INWG WIND TURBINE AMPLITUDE MODULATION & PLANNING CONTROL STUDY

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1 ABSTRACT

The Independent Noise Working Group (INWG) formed during August 2014 is an independent group of concerned experts and non-experts having no connections with the wind industry supply chain. The objective of the INWG being to conduct an independent and scientific study into wind turbine noise AM that is able to credibly challenge the methodologies and findings of the IoA sponsored AM study published to date.

The INWG study conclusively demonstrates that EAM is a frequent occurrence and that wind turbine noise adversely affects sleep and health at the setback distances and noise levels permitted by ETSU. There is irrefutable evidence presented to discredit wind industry claims that ETSU provides a robust assessment methodology. Evidence related to low frequency noise (LFN) and its relevance to wind turbine noise assessment is also examined. The need for an AM planning condition is considered and the situation surrounding the Den Brook wind farm AM planning condition is investigated. Methods of AM control have been tested including the methodologies being proposed for assessment by the IoA AMWG. The study concludes with recommendations for a more robust noise assessment process including the control of EAM.

2 INTRODUCTION

The principal tool used to justify wind turbine noise assessments has been the ETSU[4] noise guidelines published by the UK Government during 1996 and relating specifically to wind turbines. However, despite the dramatic increase since the 1990s in the size of turbines now being deployed and mounting evidence[1, 3] that ETSU[4] 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 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.

On 1 Aug 2014 the Institute of Acoustics (IoA) announced, *Perkins[8], Aug 2014* that it was setting up an amplitude modulation working group (AMWG) as a sub-group of its main wind turbine noise working group (NWG). 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 developments.

With these concerns surrounding the IoA sponsored AM study and 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 during August 2014 to independently review the wind turbine noise phenomena known as amplitude modulation.

The INWG released its terms of reference document[5] 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 were targeted for spring 2015, since delayed to summer 2015.

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 as shown at Table 1. Each work package was reviewed by group members and where relevant by third party reviewers. The findings of the individual work packages were then consolidated into a summary report designated INWG WP10.

The INWG are a multi-disciplinary team fully independent of the wind industry supply chain with expertise or access to expertise including acoustics, environmental health (LPA), health & sleep, legal & planning, physics, meteorology, statistics & data analysis. The INWG steering committee consists of:

- Richard Cowen, LLB: 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 the 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 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: Senior Acoustic Consultant, MAS Environmental
- 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.

Work Package	Work Package Subject	Lead author
1	Define and quantify 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	Draft AM planning condition	Sarah Large
6.1 & 6.1A	Legal remedies	Richard Cowen
6.2	Community experience of Statutory Nuisance	Bev Gray
7	Test of the IoA AMWG methodologies	Sarah Large
8	Review of IoA AM study and methodology	Richard Cox
9	The Cotton Farm monitor experience	Bev Gray
10	Study summary	Richard Cox

Table 1: Work package division of work

3 INWG AM STUDY INVESTIGATIONS

The purpose of the INWG study is to determine primarily the science and evidence behind wind turbine noise AM and then to determine an effective control methodology. From this assessment it was possible to arrive at a set of recommendations that can be applied to ensure people living near wind turbines can be protected from noise nuisance and adverse health effects. The INWG study has focused on six key areas when investigating wind turbine noise AM.

3.1 How AM Affects People, Is There A Problem?

At WP3.1 Trevor Sherman analysed responses from a survey of local planning authorities (LPAs) to determine the extent of the wind turbine noise problem across England. 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 survey 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?

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. Importantly 47% of LPAs with industrial wind turbines in their districts reported receiving noise complaints.

Of these 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.

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. 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, or because of a fear of adverse implications, if, for example, they had to disclose any complaint should they wish to sell their house. In summary the wind industry's claim that EAM is rare and infrequent is proven to be wrong by the survey evidence presented in WP3.1.

At WP3.2 Dr Christopher Hanning summarizes the effects of EAM on people living close to wind turbines including annoyance, sleep disturbance and health effects through a review of the available health related literature. Excessive noise is harmful to human health, particularly through adverse effects on sleep and regulation of wind turbine noise is recognised as necessary to prevent adverse effects on the human population.

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 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.

3.2 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 and should be included unless there are clear reasons not to. However, it also has to be acknowledged that there are procedures to be followed and these can take time.

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 than alternative approaches such as Statutory Nuisance.

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.

