (Electricity) Act 2000.

Recommendation 2
1.6 The committee recommends that the National Environment Protection Council establish a National Environment Protection (Wind Turbine Infrasound and Low Frequency Noise) Measure (NEPM). This NEPM must be developed through the findings of the Independent Expert Scientific Committee on Industrial Sound. The Commonwealth Government should insist that the ongoing accreditation of wind turbine facilities under the Renewable Energy (Electricity) Act 2000 in a State or Territory is dependent on the NEPM becoming valid law in that State or Territory.

Recommendation 5
1.9 The committee recommends that the Commonwealth Government establish a National Wind Farm Ombudsman to handle complaints from concerned community residents about the operations of wind turbine facilities accredited to receive renewable energy certificates. The Ombudsman will be a one-stop-shop to refer complaints to relevant state authorities and help ensure that complaints are satisfactorily addressed.

Recommendation 7
1.11 The committee recommends that the data collected by wind turbine operators relating to wind speed, basic operation statistics including operating hours and noise monitoring should be made freely and publicly available on a regular basis. The proposed Independent Expert Scientific Committee should consult with scientific researchers and the wind industry to establish what data can be reasonably made freely and publicly available from all wind turbine operations accredited to receive renewable energy certificates.

Appendix B - Reference lists

B1 Reference list by date

B2 Reference list by author

Appendix B1 - INWG AM Study Reference Literature - By Date

Date of Publication	Lead Author	Document Title	Platform	Authors
1 Aug 1832	HM Gov	Prescription Act 1832	HM Government	HM Government
17 Jul 1868	HM Gov	Rylands v Fletcher	House of Lords	House of Lords
Mar-82	Stephens	Guide to the evaluation of human exposure to noise from large wind turbines	NASA USA	David G Stephens, Kevin P Shepherd, Harvey H Hubbard, Ferdinand W Grosveld
Sep-82	Hubbard	Noise induced house vibrations and human perception	Noise Control Engineering Journal Sept / Oct 1982	Harvey H Hubbard
Apr-84	Nussbaum	Some individual differences in human response to infrsound	University of Waterloo and Institute for Aerospace Studies, University of Toronto	DS Nussbaum, S Reinis
Nov-84	Hubbard	Response measurements for two building structures excited by noise from a large horizontal axis wind turbine generator	NASA USA	Harvey H Hubbard, Kevin P Shepherd
Feb-85	Kelley	Acoustic noise associated with the MOD-1 wind turbine: Its source, impact and control	Solar Energy Research Institute for US Department of Energy	ND Kelley, HE McKenna, RR Hemphil, CL Etter, RL Garrelts, NC Linn
Nov-87	Kelley	A proposed metric for assessing the potential of community annoyance from wind turbine low frequency noise emissions	Solar Energy Research Institute for US Department of Energy	ND Kelley
Jan-88	Kelley	The MOD-2 wind turbine: Aerocoustical noise sources, emissions and potential impact	Solar Energy Research Institute for US Department of Energy	ND Kelley, HE McKenna, EW Jacobs, RR Hemphil, NJ Birkenheuer
Jan-88	Hubbard	Wind turbine acoustics research - bibliography with selected annotation	NASA USA	Harvey H Hubbard, Kevin P Shepherd
24-May-90	HM Gov	Town and Country Planning Act 1990	HM Government	HM Government
01-Nov-90	HM Gov	Environmental Protection Act 1990	HM Government	HM Government
20-Jul-95	DCLG	Circular 11/95: the use of conditions in planning permissions	DCLG	Department for Communities and Local Government
Sep-96	ETSU	ETSU-R-97 The assessment & rating of noise from wind farms	Department of Trade & Industry	Noise working group
Sep-97	BSI	BS4142 - 1997 Method for rating industrial noise affecting mixed residential and industrial areas	BSI	BSI
Nov-98	HM Gov	Human Rights Act 1998	HM Government	HM Government
Nov-00	Rose	Godfrey v Conway County Borough Council	High Court	Lord Justice Rose
May-02	Sullivan	Wilkinson v Rossendale Borough Council	High Court	Mr Justice Sullivan
22-Sep-03	van den Berg	Effects of the wind profile at night on wind turbine sound	Journal of sound and vibration	G.P. van den Berg
Jul-04	Sloth	Problems related to the use of the existing noise measurement standards when predicting noise from wind turbines and wind farms	Vestas; Auswea 2004	Erik Sloth, Niels Christian Moller, Ejler Kristensen, Bo Sonderfaard
Dec-04	Pederson	Perception and annoyance due to wind turbine noise	Acoustical Society of America 2004	Eja Pederson, Kerstin Persson Waye
Jan-05	Fowler	Toora wind farm - Review of the environmental noise monitoring program	South Gippsland Shire Council Victoria Australia	James Fowler
Feb-05	BWEA	Low frequency noise and wind turbines	BWEA	J Bass, A Bullmore, M Hayes, M Jiggins, G Leventhall, A McKenzie, M Trinick
Jul-05	Bowdler	ETSU-R-97 Why it is wrong	New Acoustics	Dick Bowdler
2005	McKenzie	Infra-sound, low frequency noise & vibration from wind turbines	All Energy 2005	Andy McKenzie HMP Ltd
Feb-06	Probyn	Local development framework, Supplementary planning document: wind power	Huntingdonshire District Council	Richard Probyn
2006	HMP	The measurement of low frequency noise at three UK wind farms	UK Department of Trade and Industry (DTI)	Hayes McKenzie Partnership (HMP)
Jul-07	Moorhouse	Research into aerodynamic modulation of wind turbine noise: Final report	University of Salford for Department for Business & Regulatory Reform	Andy Moorhouse, Malcolm Hayes, Sabine von Hunerbein, Ben Piper, Mag Adams
Sep-07	Legarth	Auralization and assessments of anoyance from wind turbines	Second international meeting on wind turbine noise, Lyon, France	Soren Vase Legarth
Jan-08	Pedersen	Wind turbines - low level noise sources interfering with restoration	IOP Publishing UK	Eja Pederson, Kerstin Persson Waye
26-Nov-08	HM Gov	Planning Act 2008	HM Government	HM Government
Mar-09	Bullmore	Prediction and assessment of wind turbine noise (Bulletin Method)	Institute of Acoustics: Acoustics Bulletin	Andrew Bullmore, Andy McKenzie, Bob Davis, Dick Bowdler, Geoff Leventhall, Malcolm Hayes, Mark Jiggins
17-Jun-09	Lee	An estimation method of the amplitude modulation in wind turbine noise for community response assessment	3rd International meeting on wind turbine noise, Aalborg, Denmark	Seunghoon Lee, Kyutae Kim, Seungmin Lee, Hogeon Kim, Soogab Lee
Aug-09	Pederson	Response to noise from modern wind farms in the Netherlands	Acoustical Society of America 2009	Eja Pederson, Frits van den Berg, Roel Bakker, Jelte Bouma
Jun-09	Di Napoli	Case study: Wind turbine noise in a small and quiet community in Finland	Third international meeting on wind turbine noise, Aalborg, Denmark	Carlo Di Napoli
2009	WHO	Night noise guidelines for Europe	World Health Organisation	WHO

