Independent Noise Working Group

Wind Turbine Amplitude Modulation &
Planning Control Study

Work Package 10 - Study Summary

Two Decades of Deception

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Political Sponsor:

Chris Heaton-Harris MP

Study available at: http://www.heatonharris.com/reports-publications

Community Sponsor:

National Alliance of Wind Farm Action Groups

Study Objective:

To protect communities and wind turbine neighbours from wind turbine noise amplitude modulation

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Work Package	Work Package Subject	Lead Author
1	Fundamentals of AM	John Yelland
2.1	Literature review	Richard Cox
2.2	AM Evidence review	Sarah Large
3.1	LPA Survey	Trevor Sherman
3.2	Health effects	Chris Hanning
4	Den Brook	Mike Hulme
5	Towards a draft AM condition	Sarah Large
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Table 1: INWG AM Study Work Package Division of Work

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Abbreviations

AMWG	IoA Amplitude Modulation Noise Working Group
AM	Amplitude Modulation
BS4142	Standard for rating and assessing industrial and commercial sound
CoA	Court of Appeal
DAM	The Japanese Depth of Amplitude Modulation D_{AM} methodology
DBJRG	Den Brook Judicial Review Group
DECC	UK government Department of Energy and Climate Change
DTI	The former government Department of Trade and Industry
EAM	Excessive/Excess Amplitude Modulation
EHO	Environmental Health Officer
ETSU	ETSU-R-97 The Assessment & Rating of Noise from Wind Farms (published by the Energy Technical Support Unit)
FFT	Fast Fourier Transform
GPG	IoA Good Practice Guide to the Application of ETSU-R-97
GTE	Greater Than Expected amplitude modulation
INWG	Independent Noise Working Group
IoA	Institute of Acoustics (UK)
ISVR	Institute of Sound and Vibration
LFN	Low frequency noise
LPA	Local Planning Authority
NAWAG	National Alliance of Wind farm Action Groups
NASA	National Aeronautics and Space Administration of the USA
NPPF	National Planning Policy Framework
NWG	Institute of Acoustics Noise Working Group
RES	Renewable Energy Systems (wind power developer)
ReUK	RenewableUK, the UK wind Industry trade association
SN	Statutory Nuisance
WHO	World Health Organisation
WP	INWG Work Package
WTN	Wind Turbine Noise

1. Executive Summary

Noise complaints from wind turbines are primarily related to a phenomenon known as Amplitude Modulation (AM). This is not the commonly observed 'swish' noise experienced in relatively close proximity (near field) to wind turbines but a sometimes relentless 'whoomp', 'thump' or 'beating' type noise that is experienced considerably further away (far field) typically at neighbouring households. It is noise character rather than loudness that tends to make wind turbine noise AM most intrusive.

The announcement by the Institute of Acoustics (IoA) on 1 August 2014 that it was setting up an amplitude modulation (AM) working group (AMWG) to conduct a study into wind turbine noise amplitude modulation (AM) was met with scepticism and concern by many people who have experienced problems with wind turbine noise.

In response the Independent Noise Working Group (INWG) was formed during late August 2014 by a diverse group of experts and non-experts having no connections with the wind industry supply chain. The objective of the INWG being to conduct an independent study into AM that can credibly challenge the findings of the IoA sponsored study. This report summarises the individual INWG work package (WP) reports from the study carried out over a period of one year.

Key Findings

- There is irrefutable evidence presented at WP2.1 and WP2.2 supported by the survey results presented at WP3.1 to show that excessive amplitude modulation (EAM) is a frequent occurrence potentially affecting neighbourhoods of all industrial scale wind turbines, often for long periods of time and most often during the night time. Wind industry claims to the contrary are thoroughly discredited.

- The Local Planning Authority (LPA) survey results presented at WP3.1 shows that not only are incidents of EAM more frequent than the wind industry hitherto has admitted, the progress in resolving them is inconclusive and there are inconsistent approaches to dealing with it across the country. None of the LPAs described a working mitigation for EAM other than curtailment. LPA's in the survey call for guidance on measuring and testing for EAM as well as nationally agreed standards that are consistently applied and provide effective mitigations for it. There is also anecdotal evidence of a 'silent majority' who suffer in silence without knowing how to complain, not wanting to get *'involved*' or because of a fear of adverse implications; if, for example, they had to disclose any complaint should they wish to sell their house.

- It is abundantly clear from the evidence examined at WP3.2 that wind turbine noise adversely affects sleep and health at the setback distances and noise levels permitted by the ETSU[6] noise guidelines. There is particular concern for the health of children exposed to excessive wind turbine noise. The inadequate consideration of EAM is a major factor in the failure of ETSU to protect the human population.

- There is irrefutable evidence presented at WP3.2 and WP2.1 to discredit wind industry and previous government claims that ETSU provides a robust noise assessment methodology. This conclusion is supported by the recent Northern Ireland Assembly report[14], January 2015, into wind energy where it recommends, "*review the use of the ETSU-R-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 wind industry claims that an AM planning condition is not necessary and that the legal remedy of statutory nuisance provides adequate protection are thoroughly discredited by the evidence presented in WP6.1, WP3.1 and WP6.2. It is shown that without an AM planning condition there is no effective remedy for wind farm neighbours against excess noise except, for example, to take civil or statutory nuisance action. However, nuisance action typically requires substantial financial resources, is a prolonged process and is at risk of being circumvented in a number of ways. In general therefore there is not a practical or affordable remedy for members of the public in the absence of planning controls.

- The Private Members Bill in Parliament introduced by David Davis MP during July 2015 highlighted the need for wind farm operators to hold public liability insurance for any nuisance including noise nuisance they may cause. This Bill highlighted the widespread practice by developers of setting up a shell company with very limited assets to operate the wind farm. This way the parent company may be able to divest itself of any legal responsibility for any nuisance it may cause, further complicating any legal remedy.

- The need to monitor wind farm noise to ensure ETSU compliance and provide evidence to pursue noise complaints has been made clear at WP6.1 and WP6.2. Currently there is no requirement for wind turbine operators to monitor noise or prove compliance with ETSU noise limits. The requirement for long term monitoring is also a recommendation of the Northern Ireland Assembly report[14], January 2015: "*the Department should bear responsibility for ensuring that arrangements be put in place for on-going long-term monitoring of wind turbine noise*".

- WP4 details the enormous effort Renewable Energy Systems (RES), the wind farm developer for the Den Brook wind farm has gone to over the last 8 years to ensure first that an AM planning condition is not applied, then to have the applied planning condition removed, and finally to have it sufficiently weakened presumably to ensure it prioritises operation of the wind farm rather than provides the intended protection against EAM. Although fronted by RES, the Den Brook wind farm proposal became a national test case for the wind industry to do whatever was necessary to prevent the Den Brook AM condition becoming 'the standard' for planning approvals.

- There is irrefutable evidence presented at WP1 and WP2.1 to show that low frequency noise (LFN) is a significant and relevant component of wind turbine noise and EAM. This evidence thoroughly discredits the wind industry claims supported by

the main IoA NWG acousticians that LFN is not relevant to wind turbine noise assessment.

- WP1 explores aspects of AM and EAM relating to their definition, causes and measurement. It shows that stall at blade zenith (12 o'clock) can explain only a small part of the EAM values observed. WP1 explains the significance of mechanical resonances of towers and blades in generating LFN, an integral component of EAM and also challenges the scientific justification for wind industry measurement practices of actively filtering out noise data below 100Hz. This being an extraordinary effort to remove something which, it is claimed, does not exist. WP1 also challenges the continued wind industry resistance to measuring noise indoors where noise nuisance is normally experienced.

- Five methods for AM control were tested as part of WP5:
  1. The ReUK template planning condition was found to be significantly flawed in a number of respects including imprecise condition wording, an inability to filter extraneous noise, and false negatives. It is concluded to be unfit for purpose.
  2. A methodology proposed by RES for the Den Brook case, like the RUK method, is flawed in a number of respects including imprecise wording, an inability to filter extraneous noise, false positives and also false negatives. The values of AM that are derived by the RES method do not appear to relate to the A weighted modulation depth or subjective impression.
  3. The original Den Brook EAM condition was found to work well with the data from all six sites tested and successfully identified EAM without being influenced by extraneous noise. Much of the success depends on its interpretation and implementation. Of note, it is implicit that it should not be used as a simple trigger value and that an assessment of frequency and duration must be made by the assessor. This is consistent with other UK planning noise controls and guidance on enforcement policy.
  4. The Japanese DAM rating method is not a condition but a rating method. Though influenced by extraneous noise, it works well to identify periods of EAM and periods of borderline AM.
  5. BS4142[2] has previously been dismissed, both in ETSU and by others, as an inappropriate means of control for wind farm noise. The issues raised to support this argument have been examined and found inapplicable to the new version of the standard[3] (2014). BS4142:2014 was found to work very well for assessment and control of cumulative wind farm noise and character impact, subject to the need for an additional mechanism where there is significant LFN which it does not address. BS4142 is advantageous over separate EAM assessment methods as it assesses noise level and character simultaneously and in context with the character of the area.

- All three of the methodologies for assessing AM being proposed by the IoA AMWG in their 2015 consultation document[11] have been shown to be significantly flawed during preliminary testing as part of WP7. These test results indicate that all three methods present significant problems where they do not reflect or mirror impact.

- The wind industry strategy of obfuscation capitalising on the IoA's trusted position as a scientific institution is discussed in WP8 and WP1. We find that the IoA through its wind turbine noise working groups has consistently operated for the benefit of the wind industry to the detriment of local communities. These activities arguably contravene both the IoA Code of Ethics and that of the Engineering Council. The effect has been to both obfuscate and hide problems related to wind turbine noise assessment from government and from the Planning Inspectorate.

Summary of Recommendations to Government Ministers

- Based on the findings at WP2.1, WP3.2 and WP5, a first step towards protecting communities from wind turbine noise amplitude modulation would be to replace the use of ETSU[6] as recommended by the Northern Ireland Assembly report[14], January 2015. ETSU should be replaced with a procedure based on the principles of BS4142: 2014. This will bring wind turbine noise assessment into line with other industrial noise controls. New guidance of this type should be formulated in a Code of Practice that sets out a BS4142: 2014 type methodology that reflects noise character and relates impact to the actual background noise level and not an artificial average.

- Based on the findings in WP6.1, experience at Cotton Farm described at WP6.2 and elsewhere it is recommended that an effective AM planning condition should be part of every wind turbine planning approval unless there is clear evidence it is not needed. It is recommended that:

    1. Where wind turbine noise level and character require simultaneous assessment then BS4142:2014 should be used. The rated wind farm noise level should not exceed +10dB above the background noise level.
    2. Where only wind turbine noise AM requires assessment then a Den Brook type planning condition should be used.

- Continuous noise monitoring of wind turbines should become a standard planning condition for all wind turbine planning approvals as recommended in the Northern Ireland Assembly report[14], January 2015. This should be funded by the wind turbine operator but controlled by the LPA with the noise data made openly available to ensure transparency. The Cotton Farm community noise monitor described at WP9 provides an example of how this can be achieved.

- There is a need to 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 as recommended in the Northern Ireland Assembly report[14], January 2015.

- The government should deal decisively with the ethical issues surrounding the Institute of Acoustics wind turbine noise working groups described in WP8. Government departments should disassociate themselves from the IoA until conflict of interest and ethics issues are resolved and full transparency is restored.

2. Preamble

During the planning process for wind turbine developments the main arguments presented against them by local residents, or '*wind turbine neighbours*' as they are often referred to, concern issues to which they can easily relate. These usually include the visual effects on the landscape and on the setting of heritage sites. However, once the turbines are built and operating there is growing evidence that noise becomes the main subject for ongoing complaints.

Noise assessment is a highly technical subject, beyond the comprehension of most wind turbine neighbours. Additionally, many environmental health officers (EHO's) employed by local planning authorities (LPA's) are insufficiently knowledgeable regarding acoustics to properly assess wind turbine noise impact assessments submitted by developers in planning applications or to effectively pursue noise nuisance complaints.

The specialist acousticians employed by wind turbine developers are in most cases able to argue successfully against local opposition or EHO challenge regarding potential noise impacts. As a result few if any wind turbine planning decisions made either by LPAs or by planning inspectors at appeal have been refused with the potential noise impact being given as a reason for refusal.

As wind power deployment has increased across the UK over the last two decades, the wind power industry has down played the issue of noise impact from wind turbines as they have simultaneously increased the size of the turbines and reduced the separation distances between turbines and residential properties. The principal tool used during this period to justify noise assessments and development plans has been the ETSU[6] noise guidelines published by the Government during 1996 specifically for wind turbines.