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

A 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. WP6.1A considers how this may affect any action by a resident bringing a claim for nuisance and agrees with the MP's suggestion that insurance is required.

3.3 The Science Behind AM

At WP1 Dr John Yelland investigates the science behind wind turbine noise and amplitude modulation and explores the true characteristics of EAM investigating its likely sources. Attention is also drawn to some serious errors in publications masquerading as objective academic research and to the paucity of truly independent competent research that has been available to or sought by government. WP1 discusses:

Blade stall at zenith
Local stall at blade zenith has been declared by the wind industry to be the sole cause of EAM. This hypothesis is attractive as well as persuasive, as dynamic control of the blade pitch to maintain the optimum angle of attack throughout the 360º of rotation would be an obvious solution, and would also increase power generation. A system to continuously monitor and adjust the angle of attack within the short timescale of the blade rotation period would entail a major development project for turbine manufacturers. Neither Government nor the wind industry have proposed any useful means of protecting wind farm neighbours from EAM until that development is completed, and we find no evidence that it has begun.

Oerlemans' adjustments
Unfortunately the local stall hypothesis simply cannot explain the observed high levels of EAM, as is shown by Oerlemans in the first paper in the ReUK December 2013 AM study[10]. 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 to the 3 dB prediction, and here we quote from the paper, "*to obtain the desired 10 dB overall noise increase*".

We believe that the Oerlemans predicted 3 dB increase in modulation depth is correct, and does account adequately for some of the lower level occurrences of EAM. There is however clearly some other explanation required for the higher levels of modulation, which may be less common but are certainly even more troublesome.

Mechanical resonances
As recently as 2012 Bass, of developer RES, proposed to a EWEA Noise Workshop: "*At least 4 possible theoretical explanations as to cause of OAM:*

1. *Same explanation as for near-field AM, we just got something wrong!*
2. *Turbulent eddy shedding - vortex streets & trailing edge serrations*
3. *Blade tip stall due to high angles of attack*
4. *'Flanging' - possibly caused by stall-induced blade vibration*"

Dr Yelland agrees with all these explanations and additionally, proposes with great confidence tower resonance, having been inside a tower when it was resonating. Yelland also agrees with Bass that objective research remains to be done.

Blade and tower resonances pose significant problems for the manufacturers of modern wind turbines. There are many papers published in this field, but the concern has been structural integrity, not noise, so it is in the structural dynamics journals that they are to be found. WP1 shows how flexible and how elastic turbine blades are and how tower resonances can be excited when synchronised to blade passing frequencies or their subharmonics.

It also shows how vortex shedding can excite and has excited resonances in both towers and blades and how blades can produce very low frequency EAM without resonating. All of these proposed mechanisms would be expected to give rise to very low frequency resonances; if we would rather not see them we would probably study only frequencies above – say – 100 Hz.

Is there really nothing below 100 Hz?
The wind industry has long ignored all acoustic emissions below 20Hz, although frequencies below 20 Hz can be heard or otherwise perceived by the human ear. With the emergence of the EAM problem the industry now ignores any acoustic emissions below 100 Hz. In the 513 pages of the ReUK 2013 report[10] the only references to lower frequencies are emphatic assertions of their irrelevance. Interestingly the Salford University listening room tests described in the ReUK report use real wind turbine noise recordings but use a high pass filter to remove all traces of sound at frequencies below 100Hz; an extraordinary effort to remove something which, it is claimed, does not exist.

SLMs are for compliance testing, not for research
When using sound level meters (SLMs) to measure $LA_{eq,100ms}$ all original frequency information is removed. This is because SLMs rectify and integrate the noise signal. When the true turbine noise emission spectrum is known, as should always be the case when compliance testing, this is of no consequence.

If the objective is to determine, rather than to conceal, the character of EAM it is essential not to pre-judge the turbine frequency spectrum, but to measure its acoustic emissions right across the audio frequency spectrum down to the blade pass frequency. Why? Because of the fundamental equation of acoustics is: frequency x wavelength = velocity

So long wavelengths mean low frequencies and the mechanical resonant frequencies of large objects (vide infra) are therefore at low frequencies. The dimensions of musical instruments are largely dictated by their frequency range; compare a violin to a double bass, or a piccolo to a bassoon. Given the dimensions of wind turbines it is only sensible to anticipate acoustic emissions at very low frequencies.