Appendix B1 - INWG AM Study Reference Literature - By Date

Date of Publication	Lead Author	Document Title	Platform	Authors
11-Dec-09	Pykett	Appeal decision APP/Q1153/A/06/2017162 Land to the south east of north Tawton and south west Bow	Planning Inspectorate	Andrew Pykett
31-Mar-10	Law Commission	Simplification of criminal law: public nuisance and outraging public decency	The Law Commission	The Law Commission
01-Jun-10	ECHR	European Convention on Human Rights	Council of Europe	European Court of Human Rights
14-Dec-10	Pike	Cotton Farm Appeal decision Ref: APP/H0520/A/09 /2119385	Planning Inspectorate	Martin Pike
06-Apr-11	DEFRA	Wind farm noise statutory nuisance complaint methodology	DEFRA	Dani Fiumicelli and Nigel Triner of AECOM
12-Apr-11	Di Napoli	Long distance amplitude modulation of wind turbine noise	4th international meeting on wind turbine noise, Rome	Carlo Di Napoli
12-Apr-11	Styles	Monitoring and mitigation of low frequency noise from wind turbines to protect comprehensive test ban seismic monitoring stations	4th international meeting on wind turbine noise, Rome	Styles, Westwood, Toon, Buckingham, Marmo, Carruthers
12-Apr-11	McLaughlin	Measurement of amplitude modulation frequency spectrum	4th international meeting on wind turbine noise, Rome	Dave McLaughlin
12-Apr-11	McCabe	Detection and qualification of amplitude modulation in wind turbine noise	4th international meeting on wind turbine noise, Rome	J N McCabe
12-Apr-11	Lundmark	Measurement of swish noise, a new method	4th international meeting on wind turbine noise, Rome	Gunnar Lundmark
26-May-11	Mummery	Hulme v Secretary of State for Communities and Local Government and RES Developments [2011] EWCA Civ 638	Court of Appeal	Lord Justice Mummery, Lord Justice Elias, Lord Justice Patten
Jun-11	Atzler	Evaluating the degree of annoyance caused by impulsive noise types	MTZ Research Acoustics	Martin Atzler, Stefan Pischinger, Bernhard Lang, Stefan Heuer
29-Jun-11	Engel	Vestas letter to Danish Minister for the Environment	Vestas	Ditlev Engel
Aug-11	Jones	Windy Bank Ornithology Report	AESL for Banks Renewables	Alan Jones, John Olley, Nick Mason, Phil Curtis
29-Sep-11	Cooke	Wind farms and noise nuisance - another chink in the armour	Property Law Journal	Jacqueline Cooke
27-Oct-11	Stigwood	The effect of a common wind shear adjustment methodology on the assessment of wind farms when applying ETSU-R-97	MAS Environmental	Mike Stigwood
Mar-12	DCLG	National Planning Policy Framework	DCLG	Department for Communities and Local Government
Apr-12	Moroney	A critique of the IoA treatment of background noise for wind farm noise assessment	Renewable Energy Foundation (REF)	Lee Moroney, John Constable
Apr-12	Smith	Mechanisms of amplitude modulation in wind turbine noise	Acoustics 2012, Nantes	M Smith, AJ Bullmore, MM Cand, R Davis
Jun-12	Thorne	The perception and effect of wind farm noise at two Victorian wind farms	Noise Measurement Services QLD Australia	Bob Thorne
18-Jun-12	Di Napoli	Assessing aerodynamic amplitude modulation from wind turbine noise	Baltic-Nordic Acoustic Meeting, Odense, Denmark	Carlo Di Napoli
06-Jul-12	Jackson	Alaska wind farm Appeal Ref: APP/B1225/A/11/2161905	Planning Inspectorate	Paul Jackson
10-Jul-12	Cox	Wind turbine noise impact assessment, where ETSU is silent	Various	Richard Cox, David Unwin and Trevor Sherman
Aug-12	Larson	Variations of sound from wind turbines during different weather conditions	Inter noise New York 2012	Conny Larson, Olof Ohlund
Sep-12	Jennings	The nature of nuisance:	Infrastructure Planning Commission	Peter Jennings representation for Brechfa Forest application
Nov-12	Nobbs	Charachterisation of noise in homes affected by wind turbine noise	Australian Acoustical Society	Benjamin Nobbs, Con J Coolan, Danielle J Mereau
12-Dec-12	Macey	Brechfa Forest West windfarm examining authority's report of findings and conclusions and recommendation to the Secretary of State for Energy and Climate Change	Planning Inspectorate	Bob Macey
24-Dec-12	Walker	A Cooperative Measurement Survey and Analysis of Low Frequency and Infrasound at the Shirley Wind Farm in Brown County, Wisconsin	Clean Wisconsin for Wisconsin Public Service Commission	Channel Islands Acoustics, Camarillo, CA Principal: Dr. Bruce Walker; Hessler Associates, Inc., Haymarket, VA Principals: George F. and David M. Hessler: Rand Acoustics, Brunswick, ME Principal: Robert Rand: Schomer and Associates, Inc., Champaign, IL Principal: Dr. Paul Schomer
08-Jan-13	Lee	Numerical modeling of wind turbine aerodynamic noise in the time domain	Acoustics Society of America	Seunghoon Lee, Seungmin Lee, Soogab Leea, Seoul National University, Republic of Korea
28-Jan-13	Perkins	Letter to Darlington BC - EAM planning condition	Parsons Brinckerhoff	Richard Perkins
12-Mar-13	DECC	The Brechfa Forest West wind farm Order 2013	Infrastructure Planning Commission	DECC
17-Mar-13	Cox	The bad science behind the wind turbine noise guidelines	Ed Davey meeting 9 Oct 2013	R Cox, D Unwin, D Bingham, R Greenough
May-13	Swinbanks	Assessment of RES revised condition 20 for evaluating excessive amplitude modulation	MAS Research Ltd	MA Swinbanks