By the 1990s it will have become apparent to the wind industry that the existing BS4142 noise guidance and limits as applied to most industrial noise sources could have become a serious constraint on the deployment of onshore wind power. Whereas the visual impact of turbines on the landscape and on heritage assets would always be subjective, noise assessments would be a simple pass or fail based on the assessment methodology and noise limits. As a result, the ETSU guidelines were developed by a joint wind industry and government working party where the protection from noise was relaxed so as not to unduly constrain the deployment of wind power. It is significant that every other form of industrial development affecting residential areas has to conform to BS4142 or a similarly based type of control, (For example minerals developments are subject to limits related to the background noise with no lower threshold). Additionally, ETSU is the only noise guidance the author is aware of that allow higher noise levels at night than during the day.

Despite a dramatic increase in the size of turbines now being deployed and mounting evidence that ETSU[6] is '*not fit for purpose*', with government support the wind industry has continued to resist any review of these guidelines and associated noise limits. It is therefore no surprise to many that there are now a much greater number of noise complaints arising from wind turbines than ever anticipated.

The main feature of these noise complaints is the highly intrusive 'whoosh' or 'thumping' noise characteristic known as amplitude modulation (AM), not the absolute decibel level or perceived loudness of the noise. For many years the wind industry has denied that excessive/excess/enhanced/'other' AM (EAM) is anything other than a rare and infrequent occurrence affecting only a very small number of wind turbines. On the contrary, it is widespread and pernicious.

In addition the same industry has consistently denied any ill health effects from wind turbine noise or the presence of harmful levels of low frequency noise. However, the overwhelming evidence that has emerged over the last few years has shown these denials to be proved wrong and misleading.

3. INWG Formation and Study Methodology

On 1 Aug 2014 the Institute of Acoustics (IoA) announced, Perkins[19] Aug 2014, that it was setting up an amplitude modulation (AM) working group (AMWG) as a sub-group of its main wind turbine noise working group (NWG). The announcement stated; '*It aims to review methods to quantify and assess AM in wind turbine noise. This review will include: the AM work funded by R–UK; the "Den Brook" condition and other historic and emerging research. A further aim is to progress a preferred metric from those considered and a preferred methodology for assessing AM.*'

However, further reading of the IoA AMWG terms of reference and options documents indicated that their AM study would be narrowly defined with limited scope to address the real problems of AM at both existing and new wind turbine sites. There was also a well-grounded fear amongst resident groups that this AM study would be a repeat of the IoA ETSU Good Practice Guide (GPG) flawed consultation, Perkins[18] 2013 and the earlier introduction of the wind shear adjustment methodology, Acoustics Bulletin[4], Bullmore March 2009, known as the 'Article Method' carried out by the IoA NWG during 2012 and 2013.

During the previous IoA GPG consultation there was a strong bias evident towards the commercial interests of the wind industry, and the end result was to allow even higher noise levels to be imposed on local residents and closer separation distances between turbines and homes. Correction for wind shear should in theory have led to increased setbacks as receptor predicted noise levels should have been greater, especially during the night. In practice, setbacks remained unchanged or decreased. MAS, Stigwood[27] Oct 2011, has investigated the method and concluded: "*Use of the article method provides a worse situation for local communities as it is more likely to result in adverse noise impact once the turbine development is built despite there being no indication of it at the planning stage and little means for reducing or resolving noise impact post-development*". The Article Method was also investigated by the Renewable Energy Foundation (REF), Moroney[16] April 2012 that also came to a similar conclusion.

As a result of these concerns, it was widely anticipated at that time that the IoA AMWG would recommend an ineffective AM planning condition, most likely based on the RenewableUK (ReUK, the renewable energy trade association) AM condition, ReUK[24] 2013 or the RES (wind power developer) proposal, RES[25] May 2014, to replace the Den Brook AM planning condition. Both of these planning conditions have been shown to be inadequate and would fail to protect communities from AM noise, Moroney[17] Mar 2014. The recently released IoA AMWG consultation document, Irvine[11] April 2015, now shows that these concerns were fully justified,

Consequently, there was a realisation by communities across the country that are affected, or have the potential to be affected by wind turbine noise AM that urgent action was required to counter the strategy being implemented by the wind power industry and its acoustic consultants via the IoA. In response to requests from Chris Heaton-Harris MP (Con., Daventry) and the National Alliance of Wind farm Action Groups

(NAWAG), an independent and multi-discipline noise working group was established to review the wind turbine noise phenomena known as amplitude modulation.

The Independent Noise Working Group (INWG) was formed during August 2014 and released its terms of reference document on 30 October 2014. The principal objective of the study was to protect communities and wind turbine neighbours from amplitude modulation noise. Completion of the study and release of its final reports was targeted for spring 2015. To ensure the study progressed to schedule a weekly team conference call was held throughout the study period. Additionally, full day group meetings were held on 21 August 2014 and 29 January 2015.

The INWG consists of a diverse group of concerned individuals from across the country. The group takes an independent and holistic view of the current wind turbine noise problem avoiding the constrained approach adopted by the IoA AMWG. The INWG are a multi-disciplinary team fully independent of the wind industry supply chain with expertise or access to expertise including:

- Acoustics
- Physics
- Meteorology
- Statistics and data analysis
- Environmental health (LPA)
- Health and sleep
- Legal and planning

The INWG steering committee consists of:

- Richard Cowen: Solicitor specialising in planning then criminal law. Has been actively involved with NAWAG on legal issues including noise and the Den Brook judgment.
- Richard Cox: (Chair) Electrical engineer with a career in power generation industry.
- Anne Crowther BSc ACA: Chartered Accountant, former venture capitalist and consultant (finance and management accountant), now business owner.
- Bev Gray: Company Director (Ret'd) Battery back-up DC power supplies for electricity generation and distribution companies, rail, communication and utility industries.
- Melvin Grosvenor: Consultant supporting rural communities with wind turbine proposals. Senior Management & Regulated Finance experience.
- Mike Hulme: Co-founder of the Den Brook Judicial Review group which along with professional, scientific and legal expertise achieved the unprecedented Den Book AM noise conditions.
- Trevor Sherman: An international management consultant specialising in senior executive coaching and leadership development training.
- John Yelland MA DPhil (Oxon) MinstP FIET AMASA MIOA: A professional physicist and engineer with experience in acoustics spanning over 40 years.

The INWG steering committee has been assisted by other specialists including:

- Mike Barnard - Consultant advising resident groups on how to produce evidential based objections to wind turbine applications. Instructed by over 40 groups and has presented expert evidence, including on noise, at many Public Inquiries.
- Doug Bingham (Ret'd) ex MIOA, Senior Acoustic Consultant AVT, Director, PAX Acoustic Engineering, many years' experience, conventional power station environmental noise.
- Dr Christopher Hanning. BSc, MRCS. MRCP, MB, BS. FRCA, MD. Honorary Consultant in Sleep Medicine, University Hospitals of Leicester
- W Les Huson BSc(Hons) MSc CPhys MInstP MIOA MAAS MEIANZ: A professional acoustical consultant and scientist with 36 years' experience including many years in the measurement and assessment of wind farm sound emissions.
- Sarah Large MIOA: MAS Environmental - Acoustician
- Mike Stigwood MIOA: Former EHO and director of MAS Environmental
- David Unwin: Emeritus Professor in Geography at Birkbeck, University of London. He has professional expertise in the statistical analysis of environmental data and meteorology.

The target customers for the study report are:

- Department of Communities & Local Government (DCLG). This will also include the Planning Inspectorate and local planning authorities (LPA's).
- Department of Energy and Climate Change (DECC)
- Department for Environment, Food and Rural Affairs (DEFRA)
- Department of Health

The study was organised into discrete work packages with each work packages assigned to the most appropriate INWG team member as shown at Table 1. Each work package was reviewed by group members and where relevant by third party reviewers. The key findings of the individual work packages were then consolidated into this summary report designated INWG WP10.

The study's findings and recommendations have now been presented to Government ministers. On 7 July 2015 presentations were made to government officials and ministers from DCLG, DEFRA and the Department of Health. On 13 October 2015 a presentation was made to the Minister of State for Energy and Climate Change and officials at DECC. The INWG highlighted the recent decision by DECC to award the contract for an '*independent study into AM*' to WSP/Parsons Brinckerhoff. This allows Richard Perkins as Technical Director of the Acoustics, Noise & Vibration Team at WSP/Parsons Brinckerhoff and also as a senior member of the IoA Council and until recently Chairman of the IoA NWG in a position to orchestrate and influence both AM studies. The presentations were well received by ministers. Additionally, the study findings and recommendations were presented at the Institute of Acoustics annual conference held at Harrogate on 15 October 2015.

4. Study Investigation - Work Package Findings

The INWG study has focused on six key areas when investigating wind turbine noise AM:

A. How people are affected by wind turbine noise including AM. To examine this we surveyed Local Planning Authorities (LPA's) to determine the extent of the problem. We also investigated the evidence supporting claims that there are possible effects on human health and associated sleep deprivation when living close to wind turbines;

B. The legal position and the remedies available in the event of wind turbine noise nuisance complaints;

C. The science behind AM, including a review of the available literature and evidence of AM in order to build up a picture of the current state of knowledge regarding wind turbine noise and amplitude modulation;

D. Developing control methodologies for limiting AM to acceptable levels that can be applied as a planning condition when wind turbine developments are being considered or that might also be applied retrospectively;

E. How individuals and communities are responding to the threat, real or perceived from wind turbines noise;

F. The response by the wind industry and its consultants in defending the status quo regarding wind turbine noise and particularly the actions of the Institute of Acoustics noise working groups in response to the mounting evidence surrounding AM.

The purpose of these INWG investigations was to determine primarily the science and evidence behind wind turbine noise AM and hence its control. From this assessment then to arrive at a set of recommendations that can be applied to ensure people living near wind turbines can be reasonably protected from noise nuisance and adverse health effects. This section summarises the contents of the individual work packages.

A. How AM affects people, is there a problem?

Complaints regarding wind turbine noise have generally been about the audible modulating characteristic of the noise often described as a 'whoosh' or 'thumping' and only rarely to the loudness of the noise. Complaints have also included 'sensation' as one of the annoying aspects. Noise annoyance has also been reported as most likely to occur during the night time when attempting to sleep.

Acousticians familiar with wind turbines have referred to this noise characteristic as amplitude modulation (AM). Wind turbine noise is normally characterised by a low level of AM that is often only audible close to the turbines and declines rapidly with distance from them. However, there is now evidence that for often significant periods of time and

especially during the night time, this noise can become much more noticeable and affects people living further away, often at 1,500m or more from the turbines. This more intrusive and annoying noise characteristic has since been described by various acousticians as excessive/excess amplitude modulation, (EAM), 'Other' amplitude modulation (OAM), and greater than expected (GTE) amplitude modulation.

Until very recently the wind industry and its acousticians have claimed that AM of sufficient magnitude to cause annoyance is extremely rare and at those few sites where it has occurred it occurs very infrequently. They also claimed that the cause of any EAM was unknown and that it was not possible to predict its occurrence. The now discredited report by Moorhouse[15], 2007, University of Salford known as the 'Salford Report' concluded: "*The low incidence of AM and the low numbers of people adversely affected make it difficult to justify further research funding*". However, since that study there have been an increasing number of reported cases of wind turbine noise nuisance and finally an admission by the wind industry in their study into EAM, RenewableUK[23] Dec 2013 that the AM problem is now, "*too large to ignore*". In contrast during the same period Japanese acousticians have described AM as a "*common occurrence*" causing "*serious annoyance*".

Through two work packages WP3.1 and WP3.2 we examine the evidence relating to the impact of wind turbine noise, whether it is a rare and infrequent occurrence as claimed by the wind industry and the health implications.