Appendix B1 - INWG AM Study Reference Literature - By Date

Date of Publication	Lead Author	Document Title	Platform	Authors
1-May-13	Perkins	A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise	Institute of Acoustics - Noise Working Group	Richard Perkins, Matthew Cand, Robert Davis, Chris Jordan, Malcolm Hayes
11-Jul-13	Major	Common Barn decision: Land at Church Farm, Rectory Lane, Southoe, Cambridge Ref: APP/H0520/A/12/2188648	The Planning Inspectorate	Philip Major
Jul-13	Unwin	Wind farm noise assessments: ETSU-R-97 and the three legged stool	Science in parliament - Summer 2013	David Unwin and Richard Cox
Jul-13	Davis	Discussion of Den Brook wind farm conditions 20 and 21	ISVR Consulting	RA Davis, MG Smith
Jul-13	Bass	RES email response to Dr Swinbanks report	RES	J Bass, Daniel Leahy
13-Aug-13	Ruffle	RES letter: Den Brook wind farm conditions 20 and 21	RES	Rachel Ruffle
20-Aug-13	McKenzie	Cotton Farm wind turbines: Phase 1 noise limit compliance assessment	Hayes McKenzie Partnership for BayWa r.e. Ltd	Andy McKenzie
28-Aug-13	Gabriel	Amplitude modulation and complaints about wind turbine noise	5th international conference on wind turbine noise	Joachim Gabriel, Thomas Neumann, Gundula Hübner, Johannes Pohl
28-Aug-13	Tachibana	Assessment of wind turbine noise in immission areas	5th International Conference on Wind Turbine Noise, Denver, INCE Europe	Hideki Tachibana, Hiroo Yano, Chiba Institute of Technology and Akinori Fukushima NEWS Environmental Design Inc, Japan
28-Aug-13	Stigwood	Audible amplitude modulation - results of field measurements and investigations compared to psychoacoustical assessment and theoretical research	5th International Conference on Wind Turbine Noise, Denver, INCE Europe	Mike Stigwood, Sarah Large and Duncan Stigwood
15-Sep-13	Fukushima	Study on the amplitude modulation of wind turbine noise: Part 1 - physical investigation	inter.noise 2013, Innsbruck, Austria	Akinori Fukushima, Kazuhiro Yamamoto, Hideo Uchida, Shinichi Sueoka
27-Sep-13	von Hünerbein	Advice on monitoring of wind turbine noise impact	University of Salford	Sabine von Hünerbein, Robert Oldfield, Andy Moorhouse
08-Oct-13	Stigwood	Evidence of failure of wind farm guidance to protect well being	Ed Davey meeting 9 Oct 2013	Mike Stigwood
09-Oct-13	Unwin	A summary of the Bad Science behind the wind turbine noise guidelines	Ed Davey meeting 9 Oct 2013	David Unwin and Richard Cox
Nov-13	EPA South Australia	Waterloo wind farm environmental noise study	Environmental Protection Authority, South Australia	EPA South Australia
Nov-13	Hoare	Rebuttal to the noise proof of evidence of Dr Matthew Cand	Shipdham Appeal APP/F2605/A/12/2185306	Dr Lee Hoare
17-Nov-13	Cooper	Automated detection and analysis of amplitude modulation at a residence and wind turbine	Australian Acoustical Society (paper peer reviewed)	Jonathan Cooper, Tom Evans: Resonate Acoustics, Adaleide, Australia
16-Dec-13	ReUK	Wind turbine amplitude modulation: Research to improve understanding as to its cause and effect	RenewableUK	RenewableUK
16-Dec-13	ReUK	Template planning condition on amplitude modulation	RenewableUK	RenewableUK
Jan-14	Larsson	Amplitude modulation of sound from wind turbines under various meteorological conditions	Acoustics Society of America	Conny Larsson and Olof Ohlund, Uppsala University, Sweden
Jan-14	Jones	Appeal APP/M6825/A/12/2189697 by RES UK & Ireland Ltd. Land surrounding Bryn Llywelyn, Llanllwni, Pencader SA39 9ED	The Planning Inspectorate	Emyr Jones
22-Jan-14	Cox	A critique of the RenewableUK report on wind turbine amplitude modulation, what it tells us and what it doesn't	Various	Richard Cox
30-Jan-14	Pope	Land at Dunsland Cross, Branis Corner, Devon	The Planning Inspectorate	Neil Pope
13-Feb-14	SoS	Turncole Farm Ref: APP/X1545/A/12/2174982	DCLG Appeal decision	Secretary of State
26-Feb-14	Neuberger	Coventry v Lawrence [2014] 1 AC 822	The Supreme Court	Lords Neuberger, Mance, Clarke, Sumption, Carnwath
06-Mar-14	DCLG	Use of planning conditions	Planning portal	Department for Communities and Local Government
19-Mar-14	Moroney	The Efficacy of the RenewableUK (RUK) Condition in controlling wind farm amplitude modulation (AM) noise	Renewable Energy Foundation (REF)	Dr Lee Moroney and Dr John Constable
20-Mar-14	Stigwood	The Cotton Farm research project long term study - initial findings and other MAS research	Institute of Acoustics meeting; Newport - Presentation	Mike Stigwood
20-Mar-14	Cox	A critique of the RenewableUK report on wind turbine amplitude modulation	Institute of Acoustics meeting; Newport - Presentation	Richard Cox
Mar-14	Huson	Amplitude modulation case study at the Leonards Hill wind farm, Victoria, Australia	IoA AM Conference, Cardiff 20 March 2014	W Les Huson, Australia
29-Apr-14	Smith	ISVR memo: Appraisal of the proposed scheme for condition 21	ISVR Consulting	Malcolm Smith, Bob Davis
08-May-14	RES	Written scheme relating to condition 21 Den Brook wind farm implementation of condition 20	RES	RES
May-14	Davis	ISVR report: Assessment of Den Brook condition 21 scheme for the implementation of condition 20	ISVR Consulting	RA Davis, MG Smith
21-May-14	WDBC	Discharge of Conditions Decision - Land adjacent to Den Brook	West Devon Borough Council	
May-14	Huson	Indoor noise survey: Knockglass Farm	L Huson & Associates report	Les Huson

Appendix B1 - INWG AM Study Reference Literature - By Date

Date of Publication	Lead Author	Document Title	Platform	Authors
12-Jun-14	Burden	Clocaenog Forest wind farm Examining Authorities Report	The Planning Inspectorate	Wendy Burden
01-Jul-14	Holland	Report on the examination into the Allerdale local plan part one	The Planning Inspectorate	Susan Holland
29-Jul-14	Stigwood	Between Michael Hulme and West Devon Borough Council and RES Developments - Witness Statement	High Court statement	Michael Stigwood
31-Jul-14	SoS	Land at Saxby Wolds, near Barton-upon-Humber, North Lincolnshire Ref: APP/Y2003/A/12/2180725	DCLG Appeal decision	Secretary of State
01-Aug-14	Perkins	IoA AM NWG options and terms of reference	Institute of Acoustics	Institute of acoustics wind turbine noise working group
07-Aug-14	Egan	Letter to Ed Davey, Secretary of State DECC from the Institute of Acoustics	Institute of Acoustics	William Egan, President of IoA
18-Aug-14	Kugler	Low-frequency sound affects active micromechanics in the human inner ear	Royal Society Open Science	Kathrin Kugler, LutzWiegrebe, Benedikt Grothe, Manfred Kössl, Robert Gürkov, Eike Krause and Markus Drexl, Germany
08-Sep-14	Davis	Between Michael Hulme and West Devon Borough Council and RES UK & Ireland – Witness Statement	High Court statement	Robert Davis
10-Sep-14	Bass	Between Michael Hulme and West Devon Borough Council and RES UK & Ireland – Witness Statement	High Court statement	Jeremy Bass
12-Sep-14	SoS	Decision letter: Clocaenog Forest wind farm	DECC Planning decision	Secretary of State
25-Sep-14	SoS	Land at Wood Farm, Church Lane, Shipdham	DCLG Appeal decision	Secretary of State
29-Sep-14	Stigwood	Between Michael Hulme and West Devon Borough Council and RES Development – 2nd Witness Statement	High Court statement	Michael Stigwood
Oct-14	BSI	BS4142:2014 Methods for rating and assessing industrial and commercial sound	BSI	BSI
01-Oct-14	SoS	Starbold decision: Land between Bishops Itchington, Gaydon and Knightcote Ref: APP/J3720/A/13/2193579	DCLG Appeal decision	Secretary of State
02-Oct-14	Vanderkooy	Measuring wind turbine coherent infrasound	University of Waterloo	John, Vanderkooy, Richard Mann, Canada
21-Oct-14	Perkins	IoA AM NWG terms of reference	Institute of Acoustics	Institute of acoustics wind turbine noise working group
21-Oct-14	Perkins	IoA AM NWG scope of work	Institute of Acoustics	Institute of acoustics wind turbine noise working group
07-Nov-14	Supperstone	High Court judgement between West Devon Borough Council and Hulme	High Court	Mr Justice Supperstone
16-Nov-14	Davey	Letter to the Institute of Acoustics from Secretary of State, DECC	Department of Energy & Climate Change (DECC)	Ed Davey MP
16-Nov-14	Stigwood	Initial findings of the Cotton Farm wind farm long term community noise monitoring project	Inter.noise 2014, Melbourne	Mike Stigwood, Duncan Stigwood, Sarah Large of MAS Environmental UK
16-Nov-14	Large	The noise charachteristic of 'compliant' wind farms that adversely affect its neighbours	Inter.noise 2014, Melbourne	Sarah Large, Mike Stigwood of MAS Environmental UK
16-Nov-14	Lenchine	Special noise character in noise from wind farms	Inter.noise 2014, Melbourne	Valeri V Lenchine, Johathan Song, Australia
16-Nov-14	Madsen	Correlation of amplitude modulation to inflow charachteristics	Inter.noise 2014, Melbourne	Helge Aa. Madsen, Franck Bertagnolio, Andreas Fischer, Christian Bak, Denmark
16-Nov-14	Søndergaard	Noise and low frequency noise from wind turbines	Inter.noise 2014, Melbourne	Bo Søndergaard, Denmark
16-Nov-14	Tachibana	Outcome of systematic research on wind turbine noise in Japan	Inter.noise 2014, Melbourne	Hideki Tachibana. Japan
16-Nov-14	Thorne	The relevance of the precautionary principle to wind farm noise planning	Inter.noise 2014, Melbourne	Bob Thorne, Australia
26-Nov-14	Cooper	The results of an acoustic testing program, Cape Bridgewater wind farm	The Acoustic Group for Energy Pacific, Australia	Steven Cooper, The Acoustic Group, Australia
04-Dec-14	Schmidt	Health effects related to wind turbine noise exposure: a systematic review	PLOS ONE journal	Jesper Hvass Schmidt, Mads Klokker, Denmark
19-Dec-14	IOA	Institute of acoustics statement in respect of wind farm noise assessment	Institute of Acoustics	IOA
21-Jan-15	Rand	R Rand letter to S Cooper: Cape Bridgewater study	Rand Acoustics, CO, USA	Robert Rand
22-Jan-15	Ambrose	S Rand letter to S Cooper: Cape Bridgewater study	SE Ambrose & Associates, ME, USA	Stephen Ambrose
29-Jan-15	Lo	Report on the committee's inquiry into wind energy	Northern Ireland Assembly	Committee for the environment: A Lo, P Cameron, C Boylan, C Eastwood, S Overend, A Maginness, I McCrea, B McElduff, I Milne, Lord Morrow, P Weir
Feb-15	NHMRC	NHMRC Statement: Evidence on wind farms and human health	Australian Government, NHMRC	National Health and Medical Research Council
11-Feb-15	DCLG	Appeal decision APP/H0520/A/13/2207023 Land to the west of Bicton industrial estate between Kimbolton and Stow Longa, Cambridgeshire	Department for Communities and Local Government	Secretary of State and Inspector Paul Griffiths
12-Feb-15	Davey	Letter to Chris Heaton-Harris MP from Ed Davey SoS	Department of Energy & Climate Change	Edward Davey MP, Secretary of State

Appendix B1 - INWG AM Study Reference Literature - By Date

Date of Publication	Lead Author	Document Title	Platform	Authors
27-Feb-15	Bahtiarian	Infrasound measurements of Falmouth wind turbines Wind #1 and Wind #2	Noise Control Engineering LLC MA USA	Michael Bahtiarian, Allan Beaudry
04-Mar-15	Sumption	R (Catt) v Commissioner of Police of the Metropolis and another	The Supreme Court	Lord Neuberger, Lady Hale, Lord Mance, Lord Sumption, Lord Toulson
26-Mar-15	DECC	Invitation to tender for the review of the evidence on effects and response to amplitude modulation	Department of Energy & Climate Change	DECC
20-Apr-15	Berger	Health-based Audible Noise Guidelines Account for Infrasound and Low Frequency Noise Produced by Wind Turbines	6th International Conference on Wind Turbine Noise, Glasgow	Robert G. Berger, Payam Ashtiani, Christopher A. Ollson, Melissa Whitfield Aslund, Lindsay C. McCallum, Geoff Leventhall, Loren D. Knopper
20-Apr-15	Bradley	Time-Dependent Interference: The Mechanism Causing Amplitude Modulation Noise?	6th International Conference on Wind Turbine Noise, Glasgow	Stuart Bradley
20-Apr-15	Cand	Measurements demonstrating mitigation of far-field AM from wind turbines	6th International Conference on Wind Turbine Noise, Glasgow	Matthew Cand, Andrew Bullmore
20-Apr-15	Cassidy	Addressing the Issue of Amplitude Modulation: A Developer's Perspective	6th International Conference on Wind Turbine Noise, Glasgow	Matthew Cassidy, Jeremy Bass
20-Apr-15	Engelhardt	Reduction of tonalities in wind turbines by means of active vibration absorbers	6th International Conference on Wind Turbine Noise, Glasgow	Jürgen Engelhardt, Sebastian Katz, Steffen Pankoke
20-Apr-15	Evans	Tonal noise from wind turbines	6th International Conference on Wind Turbine Noise, Glasgow	Tom Evans, Jonathan Cooper
20-Apr-15	Fernandez	Indoor Simulation of Wind Turbine Amplitude Modulated Noise	6th International Conference on Wind Turbine Noise, Glasgow	Felipe A. Fernandez, Ricardo A. Burdisso
20-Apr-15	Halstead	Detection of Amplitude Modulation in Southern Ontario Wind Farms	6th International Conference on Wind Turbine Noise, Glasgow	Duncan Halstead, Adam Suban-Loewen, Payam Ashtiani
20-Apr-15	Huson	Stationary wind turbine infrasound emissions and propagation loss measurements	6th International Conference on Wind Turbine Noise, Glasgow	W Les Huson, Australia
20-Apr-15	Huson	Constraints imposed by and limitations of IEC 61672 for the measurement of wind farm sound emissions	6th International Conference on Wind Turbine Noise, Glasgow	W Les Huson, Australia
20-Apr-15	Iwase	Observation of vibration velocity at many parts of wind turbine and relational analysis with propagated sound to surroundings	6th International Conference on Wind Turbine Noise, Glasgow	Teruo Iwase Niigata, Hideo Uchida, Hiroyasu Kurono, Yasuaki Okada, Koichi YOSHIHISA
20-Apr-15	Large	Compliance isn't everything	6th International Conference on Wind Turbine Noise, Glasgow	Sarah Large, Mike Stigwood
20-Apr-15	Leventhall	On the overlap region between wind turbine infrasound and infrasound from other sources and its relation to criteria	6th International Conference on Wind Turbine Noise, Glasgow	Geoff Leventhall
20-Apr-15	Palmer	Wind Turbines – A Changed Environment	6th International Conference on Wind Turbine Noise, Glasgow	William K.G. Palmer
20-Apr-15	Stigwood	Cotton Farm Wind Farm – Long term community noise monitoring project – 2 years on	6th International Conference on Wind Turbine Noise, Glasgow	Mike Stigwood, Sarah Large, Duncan Stigwood
20-Apr-15	Swinbanks	Direct Experience of Low Frequency Noise and Infrasound within a Windfarm Community	6th International Conference on Wind Turbine Noise, Glasgow	M.A.Swinbanks
23-Apr-15	Irvine	Discussion document, methods for rating amplitude modulation in wind turbine noise	Institute of Acoustics AM noise working group	Irvine, Bass, Cand, Coles, Davis, Leventhall, Levet, Miller, Sexton, Shelton
23-Apr-15	Irvine	IoA Consultation questionnaire for Methods for rating amplitude modulation in wind turbine noise	Institute of Acoustics AM noise working group	Irvine, Bass, Cand, Coles, Davis, Leventhall, Levet, Miller, Sexton, Shelton
18-Jun-15	Madigan	Select committee on wind turbines	Commonwealth of Australia	Senators John Madigan, Bob Day, Chris Back, Matthew Canavan, David Leyonhjelm, Anne Urquhart
26-May-15	Hulme	Monitoring of Greater Than Expected Amplitude Modulation (GTE-AM) from the Proposed Den Brook Wind Farm	Den Brook Judicial Review Group	Mike Hulme
18-Jun-15	Madigan	Select committee on wind turbines	Commonwealth of Australia	Senators John Madigan, Bob Day, Chris Back, Matthew Canavan, David Leyonhjelm, Anne Urquhart