Work package 3.1 – Local Planning Authority Survey

At WP3.1 Trevor Sherman analyses responses from a survey of local planning authorities (LPAs) to determine the extent of the wind turbine noise problem across England. The objectives for INWG WP 3.1 were defined as:

- *To quantify the noise and excess amplitude modulation (EAM) complaints received by LPAs in the last five years;*
- *To establish how LPAs investigate and mitigate for noise and EAM nuisance and through this determine the guidance they need;*
- *To assess the frustrations and ideas coming forward from LPAs and through this determine a way forward.*

The survey was launched by Chris Heaton-Harris MP who wrote to the Chief Executives of 265 LPAs in England advising them of the public's concerns about wind turbine noise, bringing to their attention the debate on EAM and asking them to report the incidence of noise and EAM complaints in their authority. The letter included three questions:

1 Have you received noise complaints?
2 Have you received AM complaints? and
3 If yes, how do you deal with them?

The survey results were analysed and summarised below:

Of the 203 responses to the survey 54 LPAs have received complaints about noise from industrial wind turbines. This should not be interpreted as 27% of wind farms giving rise to noise complaints as many of the LPAs that reported no complaints may well not have any operating wind farms in close proximity to housing. Significantly 47% of LPAs with industrial wind turbines in their districts reported receiving noise complaints.

Of the 54 LPAs, 17 have also investigated complaints about EAM. Over 600 individual complaints were reported as being received, with the majority being in the five year period 2010-14. The main clusters of complaints are in the East of England, East and West Midlands, North West and South West. There are less in the South East, with just one in Yorkshire and the Humber and one in the North East.

There is a high level of awareness amongst LPAs of the issues and debate on EAM. LPA executives keep themselves informed through public sources. They recognise that EAM in industrial wind turbines is as yet an unresolved issue but appear to act in ignorance of the judgement of the Court of Appeal in the Den Brook case, (see WP4 and WP6.1). Some LPAs show strong confidence in ETSU[6] and its companion Good Practice Guide[18] (GPG). Others challenge its validity and are seeking a more robust way to deal with EAM at all stages in the application and development process. They are calling for objective science-based guidance on measuring and testing for EAM as well as nationally agreed standards that are consistently applied and proven mitigations for EAM. There are many frustrations with the current arrangements.

Not only are reported incidents of EAM more frequent than the wind industry hitherto has claimed, the progress in resolving them is inconclusive and there are inconsistent approaches to dealing with it across the country. Some LPAs have agreed curtailment of operation with the wind turbine operators while investigations continue; others have only proceeded with investigations. None of the LPAs described a working mitigation for EAM other than curtailment. LPA's in the survey call for guidance on measuring and testing for EAM as well as nationally agreed standards that are consistently applied and provide effective mitigations for it. Some LPAs have taken a proactive approach on EAM by investing time and effort with developers at the pre-application stage.

A significant part of the public debate on industrial wind turbine noise generally, and on EAM specifically, is about protecting the health and well-being of wind farm neighbours, but there were no mentions of this by the respondents. There is an indication that wind farm neighbours who are well organised in local groups and with professional support can make better progress with their complaints than others. On the other hand, scatter gun complaining may not be effective.

There is also anecdotal evidence of a 'silent majority' who suffer in silence without knowing how to complain, or because of a fear of adverse implications, if, for example, they had to disclose any complaint should they wish to sell their house. For communities, a barrier to complaining might be the fear of adversely affecting community funding from wind turbine

operators. This may lead to the conclusion that a 'community charter' would be valuable for all sides.

In summary the wind industry's claim that EAM is rare and infrequent is shown to be wrong by the survey evidence presented in WP3.1.

Work package 3.2 – Health Effects

At WP3.2 Dr Christopher Hanning summarizes the effects of Excessive Amplitude Modulation (EAM) on people living close to wind turbines including annoyance, sleep disturbance and health effects through a review of the available health related literature. His report discusses ETSU's ability to protect noise sensitive receptors from sleep disruption and therefore harm to their health and in this context to consider the contribution of EAM.

Excessive noise is harmful to human health, particularly through adverse effects on sleep (WHO 2011)[28]. Regulation of wind turbine noise is recognised as necessary to prevent adverse effects on the human population. The UK guidance ETSU-R-97 (ETSU) states in its executive summary "*This document describes a framework for the measurement of wind farm noise and gives indicative noise levels* ***thought*** *(*Dr Hanning's emphasis*) to offer a reasonable degree of protection to wind farm neighbours, without placing unreasonable restrictions on wind farm development or adding unduly to the costs and administrative burdens on wind farm developers or local authorities*". It is reasonable to infer that the authors had no certainty that their recommendations were adequate nor were they solely concerned with protecting the sleep and health of wind farm neighbours and therefore moderated their recommendations accordingly.

The acoustical shortcomings of ETSU have been discussed in detail elsewhere (Bowdler[1] 2005 and Cox, Unwin, Sherman[5] 2012). Despite the growing evidence of harm and the authors' caveats, no substantive review of the fundamental principles of ETSU has been conducted nor has any substantive research been conducted in the UK. The Hayes McKenzie Partnership conducted a small study on behalf of the government, HMP for DTI[8], 2006 as a result of which they recommended reductions in night time noise levels. These recommendations were removed from the final report, only emerging after the earlier drafts were obtained using Freedom of Information requests (DTI 2006).

It is abundantly clear from the evidence examined at WP3.2 that wind turbine noise adversely effects sleep and health at the setback distances and noise levels permitted by ETSU. There is no reliable evidence that wind turbines are safe at these distances and noise levels, not a single study. In contrast there is an increasing volume of studies and evidence outlined to the contrary.

There is particular concern for the health of children exposed to excessive wind turbine noise. The inadequate consideration of EAM is a major factor in the failure of ETSU to protect the human population.

With the ETSU noise assessment methodology, allowed minimum setback distances for human habitation from modern 2.5-3MW turbines are in the region of 500m. Most published research has used setback distance rather than measured or calculated noise levels, not least because of the expense of measurement and the inaccuracies of calculation. A review of the literature shows that the average safe recommended minimum setback distance is approximately 2km. This is in contrast to the 500m or less currently being allowed for new large scale industrial wind power developments.

The evidence presented in WP3.2 shows that wind industry claims that there are no adverse health effects from wind turbine sound emissions and that ETSU provides a robust noise assessment methodology have no scientific basis and are misleading at best.

B. Existing Legal Remedies

The apparent difficulty for local residents to obtain a satisfactory resolution to wind turbine noise complaints is highlighted at WP3.1 and justified a review of the legal situation and remedies available. We find that with very few exceptions wind turbine developments have not had a planning condition to control AM imposed as part of the original planning permission. As a result wind turbine neighbours are left exposed without effective protection in the event of noise AM complaints.

Work package 6.1 – Legal Remedies

At WP6.1 Richard Cowen considers the legal issues surrounding wind turbine noise nuisance. The objectives of WP6.1 being:

1. To assess the legality of the Den Brook Condition relating to EAM following the judgement of the Court of Appeal;
2. To assess the legal appropriateness of other remedies such as Statutory and Private Nuisance that have been recommended since that judgement or may be available to persons affected by EAM;
3. To recommend the most appropriate course of action that will provide legal protection to residents hosting wind farms should EAM occur.

Objective 1 has been met by a complete review of the situation regarding a planning condition to control EAM since the judgment of the Court of Appeal in the Den Brook case. The advantage of this procedure is that a suitably worded condition strikes at the heart of this problem. However, it also has to be acknowledged that there are procedures to be followed and these can take time. The question is whether this is the most effective way of addressing the problem.

Objective 2 has been addressed through discussion of other remedies available under the Town & Country Planning Act if a planning condition is in place, namely the power to serve a stop notice, to serve a breach of condition notice or to seek an injunction. Of these, a Stop Notice runs the risk of substantial compensation being paid and a Breach of Condition notice does not have real “teeth”. However, if an injunction can be obtained, this is likely to

be a powerful tool. It may be expensive and perhaps risky to obtain, but if the Court should grant one, it should quickly resolve the problem. It cannot be considered costlier or more protracted that alternative approaches such as Statutory Nuisance.

In answering Objectives 2 and 3, other potential remedies have been considered. Some of these such as Statutory Nuisance have been actively advocated by the wind Industry and supported by Planning Inspectors. Evidence however suggests that an Abatement Notice is not an effective control to protect nearby residents from EAM. Others such as private nuisance and similar legal actions have been considered but these place too much risk and burden on residents for a problem not of their making with likely long term adverse financial implications. They may however be the only remedies available if a suitably worded condition is not imposed in the Planning Certificate. The inability of the alternative procedures to bring about effective control and exemption from those procedures in some cases may indicate action under the European Convention of Human Rights (ECHR) is the only realistic option. This is also a complex, potentially lengthy and dauntingly uncertain process.

A final purpose of WP6.1 is to recommend the most effective course of action to protect residents if there is a potential problem caused by EAM from a wind farm or turbine. While no course of action may provide the speedy remedy that is sought, it is firmly recommended that the adoption of a modified Den Brook type condition is appropriate, as the available actions that can be taken if there is such a condition are the most direct and reliable, and go to the heart of the issue. It is considered that this course of action is available now, has been endorsed by the Courts and is fully justified under the provisions of the National Planning Policy Framework (NPPF) relating to planning conditions. As a result of the doctrine of judicial precedent, it is suggested that decision makers are not justified in ignoring and saying it has no effect. There is also no basis to conclude the Den Brook Condition fails planning condition tests and cannot be suitably enforced as it presents no more hurdles than any other noise level condition which warrants removal / exclusion of extraneous noise producing activity.

All other forms of action, including those adopted by Planning Inspectors in the past, do not address this problem directly and can be subject to considerable periods of delay and likely lack any real protection. It is accepted that in future a suitably worded alternative condition may need to be drafted. While the Den Brook Condition has been accepted, with the passage of time this may need to be adapted. However, once such a condition is agreed, it is recommended that it is imposed in every planning permission for a wind turbine unless there are clear reasons to show that it is unnecessary.

This form of action would help to provide reasonable protection for affected residents. It would in turn comply with their Human Rights provisions particularly under Article 8 of the European Convention of Human Rights. Even if the Human Rights Act is repealed by this government, consideration will still have to be given to protecting citizens in these circumstances and it is represented that such a condition would still be relevant even if the law is changed.

It is further suggested that such a planning condition should be strengthened by the imposition of a monitoring condition such as that recommended by the Northern Ireland Assembly Report[14] 2015. Consideration also needs to be given to what happens if such monitoring does find a problem.

Wind industry claims that an AM planning condition is not necessary and that the legal remedy of Statutory Nuisance provides adequate protection are shown to be wrong and misleading at best by the evidence presented in WP6.1.

In his supplementary paper WP6.1A, Richard Cowen considers the need for wind farm operators to obtain public liability insurance for any nuisance including noise nuisance they may cause to nearby residents. This need for public liability insurance being highlighted during the July 2015 Private Members Bill in Parliament introduced by David Davis MP.

In introducing the Bill, David Davis MP referred to a problem one of his constituents had with noise from a local wind farm but his constituent had found it impossible to sue because the wind farm operator was purely a shell company with very limited assets. The parent company may have vast assets but if the shell company is the operator it may be impossible to obtain any damages from it and even may not be able to recover the costs of the case. In view of this, it appears that claimants' insurance companies are unwilling to commence proceedings in this type of case.

It is not known how extensive this practice is but there is evidence to suggest it is common. Even if the developer who applies for planning permission is the parent company, that company can transfer the asset to a different company at any time in an attempt to divest itself of any legal responsibility for any nuisance that it may cause.

In his Bill, David Davis MP has highlighted a problem that has been little appreciated. There may well be ways around this problem in company law but it appears that, even if this is the case, it has prevented some insurance companies from taking action on behalf of their clients on this ground alone. But whether there are in fact such remedies or not, it is yet another complication which makes putting the onus on a resident to take a nuisance action (as has been suggested by some Inspectors as mentioned in paragraph 6.35 of Paper 6.1) against the operator even more unreasonable and a course of action which should be avoided.

C. The Science Behind AM

Amplitude modulation (AM) is normally a relatively benign characteristic of wind turbine noise. It is normally the periodic 2 - 3 dB variation in the amplitude of the audible aerodynamic noise emitted by the turbine blades, modulated at the blade pass frequency by a quasi-sinusoidal envelope. Its cause is well understood and its characteristics are quantitatively consistent with that understanding. Unfortunately increasing numbers of wind farm neighbours now suffer from a rather different wind turbine noise characteristic which is far from benign. It has been called excessive amplitude modulation (EAM), and is

claimed to be not well understood. EAM has been measured from a substantial proportion of UK wind farms and from single turbines. Modulation depths up to 30 dB have been reported in the literature. It can occur over a substantial proportion of a wind farm operating time, particularly during evenings and at night time. At sites where it does occur not all local residents are similarly affected, but those who are affected suffer symptoms which are too acute, too physical and too consistent to be described as "annoyance"; there is now compelling evidence that EAM can damage health as described at WP3.2. Now that EAM has been acknowledged as a problem both by Governments and by the wind industry it is essential that its causes and effects are correctly and objectively determined. This INWG study examines the science behind AM through three work packages.