Appendix B2 - INWG AM Study Reference Literature - By Author

Lead Author	Date of Publication	Document Title	Platform	Authors
Ambrose	22-Jan-15	S Rand letter to S Cooper: Cape Bridgewater study	SE Ambrose & Associates, ME, USA	Stephen Ambrose
Atzler	Jun-11	Evaluating the degree of annoyance caused by impulsive noise types	MTZ Research Acoustics	Martin Atzler, Stefan Pischinger, Bernhard Lang, Stefan Heuer
Bahtiarian	27-Feb-15	Infrasound measurements of Falmouth wind turbines Wind #1 and Wind #2	Noise Control Engineering LLC MA USA	Michael Bahtiarian, Allan Beaudry
Bass	Jul-13	RES email response to Dr Swinbanks report	RES	J Bass, Daniel Leahy
Bass	10-Sep-14	Between Michael Hulme and West Devon Borough Council and RES UK & Ireland – Witness Statement	High Court statement	Jeremy Bass
Berger	20-Apr-15	Health-based Audible Noise Guidelines Account for Infrasound and Low Frequency Noise Produced by Wind Turbines	6th International Conference on Wind Turbine Noise, Glasgow	Robert G. Berger, Payam Ashtiani, Christopher A. Ollson, Melissa Whitfield Aslund, Lindsay C. McCallum, Geoff Leventhall, Loren D. Knopper
Bowdler	Jul-05	ETSU-R-97 Why it is wrong	New Acoustics	Dick Bowdler
Bradley	20-Apr-15	Time-Dependent Interference: The Mechanism Causing Amplitude Modulation Noise?	6th International Conference on Wind Turbine Noise, Glasgow	Stuart Bradley
BSI	Sep-97	BS4142 - 1997 Method for rating industrial noise affecting mixed residential and industrial areas	BSI	BSI
BSI	Oct-14	BS4142:2014 Methods for rating and assessing industrial and commercial sound	BSI	BSI
Bullmore	Mar-09	Prediction and assessment of wind turbine noise (Bulletin Method)	Institute of Acoustics: Acoustics Bulletin	Andrew Bullmore, Andy McKenzie, Bob Davis, Dick Bowdler, Geoff Leventhall, Malcolm Hayes, Mark Jiggins
Burden	12-Jun-14	Clocaenog Forest wind farm Examining Authorities Report	The Planning Inspectorate	Wendy Burden
BWEA	Feb-05	Low frequency noise and wind turbines	BWEA	J Bass, A Bullmore, M Hayes, M Jiggins, G Leventhall, A McKenzie, M Trinick
Cand	20-Apr-15	Measurements demonstrating mitigation of far-field AM from wind turbines	6th International Conference on Wind Turbine Noise, Glasgow	Matthew Cand, Andrew Bullmore
Cassidy	20-Apr-15	Addressing the Issue of Amplitude Modulation: A Developer's Perspective	6th International Conference on Wind Turbine Noise, Glasgow	Matthew Cassidy, Jeremy Bass
Cooke	29-Sep-11	Wind farms and noise nuisance - another chink in the armour	Property Law Journal	Jacqueline Cooke
Cooper	17-Nov-13	Automated detection and analysis of amplitude modulation at a residence and wind turbine	Australian Acoustical Society (paper peer reviewed)	Jonathan Cooper, Tom Evans: Resonate Acoustics, Adaleide, Australia
Cooper	26-Nov-14	The results of an acoustic testing program, Cape Bridgewater wind farm	The Acoustic Group for Energy Pacific, Australia	Steven Cooper, The Acoustic Group, Australia
Cox	10-Jul-12	Wind turbine noise impact assessment, where ETSU is silent	Various	Richard Cox, David Unwin and Trevor Sherman
Cox	17-Mar-13	The bad science behind the wind turbine noise guidelines	Ed Davey meeting 9 Oct 2013	R Cox, D Unwin, D Bingham, R Greenough
Cox	22-Jan-14	A critique of the RenewableUK report on wind turbine amplitude modulation, what it tells us and what it doesn't	Various	Richard Cox
Cox	20-Mar-14	A critique of the RenewableUK report on wind turbine amplitude modulation	Institute of Acoustics meeting; Newport - Presentation	Richard Cox
Davey	16-Nov-14	Letter to the Institute of Acoustics from Secretary of State, DECC	Department of Energy & Climate Change (DECC)	Ed Davey MP
Davey	12-Feb-15	Letter to Chris Heaton-Harris MP from Ed Davey SoS	Department of Energy & Climate Change	Edward Davey MP, Secretary of State
Davis	Jul-13	Discussion of Den Brook wind farm conditions 20 and 21	ISVR Consulting	RA Davis, MG Smith
Davis	May-14	ISVR report: Assessment of Den Brook condition 21 scheme for the implementation of condition 20	ISVR Consulting	RA Davis, MG Smith
Davis	08-Sep-14	Between Michael Hulme and West Devon Borough Council and RES UK & Ireland – Witness Statement	High Court statement	Robert Davis
DCLG	20-Jul-95	Circular 11/95: the use of conditions in planning permissions	DCLG	Department for Communities and Local Government
DCLG	Mar-12	National Planning Policy Framework	DCLG	Department for Communities and Local Government
DCLG	06-Mar-14	Use of planning conditions	Planning portal	Department for Communities and Local Government
DCLG	11-Feb-15	Appeal decision APP/H0520/A/13/2207023 Land to the west of Bicton industrial estate between Kimbolton and Stow Longa, Cambridgeshire	Department for Communities and Local Government	Secretary of State and Inspector Paul Griffiths
DECC	12-Mar-13	The Brechfa Forest West wind farm Order 2013	Infrastructure Planning Commission	DECC
DECC	26-Mar-15	Invitation to tender for the review of the evidence on effects and response to amplitude modulation	Department of Energy & Climate Change	DECC
DEFRA	06-Apr-11	Wind farm noise statutory nuisance complaint methodology	DEFRA	Dani Fiumicelli and Nigel Triner of AECOM
Di Napoli	Jun-09	Case study: Wind turbine noise in a small and quiet community in Finland	Third international meeting on wind turbine noise, Aalborg, Denmark	Carlo Di Napoli
Di Napoli	12-Apr-11	Long distance amplitude modulation of wind turbine noise	4th international meeting on wind turbine noise, Rome	Carlo Di Napoli

Appendix B2 - INWG AM Study Reference Literature - By Author

Lead Author	Date of Publication	Document Title	Platform	Authors
Di Napoli	18-Jun-12	Assessing aerodynamic amplitude modulation from wind turbine noise	Baltic-Nordic Acoustic Meeting, Odense, Denmark	Carlo Di Napoli
ECHR	01-Jun-10	European Convention on Human Rights	Council of Europe	European Court of Human Rights
Egan	07-Aug-14	Letter to Ed Davey, Secretary of State DECC from the Institute of Acoustics	Institute of Acoustics	William Egan, President of IoA
Engel	29-Jun-11	Vestas letter to Danish Minister for the Environment	Vestas	Ditlev Engel
Engelhardt	20-Apr-15	Reduction of tonalities in wind turbines by means of active vibration absorbers	6th International Conference on Wind Turbine Noise, Glasgow	Jürgen Engelhardt, Sebastian Katz, Steffen Pankoke
EPA South Australia	Nov-13	Waterloo wind farm environmental noise study	Environmental Protection Authority, South Australia	EPA South Australia
ETSU	Sep-96	ETSU-R-97 The assessment & rating of noise from wind farms	Department of Trade & Industry	Noise working group
Evans	20-Apr-15	Tonal noise from wind turbines	6th International Conference on Wind Turbine Noise, Glasgow	Tom Evans, Jonathan Cooper
Fernandez	20-Apr-15	Indoor Simulation of Wind Turbine Amplitude Modulated Noise	6th International Conference on Wind Turbine Noise, Glasgow	Felipe A. Fernandez, Ricardo A. Burdisso
Fowler	Jan-05	Toora wind farm - Review of the environmental noise monitoring program	South Gippsland Shire Council Victoria Australia	James Fowler
Fukushima	15-Sep-13	Study on the amplitude modulation of wind turbine noise: Part 1 - physical investigation	inter.noise 2013, Innsbruck, Austria	Akinori Fukushima, Kazuhiro Yamamoto, Hideo Uchida, Shinichi Sueoka
Gabriel	28-Aug-13	Amplitude modulation and complaints about wind turbine noise	5th international conference on wind turbine noise	Joachim Gabriel, Thomas Neumann, Gundula Hűbner, Johannes Pohl
Halstead	20-Apr-15	Detection of Amplitude Modulation in Southern Ontario Wind Farms	6th International Conference on Wind Turbine Noise, Glasgow	Duncan Halstead, Adam Suban-Loewen, Payam Ashtiani
HM Gov	1 Aug 1832	Prescription Act 1832	HM Government	HM Government
HM Gov	17 Jul 1868	Rylands v Fletcher	House of Lords	House of Lords
HM Gov	24-May-90	Town and Country Planning Act 1990	HM Government	HM Government
HM Gov	01-Nov-90	Environmental Protection Act 1990	HM Government	HM Government
HM Gov	Nov-98	Human Rights Act 1998	HM Government	HM Government
HM Gov	26-Nov-08	Planning Act 2008	HM Government	HM Government
HMP	2006	The measurement of low frequency noise at three UK wind farms	UK Department of Trade and Industry (DTI)	Hayes McKenzie Partnership (HMP)
Hoare	Nov-13	Rebuttal to the noise proof of evidence of Dr Matthew Cand	Shipdham Appeal APP/F2605/A/12/2185306	Dr Lee Hoare
Holland	01-Jul-14	Report on the examination into the Allerdale local plan part one	The Planning Inspectorate	Susan Holland
Hubbard	Sep-82	Noise induced house vibrations and human perception	Noise Control Engineering Journal Sept / Oct 1982	Harvey H Hubbard
Hubbard	Nov-84	Response measurements for two building structures excited by noise from a large horizontal axis wind turbine generator	NASA USA	Harvey H Hubbard, Kevin P Shepherd
Hubbard	Jan-88	Wind turbine acoustics research - bibliography with selected annotation	NASA USA	Harvey H Hubbard, Kevin P Shepherd
Hulme	26-May-15	Monitoring of Greater Than Expected Amplitude Modulation (GTE-AM) from the Proposed Den Brook Wind Farm	Den Brook Judicial Review Group	Mike Hulme
Huson	Mar-14	Amplitude modulation case study at the Leonards Hill wind farm, Victoria, Australia	IoA AM Conference, Cardiff 20 March 2014	W Les Huson, Australia
Huson	May-14	Indoor noise survey: Knockglass Farm	L Huson & Associates report	Les Huson
Huson	20-Apr-15	Stationary wind turbine infrasound emissions and propagation loss measurements	6th International Conference on Wind Turbine Noise, Glasgow	W Les Huson, Australia
Huson	20-Apr-15	Constraints imposed by and limitations of IEC 61672 for the measurement of wind farm sound emissions	6th International Conference on Wind Turbine Noise, Glasgow	W Les Huson, Australia
IOA	19-Dec-14	Institute of acoustics statement in respect of wind farm noise assessment	Institute of Acoustics	IOA
Irvine	23-Apr-15	Discussion document, methods for rating amplitude modulation in wind turbine noise	Institute of Acoustics AM noise working group	Irvine, Bass, Cand, Coles, Davis, Leventhall, Levet, Miller, Sexton, Shelton
Irvine	23-Apr-15	IoA Consultation questionnaire for Methods for rating amplitude modulation in wind turbine noise	Institute of Acoustics AM noise working group	Irvine, Bass, Cand, Coles, Davis, Leventhall, Levet, Miller, Sexton, Shelton
Iwase	20-Apr-15	Observation of vibration velocity at many parts of wind turbine and relational analysis with propagated sound to surroundings	6th International Conference on Wind Turbine Noise, Glasgow	Teruo Iwase Niigata, Hideo Uchida, Hiroyasu Kurono, Yasuaki Okada, Koichi YOSHIHISA
Jackson	06-Jul-12	Alaska wind farm Appeal Ref: APP/B1225/A/11/2161905	Planning Inspectorate	Paul Jackson
Jennings	Sep-12	The nature of nuisance:	Infrastructure Planning Commission	Peter Jennings representation for Brechfa Forest application
Jones	Aug-11	Windy Bank Ornithology Report	AESL for Banks Renewables	Alan Jones, John Olley, Nick Mason, Phil Curtis