Work package 2.1 – Review of Literature

At WP2.1 Richard Cox presents the results of a review of the available literature on wind turbine noise (WTN). Over 160 documents are included in the INWG study of amplitude modulation and of these at least 85 documents can be considered technical in content. This contrasts with the IoA AMWG literature review, which lists a total of just 35 documents.

These 160 documents have been reviewed and most are referenced by the various work packages. The review has focused on the most recent findings and knowledge surrounding wind turbine sound and amplitude modulation (AM), but also includes earlier work where it remains relevant. The last 3 years have seen a surge in scientific activity related to wind turbine noise problems that challenges the status quo imposed by the wind industry and its acoustics consultants. As a result, knowledge of wind turbine noise characteristics, and its effects on people has advanced rapidly.

The evidence reviewed confirms 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. See also WP2.2, WP 3.1, WP3.2 and WP9.

Evidence spanning over the past 30 years shows a clear evolution of knowledge relating both to the science behind WTN and the effects on people exposed to it. Starting with the NASA research[7, 9, 12, 13], in the USA during the 1980s through to the Northern Ireland Assembly inquiry report[14] of January 2015, the key scientific aspects of WTN including AM are now well understood and defined. However, further research is required especially regarding the effects on health, see WP3.2. 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.

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 IoA, by the wind industry 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. See also WP8.

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 significant low frequency content is 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.

The Northern Ireland Assembly inquiry report[14], January 2015, 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*". Given the 1980s NASA research into EAM and LFN, it is surprising to discover these findings were ignored when during 1996 the UK Government and wind industry produced the ETSU[6] noise guidance for the UK. When we read ETSU we find:

- LFN is not considered despite the evidence available then 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 unsuitable when low frequency is present;
- Measurements are made only outdoor 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 2013 IoA sponsored Good Practice Guide[18] to the implementation of ETSU, now more or less mandatory in wind turbine noise

assessments in the UK, also by and large ignores these same issues. 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 the earlier research findings.

The Northern Ireland Assembly report[14], January 2015 on the committee's inquiry into wind energy provides what is probably the most comprehensive and credible review of its kind to date. 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.

Fortunately, with some limited modifications the update to BS4142[3] during 2014 now provides a readily available and suitable replacement set of principles to ETSU. BS4142 also has the benefit of decades of widespread and proven use with all other forms of industrial noise source.

Work package 2.2 – AM Evidence Review

At WP2.2 Sarah Large looks primarily for evidence of audible amplitude modulation noise in support of its existence and prevalence. Amplitude modulation (AM) can be defined as the regular (cyclic) variation in noise level, usually at blade passing frequency, which exhibits a change in the noise character of the wind farm noise as the decibel level rises and falls.

AM as it typically occurs from modern wind turbines is commonly referred to as excess or enhanced amplitude modulation (EAM). This refers to AM that is considered unreasonable and in excess of that envisaged by ETSU-R-97. EAM is commonly found in the far field and is characterised by peak to trough levels of up to 10-13dB and with a mid and lower frequency range, 160-400Hz.

This evidence review focuses primarily on audible amplitude modulation (AM). This typically relates to AM from around 80Hz and up to around 1000Hz, with the higher frequencies being more dominant in earlier studies, smaller turbines and / or near field measurements. There is evidence supporting the prevalence of lower frequency AM and AM in infrasonic frequencies, including that which does and does not relate to blade pass frequency, which is discussed elsewhere but is beyond the scope of this work package.

Audible AM generated by wind turbines has been researched and documented since the late 1990s and more formally researched as a distinct topic from around 2002. Those working on behalf of government agencies have highlighted the need for AM control since around 2006.

There is a wealth of international research identifying either by measurement or written report, AM and / or specific features of noise that are characteristic of AM. AM is commonly found to impact residents in the far field most often from around 400m from the nearest turbine. Whilst there is a characteristic 'shape' of AM evident in the majority of data

presented, as measured using dB(A) and plotted with reference to time, the manifestation of AM can vary from site to site and even within sites.

This evidence based report is conclusive that AM exists and shows AM is likely generated by the majority of wind energy developments. It also shows that AM can be generated by all turbines regardless of size, model or type. AM is not rare but is prevalent and whilst meteorology may not be the sole determinant, under certain meteorological conditions adverse AM can occur for long periods of time.

This work package provides a summary of open access documents and data from a single UK acoustics consultancy. Access to papers published in subscription-only journals or to the resources available to larger consultancies can only be expected to increase documented cases of AM and provide further evidence supporting the prevalence of AM.

Work package 1 – Fundamentals of AM

At WP1 Dr John Yelland explores aspects of AM and EAM relating to their definition, causes and measurement. The objectives of WP1 are to provide a technical description and definition of a characteristic of wind turbine noise that has become known as amplitude modulation and to investigate its measurement, its possible causes and any feasible mitigation.

Amplitude modulation is considered excessive when the “modulation depth” of the time series envelope exceeds the maximum of the 2 – 3 dB range reported in ETSU. Compared with normal AM the peaks of EAM are narrower, with modulation depths up to 30 dB(A) reported.

The use of the term “modulation” in the acronym EAM was unfortunate as it pre-judged the spectral content of EAM at a time when it was little understood. In signal processing terms a modulated waveform is typically the product of a carrier frequency signal multiplied by a normally much lower modulation frequency or band of frequencies. EAM however is the sum of incoherent noise, modulated both in frequency and in amplitude, together with high levels of very low frequency tones. “Modulation” should therefore be understood in its lay definition rather than in any technical definition. Use of the term does not suppress the very low frequencies from wind turbine noise, although it does appear to have suppressed serious consideration thereof by the wind industry or its acousticians.

The RenewableUK AM research report, (“the ReUK report”) states that EAM is entirely due to increased aerodynamic noise from the turbines blades which can stall at blade zenith (“12 o’clock”) in high wind shear. WP1 shows that this can explain only a small part of the greater modulation values observed. A major contribution comes from noise below 100 Hz. WP1 also shows that the ReUK report and the IoA AMWG discussion document largely derived from it repeatedly exclude any consideration of acoustic emissions at frequencies below 100 Hz. The ReUK report includes no measurements below 100 Hz to support the exclusion. In truth the greatest observed modulation values are fairly easily explained by consideration of the very low frequency emissions which are a consequence of the structural dynamics of

large modern wind turbines rather than aerodynamic noise from the blades. These very low frequency emissions are well known to turbine manufacturers, but by reason of mechanical fatigue issues rather than noise nuisance.

The causes of EAM

The blade pitch of a turbine is normally adjusted for optimum energy conversion at the hub height wind speed. High wind shear creates EAM because, in the higher wind speed that pertains at blade zenith for a given hub height wind speed, the blade may not move fast enough to "keep up with" the wind; it therefore stalls. However, blade stall at zenith can quantitatively explain a 3 dB increase in the aerodynamic noise on stall, but, notwithstanding repeated claims to the contrary in the ReUK report, it cannot explain modulation heights of up to 30 dB in measured noise level, also cited by Oerlemans in the ReUK report.

When a blade stalls and loses the force of the wind it also rebounds due to its elasticity generating a sound pressure pulse at the blade pass frequency (BPF). Because of the impulsive nature of the rebound its harmonics reach up into the lower part of the audio spectrum, i.e. above 20 Hz. When the BPF is close to a blade resonance frequency, or a subharmonic thereof, the blade oscillation can build in amplitude. Thus transient stall generates very low frequency noise as well as increasing the level of aerodynamic noise. Because of the vast area of a modern turbine blade the acoustic power of the very low frequency noise can be considerable. Its directivity differs from that of the aerodynamic noise; the blade acts as a dipole source, propagating equally upwind and downwind, although the wind shear still enhances the downwind propagation.

The higher nocturnal wind shear can thus increase peak wind turbine noise at night by three different mechanisms. In addition to the higher aerodynamic noise emission levels from the turbines from transient blade stall and higher noise immission levels at homes due to wind shear enhanced noise propagation there will also be very low frequency noise due to blade rebound and possible resonance.

Although blade stall has been described as transient most aerofoils have a hysteresis loop in their stall characteristic, in the case of turbine blades exacerbated by their considerable elasticity. The duration of stall is therefore a significant part of the blade passing period, as at zenith the vertical velocity component of the blade motion obviously passes through a minimum of zero.

The smaller wind turbines of the 1990s were designed with sufficient rigidity not to vibrate; today's turbines are designed with less material and more design subtlety in order to control and survive resonant vibration rather than to eliminate it by rigidity. Towers with a fundamental resonance frequency f_t higher than the BPF are referred to as "stiff", whilst those with f_t between the f_r and the 3 f_r are referred to as "soft-stiff" or just "soft". If f_t is lower than f_r the tower is referred to as "soft-soft". The principal benefits of stiff towers are modest – they allow the turbine to run up to speed without passing through resonance, however they also tend to radiate less sound.

Wind blowing past a cylinder (not necessarily a circular cylinder, but any bluff object) can create vortices which are shed alternately on each side of the cylinder. A common small scale experience of this is the whistling of overhead wires in a strong breeze; the alternating shedding of vortices applies an alternating force to the wire along its length, causing it to oscillate. The same applies to a tall factory chimney, where the effect can be more serious. The tower of a large modern wind turbine has resonant frequencies typically around 1 Hz or less.

Vortex-induced vibration (VIV) is well understood and well documented in journals of fluid dynamics and structural mechanics. If the vortex shedding frequency matches the resonant frequency of a structure the oscillations can destroy it. Wind turbine manufacturers are well aware of VIV; their concerns until recently have related only to fatigue and the structural integrity of the turbines rather than their noise emissions. A frequently seen solution to VIV is the fitting of a helical "spoiler" around the outside of a chimney. This deflects the airflow upwards on one side of the chimney and downwards on the other side, thus avoiding the formation of vertical cylindrical vortices. Spoilers are not fitted to wind turbine towers, possibly for aesthetic reasons, but the towers do often have damping devices fitted internally to control resonance.

The regular passing of the tower by the turbine blades can also cause a tower to oscillate at one of its resonant frequencies. Much has been made by the wind industry of the reduction in turbine noise that was achieved by the transition from downwind designs to the now almost universal upwind designs. The problem with downwind turbines was that the blades passed through the wind shadow of the tower, producing an infrasound or very low frequency pulse at the BPF. This did cause the relatively small early downwind turbines to be very noisy for their size. Replacing the blade-passing-through-wind-shadow-of-tower event by the tower-passing-through-wind-shadow-of-blade event of upwind turbines whilst solving one problem created another; the latter event can and does cause tower oscillation.

Finally turbine blades, like turbine towers, can be caused to resonate by vortex shedding. As they are usually made of glass fibre composites they are highly elastic.

The ReUK report

When decision makers are not specialists in the science on which their decisions should be based it is essential that they are aware of the academic status and any beneficial interests of the people and publications from which they take their guidance. This is particularly relevant when the technology is complex and the potential financial gains of its promoters are high, as in the present case. The ReUK report was commissioned by the wind industry lobby organisation RenewableUK, which in its own words is the "*leading renewable energy trade association working to grow your business*", so makes no claim to be an impartial academic institution. The ReUK report is considered to be technically unsound and highly misleading. Its authors work in or largely for the wind industry and we find no evidence that the report has been peer reviewed, in spite of its statement (page 372) that "it will be peer-reviewed by other specialists working in the field." The three work package reports by Bullmore and Cand of Hoare Lea state on their audit sheets that the authors have reviewed each other's papers; this is not peer review. Cand in particular is identified as an author of four of the six UK produced work packages listed on pdf page 2 of the ReUK report and his

"considerable contribution" is gratefully acknowledged in one of the remaining two. The claim of "peer reviews" by an author's colleagues who rely on the same customer base and belong to the same professional institution as the author is worthless and serves only to demean the author and the institution.

The local stall hypothesis cannot explain the observed high levels of EAM, as is shown by Oerlemans in the first paper "WP A1 - An explanation for enhanced amplitude modulation of wind turbine noise" in the ReUK report. It is of great concern that the ReUK report's interpretation of that paper draws the opposite conclusion. Oerlemans uses the well-established and reliable BMP aerofoil noise model to calculate the aerodynamic noise from wind turbine blades, and shows that the 2 – 3 dB modulation depth of normal AM increases by about 3 dB in stall. This however is far short of the measured EAM modulation depths from 10 to 30 dB that Oerlemans reports in his paper. The 27 dB difference between theory and measurement is somewhat questionably accounted for by two devices; first by choosing 10 dB rather than 30 dB as the target modulation depth prediction, then by simply adding another 7 dB (essentially a fiddle factor) to the 3 dB prediction, and here we quote from the paper, "*to obtain the desired 10 dB overall noise increase*".