Appendix B2 - INWG AM Study Reference Literature - By Author

Lead Author	Date of Publication	Document Title	Platform	Authors
Jones	Jan-14	Appeal APP/M6825/A/12/2189697 by RES UK & Ireland Ltd. Land surrounding Bryn Llywelyn, Llanllwni, Pencader SA39 9ED	The Planning Inspectorate	Emyr Jones
Kelley	Feb-85	Acoustic noise associated with the MOD-1 wind turbine: Its source, impact and control	Solar Energy Research Institute for US Department of Energy	ND Kelley, HE McKenna, RR Hemphil, CL Etter, RL Garrelts, NC Linn
Kelley	Nov-87	A proposed metric for assessing the potential of community annoyance from wind turbine low frequency noise emissions	Solar Energy Research Institute for US Department of Energy	ND Kelley
Kelley	Jan-88	The MOD-2 wind turbine: Aerocoustical noise sources, emissions and potential impact	Solar Energy Research Institute for US Department of Energy	ND Kelley, HE McKenna, EW Jacobs, RR Hemphil, NJ Birkenheuer
Kugler	18-Aug-14	Low-frequency sound affects active micromechanics in the human inner ear	Royal Society Open Science	Kathrin Kugler, LutzWiegrebe, Benedikt Grothe, Manfred Kössl, Robert Gürkov, Eike Krause and Markus Drexl, Germany
Large	16-Nov-14	The noise charachteristic of 'compliant' wind farms that adversely affect its neighbours	Inter.noise 2014, Melbourne	Sarah Large, Mike Stigwood of MAS Environmental UK
Large	20-Apr-15	Compliance isn't everything	6th International Conference on Wind Turbine Noise, Glasgow	Sarah Large, Mike Stigwood
Larson	Aug-12	Variations of sound from wind turbines during different weather conditions	Inter noise New York 2012	Conny Larson, Olof Ohlund
Larsson	Jan-14	Amplitude modulation of sound from wind turbines under various meteorological conditions	Acoustics Society of America	Conny Larsson and Olof Ohlund, Uppsala University, Sweden
Law Commission	31-Mar-10	Simplification of criminal law: public nuisance and outraging public decency	The Law Commission	The Law Commission
Lee	17-Jun-09	An estimation method of the amplitude modulation in wind turbine noise for community response assessment	3rd International meeting on wind turbine noise, Aalborg, Denmark	Seunghoon Lee, Kyutae Kim, Seungmin Lee, Hogeon Kim, Soogab Lee
Lee	08-Jan-13	Numerical modeling of wind turbine aerodynamic noise in the time domain	Acoustics Society of America	Seunghoon Lee, Seungmin Lee, Soogab Leea, Seoul National University, Republic of Korea
Legarth	Sep-07	Auralization and assessments of anoyance from wind turbines	Second international meeting on wind turbine noise, Lyon, France	Soren Vase Legarth
Lenchine	16-Nov-14	Special noise character in noise from wind farms	Inter.noise 2014, Melbourne	Valeri V Lenchine, Johathan Song, Australia
Leventhall	20-Apr-15	On the overlap region between wind turbine infrasound and infrasound from other sources and its relation to criteria	6th International Conference on Wind Turbine Noise, Glasgow	Geoff Leventhall
Lo	29-Jan-15	Report on the committee's inquiry into wind energy	Northern Ireland Assembly	Committee for the environment: A Lo, P Cameron, C Boylan, C Eastwood, S Overend, A Maginness, I McCrea, B McElduff, I Milne, Lord Morrow, P Weir
Lundmark	12-Apr-11	Measurement of swish noise, a new method	4th international meeting on wind turbine noise, Rome	Gunnar Lundmark
Macey	12-Dec-12	Brechfa Forest West windfarm examining authority's report of findings and conclusions and recommendation to the Secretary of State for Energy and Climate Change	Planning Inspectorate	Bob Macey
Madigan	18-Jun-15	Select committee on wind turbines	Commonwealth of Australia	Senators John Madigan, Bob Day, Chris Back, Matthew Canavan, David Leyonhjelm, Anne Urquhart
Madsen	16-Nov-14	Correlation of amplitude modulation to inflow charachteristics	Inter.noise 2014, Melbourne	Helge Aa. Madsen, Franck Bertagnolio, Andreas Fischer, Christian Bak, Denmark
Major	11-Jul-13	Common Barn decision: Land at Church Farm, Rectory Lane, Southoe, Cambridge Ref: APP/H0520/A/12/2188648	The Planning Inspectorate	Philip Major
McCabe	12-Apr-11	Detection and qualification of amplitude modulation in wind turbine noise	4th international meeting on wind turbine noise, Rome	J N McCabe
McKenzie	2005	Infra-sound, low frequency noise & vibration from wind turbines	All Energy 2005	Andy McKenzie HMP Ltd
McKenzie	20-Aug-13	Cotton Farm wind turbines: Phase 1 noise limit compliance assessment	Hayes McKenzie Partnership for BayWa r.e. Ltd	Andy McKenzie
McLaughlin	12-Apr-11	Measurement of amplitude modulation frequency spectrum	4th international meeting on wind turbine noise, Rome	Dave McLaughlin
Moorhouse	Jul-07	Research into aerodynamic modulation of wind turbine noise: Final report	University of Salford for Department for Business & Regulatory Reform	Andy Moorhouse, Malcolm Hayes, Sabine von Hunerbein, Ben Piper, Mag Adams
Moroney	Apr-12	A critique of the IoA treatment of background noise for wind farm noise assessment	Renewable Energy Foundation (REF)	Lee Moroney, John Constable
Moroney	19-Mar-14	The Efficacy of the RenewableUK (RUK) Condition in controlling wind farm amplitude modulation (AM) noise	Renewable Energy Foundation (REF)	Dr Lee Moroney and Dr John Constable

Appendix B2 - INWG AM Study Reference Literature - By Author

Lead Author	Date of Publication	Document Title	Platform	Authors
Mummery	26-May-11	Hulme v Secretary of State for Communities and Local Government and RES Developments [2011] EWCA Civ 638	Court of Appeal	Lord Justice Mummery, Lord Justice Elias, Lord Justice Patten
Neuberger	26-Feb-14	Coventry v Lawrence [2014] 1 AC 822	The Supreme Court	Lords Neuberger, Mance, Clarke, Sumption, Carnwath
NHMRC	Feb-15	NHMRC Statement: Evidence on wind farms and human health	Australian Government, NHMRC	National Health and Medical Research Council
Nobbs	Nov-12	Charachterisation of noise in homes affected by wind turbine noise	Australian Acoustical Society	Benjamin Nobbs, Con J Coolan, Danielle J Mereau
Nussbaum	Apr-84	Some individual differences in human response to infrsound	University of Waterloo and Institute for Aerospace Studies, University of Toronto	DS Nussbaum, S Reinis
Palmer	20-Apr-15	Wind Turbines – A Changed Environment	6th International Conference on Wind Turbine Noise, Glasgow	William K.G. Palmer
Pedersen	Jan-08	Wind turbines - low level noise sources interfering with restoration	IOP Publishing UK	Eja Pederson, Kerstin Persson Waye
Pederson	Dec-04	Perception and annoyance due to wind turbine noise	Acoustical Society of America 2004	Eja Pederson, Kerstin Persson Waye
Pederson	Aug-09	Response to noise from modern wind farms in the Netherlands	Acoustical Society of America 2009	Eja Pederson, Frits van den Berg, Roel Bakker, Jelte Bouma
Perkins	28-Jan-13	Letter to Darlington BC - EAM planning condition	Parsons Brinckerhoff	Richard Perkins
Perkins	1-May-13	A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise	Institute of Acoustics - Noise Working Group	Richard Perkins, Matthew Cand, Robert Davis, Chris Jordan, Malcolm Hayes
Perkins	01-Aug-14	IoA AM NWG options and terms of reference	Institute of Acoustics	Institute of acoustics wind turbine noise working group
Perkins	21-Oct-14	IoA AM NWG terms of reference	Institute of Acoustics	Institute of acoustics wind turbine noise working group
Perkins	21-Oct-14	IoA AM NWG scope of work	Institute of Acoustics	Institute of acoustics wind turbine noise working group
Pike	14-Dec-10	Cotton Farm Appeal decision Ref: APP/H0520/A/09 /2119385	Planning Inspectorate	Martin Pike
Pope	30-Jan-14	Land at Dunsland Cross, Branis Corner, Devon	The Planning Inspectorate	Neil Pope
Probyn	Feb-06	Local development framework, Supplementary planning document: wind power	Huntingdonshire District Council	Richard Probyn
Pykett	11-Dec-09	Appeal decision APP/Q1153/A/06/2017162 Land to the south east of north Tawton and south west Bow	Planning Inspectorate	Andrew Pykett
Rand	21-Jan-15	R Rand letter to S Cooper: Cape Bridgewater study	Rand Acoustics, CO, USA	Robert Rand
RES	08-May-14	Written scheme relating to condition 21 Den Brook wind farm implementation of condition 20	RES	RES
ReUK	16-Dec-13	Wind turbine amplitude modulation: Research to improve understanding as to its cause and effect	RenewableUK	RenewableUK
ReUK	16-Dec-13	Template planning condition on amplitude modulation	RenewableUK	RenewableUK
Rose	Nov-00	Godfrey v Conway County Borough Council	High Court	Lord Justice Rose
Ruffle	13-Aug-13	RES letter: Den Brook wind farm conditions 20 and 21	RES	Rachel Ruffle
Schmidt	04-Dec-14	Health effects related to wind turbine noise exposure: a systematic review	PLOS ONE journal	Jesper Hvass Schmidt, Mads Klokker, Denmark
Sloth	Jul-04	Problems related to the use of the existing noise measurement standards when predicting noise from wind turbines and wind farms	Vestas; Auswea 2004	Erik Sloth, Niels Christian Moller, Ejler Kristensen, Bo Sonderfaard
Smith	Apr-12	Mechanisms of amplitude modulation in wind turbine noise	Acoustics 2012, Nantes	M Smith, AJ Bullmore, MM Cand, R Davis
Smith	29-Apr-14	ISVR memo: Appraisal of the proposed scheme for condition 21	ISVR Consulting	Malcolm Smith, Bob Davis
Søndergaard	16-Nov-14	Noise and low frequency noise from wind turbines	Inter.noise 2014, Melbourne	Bo Søndergaard, Denmark
SoS	13-Feb-14	Turncole Farm Ref: APP/X1545/A/12/2174982	DCLG Appeal decision	Secretary of State
SoS	31-Jul-14	Land at Saxby Wolds, near Barton-upon-Humber, North Lincolnshire Ref: APP/Y2003/A/12/2180725	DCLG Appeal decision	Secretary of State
SoS	12-Sep-14	Decision letter: Clocaenog Forest wind farm	DECC Planning decision	Secretary of State
SoS	25-Sep-14	Land at Wood Farm, Church Lane, Shipdham	DCLG Appeal decision	Secretary of State
SoS	01-Oct-14	Starbold decision: Land between Bishops Itchington, Gaydon and Knightcote Ref: APP/J3720/A/13/2193579	DCLG Appeal decision	Secretary of State
Stephens	Mar-82	Guide to the evaluation of human exposure to noise from large wind turbines	NASA USA	David G Stephens, Kevin P Shepherd, Harvey H Hubbard, Ferdinand W Grosveld
Stigwood	27-Oct-11	The effect of a common wind shear adjustment methodology on the assessment of wind farms when applying ETSU-R-97	MAS Environmental	Mike Stigwood