The ReUK report paper "WP B1 - The measurement and definition of amplitude modulation(s)" addresses a problem which in reality does not exist: the search for an automated process to determine whether or not the amplitude modulation height of a time series waveform is of acceptable magnitude. All that is required to determine the modulation height is the eye and a ruler; all that is required to verify that the signal is indeed from a wind turbine and not some other source is the ear, for which purpose sound is recorded along with the LAeq.

There is no legitimate benefit to be derived from the use of complex and opaque signal processing techniques to derive a "metric" from a time series signal with clear and stable periodicity. It is noticeable that all the methods proposed by the IoA AMWG understate the modulation height when compared with the simple observation of the time series signal, as is demonstrated by Large in INWG Work Packages 5 and 7. Whatever method is used transparency is essential.

The ReUK report paper "WP B2 - Development of an AM dose-response relationship" describes the Salford listening room test commissioned by RUK. The listening room has a surprising inclusion in its sound reproduction system: a high pass filter with a corner frequency of 140 Hz and 20 dB attenuation at 100 Hz. The resulting filtering out of all frequencies below 100 Hz in the measurement of EAM will completely remove any and all of the turbine noise signals from the sources described above along with some of the downward shifted frequency content of the aerodynamic noise in stall. This equipment was used to replay real wind farm noise recordings for volunteers to rate the degree of annoyance they caused. The ReUK report, wind industry developers and their IOA AMWG acousticians repeatedly assert that the noise of EAM is all aerodynamic and has little content below 100 Hz; this would seem to make the 100 Hz filter redundant. No spectral measurements have been published in the ReUK report to support this assertion; indeed independent measurements demonstrate the contrary.

Measurement problems

Whilst the sound of normal AM turbine noise, with its normal 2 – 3 dB of AM, can cause annoyance, EAM differs from AM it that it can present a health hazard. This is a fundamental distinction between the effects of AM and EAM, and a fundamental reason why the appropriate measure of EAM is given by the true sound pressure level measured as dB re 20 µPa. By way of illustration, for the ear to perceive sound at 20 Hz and sound at 2 kHz to be of equal loudness the sound pressure level at 20 Hz needs to be 50 dB higher than the sound pressure level at 2 kHz. Below 10 Hz the A-weighting function is not even defined. The common objective is, or should be, the determination of the levels at which wind turbine noise becomes:

a) annoying to an extent that should be considered in the planning balance, or
b) a potential health hazard, in which case the application/appeal should fail notwithstanding any other planning considerations.

It is important to use tools appropriate to each task. One tool which is clearly unsuitable for (b) is the A-weighting curve, which over rather more than 50 years has become entrenched, and often mandated, in environmental and industrial noise regulation. The original objective of the A-weighting curve was to reproduce the sensitivity of the average human ear over the audible frequency spectrum (defined as 20 Hz to 20 kHz) at low sound levels. It achieves that function well, but only at low sound levels; it is not suitable for, and was never intended for, the present purpose, where unacceptable levels of low and very low frequency sound may be present at high levels. The fundamental frequencies involved are the turbine rotation frequency, the blade pass frequency, and blade and tower resonant frequencies. All of these and many harmonics thereof, fall below 20 Hz, where the A-weighting curve is not even defined.

The use of A-weighting reduces the sound level measurement value – but not of course the sound level - by 50 dB at 20 Hz. At these low frequencies G-weighting is equally inappropriate as it too reduces measurements, by 50 to 100 dB at blade pass frequencies. Any weighting is inappropriate. As even the straightforward unweighted measurement of sound power level is referred to as “Z weighting” the concept of weighting is obviously well entrenched in the acoustic mind set; inaudible pulsing pressure waves around 1 Hz however are far better understood in terms of physics rather than acoustics.

The IoA AMWG Discussion Document states that in order to “*filter out noise in the ambient environment occurring at frequencies below 100 Hz (which tends to be influenced by wind noise mainly*)” proposes the use of a 100 Hz high pass filter for AM compliance measurements. Given that stall noise frequencies peak at around 100Hz, compared with about 400 to 800 Hz in laminar flow, the 100 Hz HPF will cause significant understatement of the modulation height.

ETSU (page 31) considers frequencies down to 20 Hz in contemplation of the noise from the far smaller turbines current at the time of its drafting when it states:
“*It should be noted that low frequency noise, for example, from ventilation systems, can disturb rest and sleep even at low intensity. Where noise is continuous, the equivalent noise level should not exceed 30dB(A) indoors, if negative effects on sleep are to be avoided. In the*

presence of a large proportion of low frequency noise a still lower guideline value is recommended. It should be noted that adverse effect of noise partly depends on the nature of the source." [WHO]

The comments with respect to low frequency noise reflect the effect of using an A-weighted sound pressure level. If most of the acoustic energy was concentrated at a very low frequency, then high levels of acoustic energy might exist but an A-weighted level may still only be 30dB(A). As an example, the A-weighting network applies a correction of 50dB at a frequency of 20Hz. Therefore, a level of 80dB at 20Hz would meet this 30dB(A) requirement.

The IoA GPG endorses the use of ISO 9613-2 for wind farm immission noise level prediction and of IEC 61400 11 for turbine noise measurement. Both these standards require measurements only down to 45 Hz, a seemingly perverse movement upwards in frequency from 20 Hz over a 16 year period during which turbine noise emissions decreased considerably in frequency due to the increase in turbine dimensions. That the lower frequency limit should be raised even further to 100 Hz for EAM noise measurements, which clearly have a significant content below 100 Hz, seems yet more perverse.

The IoA AMWG state that all EAM of any value is fully explained by increased blade aerodynamic noise above 100 Hz. This claim is easily resolved by measurement, and it is most extraordinary that the IoA AMWG has not reported, and therefore presumably has not made, any such measurements. The word “infrasound” appears 15 times in the ReUK report, but always in the context of asserting its non-existence in wind turbine noise.

The measurement system used by the IoA AMWG, because any standard SLM (sound level meter) rectifies and integrates the signal from the microphone, destroys the original frequency information in the microphone signal. The INWG is therefore undertaking a series of measurements of turbine noise spectra at sites notorious for troublesome EAM, as theory should always be proved by measurement, in part to give confidence to those unable to understand the theory. Representatives of the IoA AMWG will be invited to participate in those measurements.

On the question of whether EAM compliance measurements should be made indoors or outdoors, the IoA AMWG discussion document proposes outdoors, and justifies this by the statement: *“...measurements are made outdoors for consistency with other procedures for measuring wind turbine noise (such as ETSU-R-97)*.”

In truth AM compliance measurements have little relationship to ETSU background noise measurements. The descriptor proposed by the AMWG is LAeq, whereas ETSU refers exclusively to LA90. Furthermore EAM is an area where ETSU offers no guidance; there is therefore nothing to be consistent with. It has also been suggested that access indoors may be refused by residents; it is however most unlikely that residents suffering from a serious wind turbine noise problem would not cooperate with attempts to resolve that problem.

The advantages of indoor measurement are threefold:

a) Wind noise is significantly reduced, particularly at low frequencies, making the turbine noise measurements less contaminated and therefore more reliable. The higher outdoor background noise would of course raise the troughs in the EAM trace far more than it raised the peaks, thus understating the EAM modulation index.
b) The 8 dB attenuation from outdoors to indoors through an open window assumed by ETSU when setting the 43 dB(A) night time limit does not apply at low frequencies; and is certain to be reduced at frequencies below 100 Hz and at lower frequencies is often replaced by amplification due to room resonances.
c) The resident can be provided with a pushbutton to timestamp the sound recording on occasions when the noise is considered unacceptable, which greatly reduces the subsequent labour of data analysis by directing the person analysing the data to its relevant high EAM content.

Finally what good reason can there possibly be for measuring the noise level in a very different place from that where the noise level is giving rise to complaints?

D. Effective Control of AM

At WP5 the available options for controlling EAM are assessed and tested against various criteria using real world data. WP7 (to be released later) describes the results of testing of the IoA AMWG proposed AM control methodologies. However, the results of some WP7 preliminary testing is discussed below.

Work package 5 – Towards a Draft AM Planning Condition

At WP5 Sarah Large investigates the available options for the control of AM. Whilst EAM is primarily described by a peak to trough variation there are many other associated character features that undoubtedly contribute to the adverse perception of wind farm noise and EAM. This includes frequency content (particularly low frequency modulation), rhythmic aspects of the noise (beating), the erratic or steady nature of peak occurrences, predictability of the noise, interactive effects of multiple turbines generating AM or EAM, tonality, impulsivity, changes in spectral content from moment to moment, the rate of fall in decibel level, average or peak decibel level and other non-acoustical factors.

This work package deals only with audible EAM, defined in this work package as the audible level of amplitude modulation (AM) noise received in the far field. There are a number of existing methods for identifying and assessing EAM, though few have been formally adopted. It is widely acknowledged that ETSU-R-97, the decibel procedure adopted in the UK, does not account for the noise characteristic of EAM and as such an additional means of control is needed for this widely occurring aspect of wind farm noise.

Four main methods for assessing or limiting EAM have been critically examined in this work package. These methods are representative of the range of assessment / control methods currently proposed for EAM. Each method was tested with real world data from six different sites ranging from smaller single turbines to large wind farm developments. The

methods tested were the ReUK template planning condition, a methodology proposed by RES for the Den Brook case, the original Den Brook EAM condition and the Japanese DAM methodology. In addition BS4142:2014 and BS4142:1997 were tested with data from two of the six sites.

Each method was assessed against necessary and desirable criteria for the protection of amenity as normally defined for planning controls. This included evaluation of whether the method worked with real life data, the practicality of implementing each method, whether the methods produced false positives or false negatives and most importantly whether the method was effective and thus was capable of being used to prevent periods of significant adverse impact.

The ReUK proposed method aims to assess EAM using FFT analysis to calculate average AM values that can be converted to a penalty and applied to an ETSU-R-97 noise limit. The method is essentially designed to be run as an automated process. This method was found to be significantly flawed in a number of respects including imprecise condition wording, inability to filter extraneous noise and false negatives. The values of AM that are derived by the ReUK method do not correspond to typical AM peak to trough levels and do not appear to relate to subjective impact. Most importantly this method failed to enable enforcement against adverse impact in any real case of identified EAM. Thus, application of a simple decibel penalty applied to existing ETSU-R-97 limits using this method was found not to provide a means of enforcement against impact in the most serious and significant of cases of EAM. It is concluded that the ReUK method is unfit for purpose.

The RES method uses FFT to derive an AM value and then looks for periods where this value exceeds 2.5. This method acts on a trigger value (2.5) and as a precursor to the original Den Brook EAM assessment method. Other stages follow in the methodology but only this initial trigger stage has been tested in this work package. The RES method is essentially designed to be run as an automated process. The RES method, like the RUK method, was found to be flawed in a number of respects including imprecise condition wording, inability to filter extraneous noise, false positives and false negatives. The values of AM that are derived by the RES method do not appear to relate to subjective impact. The redeeming feature of the RES method is the means of control, use of a trigger value rather than any independent assessment of EAM acceptability. Whilst the RES method misses significant periods of EAM a slightly modified version of the RES algorithm allowed some improvement to the identification of EAM. This modified approach could be used as an assisting tool for identifying EAM, using a trigger value, but due to the flaws listed above it is not recommended as a standalone assessment method.

The DAM method simply provides a means to rate EAM, using an AM index, and offers no guidance on how it might be used in part of a condition or what is an acceptable or unacceptable DAM value. Though influenced by extraneous noise, the DAM method worked well to identify periods of EAM and periods of borderline AM. In some cases it did not well reflect the peak to trough level of modulation, particularly where there was erratic AM, but in most cases the DAM AM index well reflected the typical peak to trough modulation. The DAM method for deriving an AM value is considered successful if used as a trigger value and

could be used to determine a typical peak to trough value when EAM is not erratic or heavily influenced by extraneous noise.

The Den Brook method was found to work well with the data from all six sites tested and successfully identified EAM without being influenced by extraneous noise. Much of the success depends on the interpretation and implementation of the Den Brook method and this has been discussed in greater detail in the body of this work package. Of note, it is implicit that the Den Brook method should not be used as a simple trigger value and that an assessment of frequency and duration must be made by the assessor as to the extent of impact. This is consistent with other UK planning noise controls. If the Den Brook condition were to be treated as a simple metric or trigger value a higher peak to trough value in the region of 6dB would need to be used. However, it is not recommended that this condition is used as a simple trigger value.

The 2014 version of BS4142 was also used to assess impact at two of the six sites. BS4142 has previously been dismissed, both in ETSU-R-97 and by others, as an appropriate means of control for wind farm noise. The issues raised to support these arguments have been examined below and found inapplicable to the new version of the standard. BS4142:2014 was found to work very well for assessment and control of cumulative wind farm noise and character impact.

The ability of noise conditions to build in an assessment of frequency and duration with the control of unwanted sound was discussed at an early stage in the formulation of the work package scope. The difficulty of rating EAM for frequency and duration in the absence of research looking at long term impact of EAM and subjective response was raised as a legitimate issue. It is concluded that assessment of the extent of impact should remain the responsibility of those assessing and enforcing impact. This is consistent with the approach of the majority of noise conditions applied across the UK where a short time metric is applied but enforcement normally requires prolonged or high exceedance.

This work package shows that existing methods of controlling and assessing AM can be successfully modified and implemented to provide a prescriptive and unified assessment process for EAM. Where wind farm noise level and wind farm noise character require simultaneous assessment the use of a BS4142:2014 type approach is recommended. The rated wind farm noise level should not exceed +10dB above the background sound level.

Where wind farm noise EAM requires assessment in isolation, procedures based on the principles of the Den Brook condition should be used. This may be complemented by a simplified RES method, used to help identify periods of EAM where many weeks of data have been obtained, and by the DAM method where the extent of modulation is debated. A DAM rating of 3.5 or above / an AM index of 5 or above should be considered EAM. Use of ETSU-R-97 could be continued where the noise from a wind farm is steady, benign and anonymous, typically where the LAeq is not more than 2dB above the LA90, but with the caveat of widespread criticisms of the method and the allowance of excess noise particularly at night time. Whilst a review of the ETSU-R-97 methodology and recommended noise limits is long overdue, it is beyond the scope of this work package.

Work package 7 – Testing of IoA AMWG Proposed Methodologies

At WP7 (to be released later) Sarah Large tests the effectiveness of the AM rating methodology currently proposed by the IoA AM Working Group (AMWG) in their consultation document, Irvine[11] April 2015. The AMWG was set up with the aim of reviewing existing evidence on AM and producing guidance on the assessment of AM. Whilst originally the goal of the group was clearly to provide a means to assess AM, which could then be included in a 'standard' form of planning condition for wind energy development, recent publications released by the IoA AMWG confirm that their scope is now limited to providing a metric for AM.

Despite acknowledging numerous characteristics of EAM that determine psycho-acoustical response including, modulation depth, modulation rise time, modulation frequency content, the IoA AMWG have focused only on modulation depth as the defining factor for EAM. There is no consideration of how other characteristics might interrelate or be combined into assessment of EAM at a later stage.

Focusing only on modulation depth, the same group have identified and tested three main metrics for AM. This includes:

1. Method 1, a time series method being a variation of the Japanese DAM method as tested in WP5.
2. Method 2, a fast fourier transform (FFT) method similar to the approaches used in the ReUK template planning condition and the RES Written Den Brook scheme, condition 21, also discussed in WP4 and WP5.
3. Method 3, a hybrid method also incorporating FFT analysis.

The IoA has provided open access software that enables these three methods to be tested independently with real world data.

Values of EAM can be determined using all three metrics when there is no AM in the noise trace and also when the noise trace is dominated by extraneous noise. All three methods are susceptible to false positives, indicating that there is EAM when there is none, which is a significant flaw for any method that aims to be automated. Methods 2 and 3 also produce false negatives, suggesting that there is no EAM when the data shows significant EAM with modulation between 6-12dB peak to trough.

None of the proposed methods well describe EAM that varies erratically. There appears to be no subjective relationship between the EAM values derived from methods 1, 2 and 3 and the character of the EAM indicated in the time series. Of the three metrics, method 1, which is based on the Japanese DAM method, was found to work best with real world data. Method 2 is significantly flawed. Catastrophic failings have been identified at this preliminary stage of testing and this suggests that method 2 is not an appropriate means to assess EAM. Method 3 is similarly flawed though the resulting AM values are generally higher than those derived from method 2 and the method 3 values are generally more responsive to changes in EAM.

The results from preliminary testing indicate that all three methods present significant problems where they do not reflect or mirror impact. Method 2 should be abandoned. Methods 1 and 3 also present significant difficulties though method 1 may have some limited benefit as a supportive tool when applying other methods of analysis. As concluded in WP5, current tools and knowledge do not support or facilitate an automated and standardised metric for EAM.

Completion of WP7 is dependent on the IoA AMWG formulating a final recommended method which will then be tested more extensively including its application as part of a planning condition. However, preliminary testing indicates that the proposed methods are insufficient.

E. Community Response

This section of the INWG study investigates how local communities have responded to a wind farm being imposed on their neighbourhood and their relationships with the wind farm developers and the developers' acoustics consultants. Three work packages examine situations before and after wind farms becomes operational.

Work package 4 – Den Brook

At WP4 Mike Hulme documents the legal, planning and technical issues surrounding the Den Brook AM planning condition[22] (2009). This work package details the enormous effort Renewable Energy Systems (RES), the wind farm developer, has gone to over the last 8 years to ensure first that an AM planning condition is not applied, then to have the applied planning condition removed, and finally to have it sufficiently weakened presumably to ensure it prioritises development of the wind farm rather than provide the intended protection against EAM.

Hulme documents the '*decade of deception*' experienced by the local community at the hands of the developer RES and its acoustic consultants. Despite all the efforts by RES and the recently compliant local authority, the Den Brook AM control mechanism remains extant. The wind farm is now expected to be built during 2016, some 11 years after the original planning application.

Developments during the first five years of the proposed Den Brook wind farm, located near North Tawton, West Devon, are well documented on aspects related to EAM by the four-hour, BBC2 documentary series 'Wind Farm Wars'. Whilst briefly capturing the project from its beginnings, WP4 more specifically examines the development of EAM related matters since the documentary filming ended and planning permission was granted for a second time[22] in December 2009, but this time, with the unprecedented EAM noise controls and conditions appended.

A Den Brook Judicial Review Group (DBJRG) was established in March 2007 with the principal aim of ensuring acoustic impacts from the proposed wind turbines were properly conditioned and thus controlled in order to adequately preserve people's well-being and

human rights within the Den Brook neighbourhood. More specifically, DBJRG represents the interests of local residents whose amenity, sleep patterns and properties are considered to be at risk of adverse noise effects from the proposed Den Brook wind farm.

DBJRG has initiated a number of legal actions during the past eight years. Amongst the outcomes, noise data analyses firstly undertaken in-house by RES and later the developer's commissioned acoustic consultants, Hoare Lea Acoustics, were found to be flawed to such an extent that the initial 2007 planning permission for the Den Brook wind farm was quashed by ruling of the Court of Appeal (CoA).

Planning conditions 20 and 21 were then imposed for the control of EAM wind turbine noise with the grant of planning permission in December 2009 by a senior Planning Inspector. The stand-alone EAM conditions were later ratified by a further Court of Appeal judgment such that *inter alia* in the ruling of Lord Justice Elias the following terms were specifically specified:

> **"…there is an obligation on the developers to comply with the AM levels specified in condition 20 and that obligation will run for the duration of the planning permission."**

Following the latter 2011 CoA judgment, Den Brook developer RES submitted a section 73 application to the Local Planning Authority (LPA) clearly intended for obtaining a substantive weakening of the imposed EAM noise conditions. RES's proposals became the subject of reports carried out by the Institute of Sound and Vibration (ISVR) on behalf of the LPA and Dr Malcolm Swinbanks *et al* on behalf of DBJRG. Dr Swinbanks' in-depth examination of RES's proposals exposed procedures that included undisclosed in-house software code which perversely reduced by up to 50% the measured levels of EAM that were to be assessed for compliance purposes.

RES subsequently withdrew the section 73 application and in the alternative devised a 'Written Scheme' in conjunction with recommendations from ISVR based on requirements of condition 21 of the planning permission. A detailed and highly complex Written Scheme[26] was formulated for specific measurement of wind turbine AM noise that was later discharged by the LPA on 21 May 2014. However, internal procedures implemented by the LPA dictated that no third party consultation was entered into by LPA officers for arriving at their decision to approve and discharge the Written Scheme.

Following discharge, DBJRG's professional acoustic consultants tested the condition 21 Written Scheme by systematic application of real-world wind turbine noise data to the approved methodology. In particular, testing of the Written Scheme's stage 4, which incorporates complex mathematical procedures professed to filter out apparently invalid complaints before compliance testing is fully carried out. This revealed substantive discrepancies that clearly undermine the 2011 CoA ruling - i.e. that the EAM limits specified by condition 20 must apply for the life of the planning permission. Moreover, it is represented (see WP6.1) that under the Doctrine of Precedent condition 20 is to remain intact unless overturned by an equal or higher authority than the CoA. Clearly, neither RES nor the LPA constitute such a higher authority.

DBJRG's ensuing efforts for resolving the flawed methodology fell to requiring further intervention through the courts. Detailed, expert evidence clearly identifying and illustrating the problematic aspects was submitted such that the LPA, its consultants ISVR, and RES were all made fully aware of flaws identified within the approved Written Scheme.

Notwithstanding the submitted evidence, neither RES nor the LPA's consultants ISVR addressed the most transparent flaw identified within stage 4 of the Written Scheme, i.e. stage 4(c). Stage 4(c) requires:

> ***If this assessment*** [i.e. stage 4, clauses (a) and (b)] ***indicates that GTE-AM is present, then the LAeq, 125msec data required by Condition 20 shall be band pass filtered, from 0.9fc to 1.1fc, and the application of the Condition 20 methodology repeated. This is essential to ensure that the variation causing apparent non-compliance with Condition 20 derives solely from that occurring at the blade passing frequency, fc.***

Band pass filtering in the manner prescribed by stage 4(c) of the Written Scheme eliminates crucial harmonic components of the EAM noise from the raw data employed for compliance testing against the EAM parameters specified by condition 20. Thus, the amount of EAM noise presented for assessment would be significantly and materially understated for all compliance testing in the event of a noise complaint.

The court however, not having specific expertise in acoustics, held that where there was no agreement between experts, determinations in respect of the submitted technical expert evidence was a matter for the LPA. DBJRG then approached RES's senior technical manager Dr Jeremy Bass for his considered view of whether the stage 4(c) requirement to filter raw data alters in any way the level of EAM controls established by condition 20 (Dr Bass is understood to have authored the procedures specified, including stage 4(c) of the Written Scheme). Dr Bass however deferred to the LPA for a determination of the matter. Similarly, the LPA's consultants ISVR also evaded addressing the specific question.

The LPA has since been approached, 11 June 2015, by Mel Stride MP seeking the LPA's understanding and position regarding the consequences of stage 4(c) on condition 20. Up to the time of writing, i.e. 31 July 2015, a response has not been forthcoming from WDBC.

Moreover, longstanding concerns remain that RES, in consort with commissioned acoustics advisers Hoare Lea Acoustics and the Hayes McKenzie Partnership, misinformed and indeed misled not only the surrounding communities but decision makers within the LPA and later the Planning Inspectorate that EAM was not an issue requiring attention or indeed assessment. The now clearly malfeasant position was maintained throughout the extensive Den Brook planning process despite widespread and growing empirical evidence to the contrary.

Furthermore, it is a matter of public record that during a meeting, 7th November 2013, held to discuss the condition 21 Written Scheme, Dr Bass conceded that the industry wind turbine line (as adopted by RES for many years) that EAM is rare and an EAM condition is

not necessary to protect amenity was no longer tenable: *"...that idea has been completely exploded by the weight of evidence presented by Mike Stigwood* [professional acoustics adviser to DBJRG] *in particular."* Dr Bass went on to say that he suspected in the future, developers at public inquiries will no longer try the argument that EAM is rare and shouldn't have a condition. He added that "*it seems to me the entirely rational position."*

Absenting remaining issues with more complex aspects of stages 4(a) and 4(b) of the Written Scheme, stage 4(c) is arguably both materially imperative and unlawful. It requires potentially important aspects and significant portions of any EAM noise to be excluded from all condition 20 compliance assessments.