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Lead Author	Date of Publication	Document Title	Platform	Authors
Stigwood	28-Aug-13	Audible amplitude modulation - results of field measurements and investigations compared to psychoacoustical assessment and theoretical research	5th International Conference on Wind Turbine Noise, Denver, INCE Europe	Mike Stigwood, Sarah Large and Duncan Stigwood
Stigwood	08-Oct-13	Evidence of failure of wind farm guidance to protect well being	Ed Davey meeting 9 Oct 2013	Mike Stigwood
Stigwood	20-Mar-14	The Cotton Farm research project long term study - initial findings and other MAS research	Institute of Acoustics meeting; Newport - Presentation	Mike Stigwood
Stigwood	29-Jul-14	Between Michael Hulme and West Devon Borough Council and RES Developments - Witness Statement	High Court statement	Michael Stigwood
Stigwood	29-Sep-14	Between Michael Hulme and West Devon Borough Council and RES Development – 2nd Witness Statement	High Court statement	Michael Stigwood
Stigwood	16-Nov-14	Initial findings of the Cotton Farm wind farm long term community noise monitoring project	Inter.noise 2014, Melbourne	Mike Stigwood, Duncan Stigwood, Sarah Large of MAS Environmental UK
Stigwood	20-Apr-15	Cotton Farm Wind Farm – Long term community noise monitoring project – 2 years on	6th International Conference on Wind Turbine Noise, Glasgow	Mike Stigwood, Sarah Large, Duncan Stigwood
Styles	12-Apr-11	Monitoring and mitigation of low frequency noise from wind turbines to protect comprehensive test ban seismic monitoring stations	4th international meeting on wind turbine noise, Rome	Styles, Westwood, Toon, Buckingham, Marmo, Carruthers
Sullivan	May-02	Wilkinson v Rossendale Borough Council	High Court	Mr Justice Sullivan
Sumption	04-Mar-15	R (Catt) v Commissioner of Police of the Metropolis and another	The Supreme Court	Lord Neuberger, Lady Hale, Lord Mance, Lord Sumption, Lord Toulson
Supperstone	07-Nov-14	High Court judgement between West Devon Borough Council and Hulme	High Court	Mr Justice Supperstone
Swinbanks	May-13	Assessment of RES revised condition 20 for evaluating excessive amplitude modulation	MAS Research Ltd	MA Swinbanks
Swinbanks	20-Apr-15	Direct Experience of Low Frequency Noise and Infrasound within a Windfarm Community	6th International Conference on Wind Turbine Noise, Glasgow	M.A.Swinbanks
Tachibana	16-Nov-14	Outcome of systematic research on wind turbine noise in Japan	Inter.noise 2014, Melbourne	Hideki Tachibana. Japan
Tachibana	28-Aug-13	Assessment of wind turbine noise in immission areas	5th International Conference on Wind Turbine Noise, Denver, INCE Europe	Hideki Tachibana, Hiroo Yano, Chiba Institute of Technology and Akinori Fukushima NEWS Environmental Design Inc, Japan
Thorne	Jun-12	The perception and effect of wind farm noise at two Victorian wind farms	Noise Measurement Services QLD Australia	Bob Thorne
Thorne	16-Nov-14	The relevance of the precautionary principle to wind farm noise planning	Inter.noise 2014, Melbourne	Bob Thorne, Australia
Unwin	Jul-13	Wind farm noise assessments: ETSU-R-97 and the three legged stool	Science in parliament - Summer 2013	David Unwin and Richard Cox
Unwin	09-Oct-13	A summary of the Bad Science behind the wind turbine noise guidelines	Ed Davey meeting 9 Oct 2013	David Unwin and Richard Cox
van den Berg	22-Sep-03	Effects of the wind profile at night on wind turbine sound	Journal of sound and vibration	G.P. van den Berg
Vanderkooy	02-Oct-14	Measuring wind turbine coherent infrasound	University of Waterloo	John, Vanderkooy, Richard Mann, Canada
von Hünerbein	27-Sep-13	Advice on monitoring of wind turbine noise impact	University of Salford	Sabine von Hünerbein, Robert Oldfield, Andy Moorhouse
Walker	24-Dec-12	A Cooperative Measurement Survey and Analysis of Low Frequency and Infrasound at the Shirley Wind Farm in Brown County, Wisconsin	Clean Wisconsin for Wisconsin Public Service Commission	Channel Islands Acoustics, Camarillo, CA Principal: Dr. Bruce Walker; Hessler Associates, Inc., Haymarket, VA Principals: George F. and David M. Hessler: Rand Acoustics, Brunswick, ME Principal: Robert Rand: Schomer and Associates, Inc., Champaign, IL Principal: Dr. Paul Schomer
WDBC	21-May-14	Discharge of Conditions Decision - Land adjacent to Den Brook	West Devon Borough Council	
WHO	2009	Night noise guidelines for Europe	World Health Organisation	WHO