Such requirements appended to the condition 20 EAM controls imposed for the granting of planning permission materially and ominously prejudice neighbours of the proposed Den Brook wind farm, hold grave implications in relation to Article 8 of the Human Rights convention, and fly directly in the face of the extant 2011 CoA ruling.

Notice was therefore served on RES, 26 May 2015, which formally advised and warned the developer that DBJRG is to carry out professional 24/7 noise monitoring (see WP9) of the Den Brook wind farm. DBJRG has also advised that it will be looking to install infrasound and low frequency noise monitoring. The monitoring aims to ensure full, accurate and proper assessment of noise impacts to enable fair and direct compliance testing against the lawfully ratified Den Brook AM condition 20 parameters.

Work package 6.2 – Control of AM without a planning condition

At WP6.2 Bev Gray reviews from a community perspective the practical experiences and causal effects of Statutory Nuisance (SN) laws when used as a means of protection from Excessive Amplitude Modulation (EAM). This work package compliments WP6.1 – legal review by Richard Cowan.

A wind farm AM planning condition, like the Den Brook condition, is very often requested by local authorities and interested Rule 6 parties (during planning appeals) as a means of protecting local communities living near wind farms from the modulating or 'thumping' sounds coming from the rotating turbine blades. This thumping sound can be especially noticeable at night.

Statutory Nuisance (SN), the wind industry developers' recommended alternative to an (AM) planning condition, such as the Den Brook condition, (see WP4) is often used as a reason not to provide a planning control for this modulating noise.

This request is usually agreed to by the Planning Inspectors adjudicating wind farm appeals despite them being separate legislative regimes and there being a lack of expertise within the Inspectorate regarding the limitations of statutory nuisance. Statutory Nuisance does not offer the same protection in law as a clearly defined (AM) planning condition and is subject to many hurdles not found with planning procedures. Most wind farm approvals

have no mention of AM noise controls or Statutory Nuisance at all. As we see from WP6.1 these local populations then have no effective protection from EAM noise emissions.

Activation of SN provisions is normally instigated by a formal complaint to the local authority, although there is a duty to inspect their area for nuisances. Theoretically a local authority aware of nuisance problems should inspect to assess if they exist, but this is rare. Furthermore, if residents acquiesce to the noise it is not then considered a nuisance and almost always a complaint is required to trigger action. Local authorities will also not act unless a complaint is made on what they term a 'formal' basis. Anonymous complaints are not normally acted upon as impact involves assessing levels inside dwellings, especially in relation to night time. The process places onus on the residents to complain and endure the additional interruptions and impact upon their lives of making a complaint. This can be substantial and can potentially blight theirs and their neighbour's property since there is a legal duty to reveal such complaints if they subsequently seek to sell.

This process is logically the wrong way round. It should be a legal requirement for wind farm operators to ensure compliance, and that they are not causing unreasonable impact within communities. They should be able to prove the noise generated by their turbines is kept below agreed levels which are known to be harmful or cause annoyance. Wind farm operators effectively introduce the noise pollution and profit from the activity. It is not unreasonable that they should be legally obliged to ensure they do so without detriment or harm to others.

In the event of public infrastructure developments such as new road and rail systems, compensation procedures developed under the Land Compensation Act are in place to help protect those affected. This is not triggered with wind farms and other private development despite the wind power objective of providing a national energy resource. This means a minority suffer without protection for the claimed benefits of the majority.

In the absence of other forms of national protection it falls to the local authorities to ensure they have the facility and ability to monitor these noise levels to ensure and prove compliance by the turbine operators and confirm (or not), in the case of noise complaints from the community, the validity of any complaint by immediate reference to the recorded evidence. Currently any general noise compliance checks are passed to the operators to self-regulate and then inform the planning authority of their results. Reducing energy production in order to reduce noise has significant financial impact for operators. There should be no reason for regulators to not directly check compliance and put in place the resources to enable independent verification.

The way Statutory Nuisance is currently being used as a means of protection of local communities from wind farm noise should cause serious concern to legislators and organisations using this legislation, at both a local and national level. Statutory Nuisance is described as a 'summary procedure' which indicates it should provide a quick remedy. This may be feasible with simple issues such as excessive music noise from the house next door but does not seem to work in complex cases involving large financial investments where the pressure to appeal and fight any action is substantial. The Statutory Nuisance process can take many years in practice. In the case of Cotton Farm wind farm in Cambridgeshire,

investigations of nuisance complaints continue for more than two years after they first started operation without any indication whether the local authorities are minded to take action. If they do, then several years of process are likely to follow. Once this process is exhausted there is a risk of a fine not greater than £20,000 to the operator which is similar to the likely income in one week from one turbine. It is therefore not a deterrent in any event.

If a Council were successful in serving a noise abatement notice and this was upheld by the courts, perhaps several years later, then any prosecution faces a risk of the wind farm changing ownership. This would mean the whole process has to start all over again from the beginning. A wind farm operator could continue this for many years.

The use of Statutory Nuisance in place of an AM planning condition seems to have, in the author's opinion, the singular effect of ensuring the wind farm operators have no legal responsibility in controlling wind turbine AM noise output. Also they seem to have no responsibility to monitor noise output, or to prove absence of nuisance / compliance in case of complaints. Nor do they have the legal responsibility for ensuring the AM noise keeps below the 3dB peak to trough maximum limit identified in research as causing adverse impact. The wind industry's noise guidance, ETSU, has allowed for a small degree of AM of up to 3dB when close to turbines (50m) which diminishes further away. It is clear any AM greater than this or further from the turbines, is excessive and is not covered by the noise controls.

Wind farms are not currently monitored routinely for noise and no recordings are made. Therefore it is impossible for any action under Statutory Nuisance to be implemented by any local authority because there is no actual evidence for the Council to act on or use. Even if a local authority did serve notice on operators of their view of nuisance and the notice was subsequently upheld by the courts, prosecution then has to follow this process; and there is no requirement on the Council to prosecute for a breach. This is probably one of the reasons why there has been no legal redress under Statutory Nuisance despite country wide complaints about wind farm noise. Whilst theoretically there is protection, in practice none exists. It is akin to a parking fine being much smaller than the parking fee. It is cheaper to take the fine than pay for parking in the same way it is much cheaper to fight statutory nuisance action and continue operating risking any fine than addressing the problem. The courts have been clear other remedies will not be considered until the abatement notice route and prosecution has been exhausted.

WP6.1 examines the legal and practical use of Statutory Nuisance with regards to its use with wind farms. Its conclusion argues that the use of Statutory Nuisance, in place of an AM planning condition, such as the Den Brook AM condition, only serves to protect the wind farm operators' investments at the expense and possible health of the communities living near wind farms. It is essential wind farm developers and operators are held to account for their activities by the use of a fair, legal, easy to use and, above all, a provable AM Planning Condition that protects communities.

Work package 9 – The Cotton Farm Monitor Experience

At WP9 Bev Gray provides a review of a rural community's experience in setting up and carrying out long term continuous noise monitoring and recording of wind farm noise. This work package examines one community's experience affected by just one wind farm in Cambridgeshire. This particular case is important for three reasons:

A. The experience of fighting a wind farm proposal followed a similar pattern experienced by many other communities throughout the UK.

B. Unlike most wind farm action groups, this one community did not give up when the wind farm was given planning consent against the opinion and wishes of the community, its council officers, councillors, the council determination panel and its MP's. The local community were not reassured by the developers stating the wind farm would not generate any significant noise. They decided to install a noise monitoring system.

C. The installation and the development of the methodology for noise monitoring at Cotton Farm, along with the meteorological data, could be a blue print for monitoring wind farms by local authorities, local communities and wind farm operators elsewhere. It allows for the continuous recording of noise data, including audio, from the wind farm to ensure compliance by the operators and allow records of the noise output of the wind farm in cases of complaints and breach of conditions of ETSU dB levels and EAM noise to be revisited and be used in evidence.

The wind farm noise data, including audio recordings, which can be accessed on line at: http://www.masenv.co.uk/~remote_data/ can be used to ensure compliance by the operator and provides evidence of the noise output of the wind farm in cases of complaints. It also provides data to allow assessment of any breach of noise planning conditions or the assessment of EAM.

The community noise monitor at Cotton Farm has shown that the operational turbine noise dominates and raises the continuous ambient background noise especially at night. The original ETSU compliant noise assessment by the developer subsequently forming the basis for the approved planning conditions is currently under investigation by the local authority.

More disturbing is the frequent occurrence of the irregular and disturbing 'beat' of EAM ranging from 5dB to 10dB peak to trough; occasionally even higher. The monitor data is available as evidence, supporting the many noise complaints to the local authorities by local residents. The recordings provide incontrovertible evidence of the frequency and duration of impact which is critical to any enforcement decision.

The Cotton Farm monitor experience has demonstrated that existing wind turbines should be constantly monitored and the data recorded. There has to be a clear understanding of the problems caused by noise and a clear directive for immediate action by the authorities and operators when unacceptable noise conditions do occur. The experience pioneered by

the local community around the Cotton Farm wind farm proves this is both essential and practical.

The continuing exercise in the re-evaluation of Cotton Farm noise profiles by the local councils, with the co-operation of the owner of the wind farm during 2015 is encouraging. Monitoring wind farm noise by the community and re-evaluation by the local authorities has never been done before, and with all the data and audio recordings from the noise monitors, wind farm met mast and the turbine SCADA data, the noise profile of a wind farm will, possibly for the first time, reveal the truth regarding noise generation from an operational wind farm. Comparisons with the original EIS assessment data will also be worth examining. None of this would have been possible without the installation of the community noise monitor in Graveley.

The Cotton Farm noise monitor experience has demonstrated the value to local communities of continuous noise monitoring and validates the recommendation of the Northern Ireland Assembly report[14], January 2015, that long term monitoring of wind farm noise should be established for all wind turbine installations.

F. The Wind Industry Response to AM

The lack of confidence by wind farm resident groups in the IoA wind turbine noise working groups and the long term obfuscation by the wind industry regarding wind turbine noise and amplitude modulation provided the justification for the INWG to include a report on the actions of the IoA noise working groups and its AM study.

Work package 8 – Review of IoA AM study and methodology

At WP8 Richard Cox reviews the more recent activities of the Institute of Acoustics and its Noise Working Groups with respect to wind turbine noise amplitude modulation.

The announcement[19] on 1 August 2014 by the Institute of Acoustics (IoA) that it was forming a new amplitude modulation working group (AMWG) to study and report on wind turbine noise amplitude modulation (AM) was met with a great deal of scepticism by the resident groups fighting for protection against wind turbine noise. It was this announcement that resulted in the creation of the Independent Noise Working Group (INWG) and this independent AM study.

Ever since the current wind turbine noise guidelines known as ETSU-R-97 were produced by a joint wind industry and government committee during the mid-1990s there have been repeated accusations of conflict of interest aimed at the IoA noise working groups and the relatively small group of acousticians involved in wind power development. This small group of acousticians, who are effectively part of the wind industry supply chain, have managed to dominate the IoA and government policy regarding wind turbine noise assessment for two decades.

As a result more permissive noise assessment guidance exists for wind turbines than for any other form of industrial activity and, unusually, this guidance allows for higher noise levels at night than during the daytime. It is therefore not surprising, as demonstrated at WP3.1, WP3.2 and WP2.2 that there is a much higher incidence of noise complaints and reports of the harmful effects arising from wind turbine noise than the wind industry has admitted.

Since the launch by the IoA of their AM study during August 2014, their schedule has continued to slip and the scope has changed significantly. Initially the main objective of the AM study was to develop a standard planning condition with threshold limits and penalties for AM that would be included as a Supplementary Guidance Note (SGN) to the IoA Good Practice Guide (GPG). The original schedule indicated a consultation period starting during September with completion of the study by the end of 2014.

During October 2014 the IoA AM study scope changed[20, 21] to exclude the planning condition thresholds and penalties. The remaining objectives related to the measurement process to identify and quantify AM. Additionally, two members of the main IoA NWG (Cand and Davis) were added to the already wind industry dominated AMWG. The study schedule was also extended with the consultation period delayed from September 2014 to February 2015

Additionally, during late 2014 the Engineering Council received more than 20 complaint letters concerning alleged unprofessional and unethical conduct by the IoA NWG. Most if not all of these complainants had experience of challenging wind turbine industry noise assessments.

Coincident with (and possibly in response to) these complaints, the IoA published an unusual statement[10] on its web site during December 2014 that included a defence of the ETSU Good Practice Guide (GPG)[18] and the methodology adopted by their NWG for the treatment of wind shear during the noise assessment process. The IoA Dec 2014 statement[10] included; "*This methodology had been subjected to substantive scrutiny and debate at a number of inquiries in front of planning inspectors, but the counter evidence was dismissed, and the methodology became accepted practice*". The implication of this statement is that the IoA, a supposedly professional body licenced by the Engineering Council, would appear to be satisfied to allow Secretary of State appointed Planning Inspectors, who have little or no acoustic knowledge, to determine the scientific arguments relating to wind shear.

With reference to the GPG consultation, the IoA Dec 2014 statement[10] continued with: *"It had been the working group's intention to provide a full rebuttal of information that was submitted that was not judged to represent 'good practice'. However, the working group considered that the various consultation responses had already been presented to a number of public inquiries where rebuttal evidence and inspectors reports from these inquiries already addressed all the points raised and that this information was already in the public domain*". Once again the IoA position is absurd and untenable; no other professional, let alone scientific body would delegate the responsibility of technical rebuttal to a planning inspector whose expertise is in Town Planning.

After further delay, the IoA AMWG finally released their AM study consultation documents on 23 April 2015, Irvine[11], April 2015, with a closing date for comments of 30 June, indicating the study would be completed by the end of 2015. These proposals present serious concerns to anyone requiring an open scientific discussion and resolution to the AM noise problem. These concerns include:

- The consultation takes a very narrow view of the AM issue ignoring the vast body of scientific evidence as reviewed and summarised at WP2.1. The IoA consultation ignores any low frequency or infrasound components by filtering out data below 100 Hz. Any mention of low frequency noise (LFN) or infrasound is conspicuously absent.
- There is no mention of any intention to measure AM inside homes where the greatest impact is usually experienced.
- There is a clear AMWG preference for an automated method based on analysis in the frequency domain at blade passing frequency. However, this method ignores sound components outside the imposed limits allowing significant scope for opacity and under-measurement of AM.
- There is also a failure to recognise that the Class 1 instrumentation recommended by the IoA is unsuited for the low background noise environments and low frequency requirements that may be necessary when measuring wind turbine noise. This is due to the instrumentation's limited noise floor and frequency range.

The recent decision by DECC to award the contract for an '*independent study into AM*' to WSP/Parsons Brinckerhoff ensures that Richard Perkins as Technical Director of the Acoustics, Noise & Vibration Team at WSP/Parsons Brinckerhoff and also until recently as Chairman of the IoA NWG and a senior member of the IoA Council is now able to orchestrate and influence both AM studies.

This chronology of the activities by the IoA detailed at WP8 shows that it's NWG and specialist subgroup the AMWG devoted to the study of excess amplitude modulation have continued to operate for the benefit of the onshore wind industry in the UK and to the detriment of local communities hosting wind turbines. This is also arguably against both the IoA Code of Ethics and that of the Engineering Council. The effect has been to both obfuscate and hide problems related to wind turbine noise assessment from government and from the Planning Inspectorate. Whether or not this behaviour is carried forward into the future remains to be seen (October 2015).

5. Conclusions and Recommendations

After conducting a comprehensive twelve month study of wind turbine noise amplitude modulation, the INWG reports have concluded:

- There is irrefutable evidence presented at WP2.1 and WP2.2 supported by the survey results presented at WP3.1 to show that EAM is a frequent occurrence potentially affecting all industrial wind turbines, often for long periods of time and most frequently during the night time. The wind industry claim and that of acousticians on the IoA NWGs that EAM is rare and infrequent has been thoroughly discredited.

- The Local Planning Authority (LPA) survey presented at WP3.1 shows that not only are incidents of EAM more frequent than the wind industry hitherto has claimed, the progress in resolving them is inconclusive and there are inconsistent approaches to dealing with it across the country. Some LPAs have agreed curtailment of operation with the wind turbine operators while investigations continue; others have only proceeded with investigations. None of the LPAs described a working mitigation for EAM other than curtailment. LPA's in the survey call for guidance on measuring and testing for EAM as well as nationally agreed standards that are consistently applied and provide effective mitigations for it. There is also anecdotal evidence of a 'silent majority' who suffer in silence without knowing how to complain, not wanting to get '*involved*' or because of a fear of adverse implications; if, for example, they had to disclose any complaint should they wish to sell their house.

- It is abundantly clear from the evidence examined by Dr Hanning at WP3.2 that wind turbine noise adversely affects sleep and health at the setback distances and noise levels permitted by ETSU. There is no reliable evidence that wind turbines are safe at these distances and noise levels, not a single study. In contrast there is an increasing volume of studies and evidence outlined to the contrary. There is particular concern for the health of children exposed to excessive wind turbine noise. The inadequate consideration of EAM is a major factor in the failure of ETSU to protect the human population.

- There is irrefutable evidence presented at WP3.2 and WP2.1 to discredit wind industry and government claims that ETSU[6] provides a robust noise assessment methodology. This conclusion is supported by the recent Northern Ireland Assembly report[14], January 2015 inquiry into wind energy where it recommends, "*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 wind industry claims that an AM planning condition is not necessary and that the legal remedy of Statutory Nuisance provides adequate protection are thoroughly discredited by the evidence presented in WP6.1, WP3.1 and WP6.2. Without an AM planning condition there is no effective remedy for wind farm neighbours against excess noise except, for example, to take civil or statutory nuisance action.

However, nuisance action typically requires substantial financial resources, is a prolonged process and is at risk of being circumvented in a number of ways. In general therefore there is not a practical or affordable remedy for members of the public in the absence of planning controls.

- The Private Members Bill in Parliament introduced by David Davis MP during July 2015 highlighted the need for wind farm operators to hold public liability insurance for any nuisance including noise nuisance they may cause. This Bill highlighted the widespread practice by developers of setting up a shell company with very limited assets to operate the wind farm. This way the parent company may be able to divest itself of any legal responsibility for any nuisance it may cause, further complicating any legal remedy.

- The need to monitor wind farm noise to ensure ETSU compliance and provide evidence to pursue noise complaints has been made clear at WP6.1 and WP6.2. Currently there is no requirement for wind turbine operators to monitor noise or prove compliance with ETSU noise limits. The requirement for long term monitoring is also a recommendation of the Northern Ireland Assembly report[14], January 2015: "*the Department should bear responsibility for ensuring that arrangements be put in place for on-going long-term monitoring of wind turbine noise*". A case study of a successful long term noise monitor at the Cotton Farm wind farm is described at WP9.

- The relevance of EAM in causing noise complaints has driven the wind industry to ensure that an AM planning condition is not applied as standard planning practice. The application of an AM planning condition to the Den Brook wind farm planning consent during 2009 presented a serious risk to the wind industry of such a planning condition becoming the standard for future wind farm consents. At WP4 Mike Hulme details the enormous effort Renewable Energy Systems (RES), the wind farm developer for the Den Brook wind farm has gone to over the last 8 years to ensure first that an AM planning condition is not applied, then to have the applied planning condition removed, and finally to have it sufficiently weakened presumably to ensure it prioritises operation of the wind farm rather than provide the intended protection against EAM. Although fronted by RES, the Den Brook wind farm proposal became a national test case for the wind industry to do whatever was needed to prevent the Den Brook AM condition becoming 'the standard' for planning approvals. WP4 describes a '*decade of deception*' as RES and the wind industry placed their commercial interests above the health and residential amenity of local residents.

- There is irrefutable evidence presented at WP1 and WP2.1 to show that low frequency noise (LFN) is a significant and relevant component of wind turbine noise and AM. This evidence thoroughly discredits the wind industry claims supported by the main IoA NWG acousticians that LFN is not relevant to wind turbine noise assessment.

- WP1 identifies the significance of mechanical resonances of towers and blades in generating LFN and challenges the scientific justification for the wind industry practice of actively filtering out all noise data below 100HZ, an extraordinary effort to remove something which, it is claimed, does not exist.

- Five methods of AM control were tested as part of WP5:

  1. The ReUK template planning condition was found to be significantly flawed in a number of respects including imprecise condition wording, an inability to filter extraneous noise, and false negatives. Application of a simple decibel penalty applied to existing ETSU limits was found not to enforce control over impact in the most serious and significant of cases. It is concluded that the RUK method is unfit for purpose.
  2. A methodology proposed by RES for the Den Brook case, like the RUK method, is flawed in a number of respects including imprecise wording, an inability to filter extraneous noise, false positives and also false negatives. The values of AM that are derived by the RES method do not appear to relate to the A weighted modulation depth or subjective impression. Due to the flaws listed above it is not recommended as a standalone assessment method.
  3. The original Den Brook EAM condition was found to work well with the data from all six sites tested and successfully identified EAM without being influenced by extraneous noise. Much of the success depends on its interpretation and implementation. Of note, it is implicit that it should not be used as a simple trigger value and that an assessment of frequency and duration must be made by the assessor. This is consistent with other UK planning noise controls and guidance on enforcement policy.
  4. The Japanese DAM rating method is not a condition but a rating method. Though influenced by extraneous noise, it works well to identify periods of EAM and periods of borderline AM. It successfully identified EAM and distinguished between borderline periods of unobtrusive AM and EAM.
  5. BS4142 has previously been dismissed, both in ETSU and by others, as an inappropriate means of control for wind farm noise. The issues raised to support this argument have been examined and found inapplicable to the new version of the standard[3] (2014). BS4142:2014 was found to work very well for assessment and control of cumulative wind farm noise and character impact, subject to the need for an additional mechanism where there is significant LFN which it does not address. BS4142 is advantageous over separate EAM assessment methods as it assesses noise level and character simultaneously and in context with the character of the area.

- All three of the methodologies for assessing AM being proposed by the IoA AMWG in their 2015 consultation document have been shown to be significantly flawed during preliminary testing as part of WP7. The results from this preliminary testing indicate that all three methods present significant problems where they do not reflect or mirror impact. Method 2 should be abandoned. Methods 1 and 3 also present significant difficulties though method 1 based on the Japanese DAM method may have some limited benefit as a supportive tool when applying other methods of

analysis. As concluded in WP5, current tools and knowledge do not support or facilitate an automated and standardised metric for EAM.

- The wind industry strategy of obfuscation capitalising on the IoA's trusted position as a scientific institution is discussed in WP8 and WP1. We find that the IoA through its wind turbine NWG and latterly its specialist subgroup the AMWG devoted to the study of excess amplitude modulation have consistently operated for the benefit of the onshore wind industry in the UK and to the detriment of local communities hosting wind turbines. This is also arguably against both the IoA Code of Ethics and that of the Engineering Council. The effect has been to both obfuscate and hide problems related to wind turbine noise assessment from government and from the Planning Inspectorate. Whether or not this behaviour is carried forward into the future remains to be seen (October 2015).

Recommendations

The INWG make the following recommendations:

- Based on the INWG findings at WP2.1, WP3.2 and WP5 we believe a first step towards protecting communities from wind turbine noise amplitude modulation would be to replace the use of ETSU as recommended by the Northern Ireland Assembly report[14], January 2015. ETSU should be replaced with a procedure based on the principles of BS4142: 2014. This will bring wind turbine noise assessment into line with other industrial noise controls. New guidance of this type should be formulated in a Code of Practice that sets out a BS4142: 2014 type methodology that reflects noise character and relates impact to the actual background noise level and not an artificial average.

- Based on the findings in WP6.1, experience at Cotton Farm described at WP6.2, and elsewhere it is recommended that an effective AM planning condition should be part of every wind turbine planning approval unless there is clear evidence it is not needed. For assessing and controlling wind turbine noise AM, it is recommended that:

  1. Where wind turbine noise level and character require simultaneous assessment then BS4142:2014 should be used. The rated wind farm noise level should not exceed +10dB above the background noise level.
  2. Where only wind turbine noise AM requires assessment then a Den Brook type planning condition could be used.

- Continuous noise monitoring of wind turbines should become a standard planning condition for all wind turbine planning approvals as recommended in the Northern Ireland Assembly report[14], January 2015. This should be funded by the wind turbine operator but controlled by the LPA with the noise data made openly available to ensure transparency. The Cotton Farm community noise monitor described at WP9

provides an example of how this can be achieved.

- There is a need to 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 as recommended in the Northern Ireland Assembly report[14], January 2015.

- The government should deal decisively with the ethical issues surrounding the Institute of Acoustics wind turbine noise working groups described in WP8. Government departments should disassociate themselves from the IoA until conflict of interest issues are resolved and full transparency is restored.

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