Turning a deaf ear to lower frequency noise
It is therefore disappointing that the ReUK 2013 report[10] prefers measurement only of the $LA_{eq,100ms}$ levels from turbines, as this removes all frequency information. One can of course see a periodic amplitude variation at the blade pass frequency when examining a chart of $LA_{eq,100ms}$ versus time. But the extent to which that variation is due on the one hand to the varying amplitude in the normal aerodynamic noise from the blades or on the other hand to lower frequencies, conceivably down to

the blade pass frequencies at around 1 Hz, cannot be known, because the $LA_{eq,100ms}$ descriptor rectifies and integrates the signal, thus removing all the original frequency information.

It is rather more than disappointing that the ReUK report and the IoA AMWG have considered it appropriate to raise the 20 Hz minimum frequency used in compliance testing to 100 Hz for their AM "research".

Other work packages from the INWG clearly demonstrate that many existing wind farms cause unacceptable levels of annoyance because they have been designed, consented and built without regard to the true character of wind turbine noise in the audio spectrum. WP1 further explores the wind turbine spectrum at lower frequencies, where there is ample evidence that mechanical resonances of blades and towers can provide further unwelcome contributions to wind turbine noise. The very high power levels of these contributions appear to cause physical damage which cannot reasonably be described as just "annoyance".

Literature review
At WP2.1 Richard Cox presents the results of a review of the available literature on wind turbine noise (WTN) and AM. Over 160 documents are reviewed as part of 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.

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 in the USA during the 1980s through to the Northern Ireland Assembly inquiry report[7] of March 2015 and beyond, the key scientific aspects of WTN including AM are now well understood and defined. 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 wind turbines.

The most important conclusion from this literature review is that ETSU, the official UK noise guidance is unfit for purpose and is failing to protect wind turbine neighbours against the effects of noise including both AM and low frequency noise (LFN). The evidence regarding LFN being a significant component of WTN including AM, is compelling and demonstrates conclusively that LFN including infrasound is an integral and relevant component of WTN.

AM evidence review
At WP2.2 Sarah Large looks primarily for evidence of audible amplitude modulation noise in support of its existence and prevalence. This evidence review focuses primarily on audible AM and 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.

This WP2.2 evidence based report is conclusive that AM exists and is not an unusual or isolated problem. 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.

3.4 Effective Control of AM

At WP5 Sarah Large investigates options for the control of AM. The objectives of WP5 are defined as:

1. To conduct a review of existing or proposed methods of identifying and controlling EAM.
2. To develop and propose one or more EAM control methods for further testing with the view to use as an EAM planning condition.

3. To ensure that any EAM condition takes account of the psycho-acoustic response as far as practicable and account for other character features associated with AM (e.g. tonality, low frequency noise, impulsivity).
4. And that the final AM condition should be:
    a. Provided in a simple format that can be applied as a standard planning condition that is comprehendible to the lay person.
    b. Accompanied by relevant software or guidance notes on its application and use.
    c. Must be robust and must prevent AM that has been justifiably complained of and / or is deemed to constitute noise nuisance.
    d. Must be repeatable, giving the same result when run by different assessors.

Five methods for AM control were tested:

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 ReUK 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. It is concluded that the RES method is unfit for purpose.

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 (2014). BS4142:2014[2] 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.

At WP7 (to be released later) Sarah Large tests the effectiveness of the AM rating methodology currently proposed by the IoA AMWG in their consultation document, *Irvine[6] April 2015*. 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. To date there has been no consideration of how other characteristics might interrelate or be combined into assessment of EAM at a later stage. The results from preliminary testing indicate that all three methods proposed by the AMWG present significant problems where they do not reflect or mirror impact. WP7 will also test in more detail the as yet to be released IoA AMWG final AM rating methodology.

3.5 Community Response

At WP4 Mike Hulme documents the legal, planning and technical issues surrounding the Den Brook AM planning condition[9] (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 planning permission's intended protection against EAM. Moreover, it is considered at WP6.1 that the weakening of EAM controls brought about by LPA acceptance of a developer drafted Written Scheme is unlawful in terms of the 2011 Court of Appeal judgement.

Hulme documents the '*decade of deception*' experienced by the local community at the hands of the developer RES and its acoustic consultants. However, despite all the efforts by RES and the recently compliant local authority, the fundamental Den Brook AM control mechanism remains extant.

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 EAM. The conclusion of WP6.2 is that the use of Statutory Nuisance, in place of an AM planning condition, such as the Den Brook AM condition, only protects the wind farm operators' investments at the expense of the amenity and possible health of the communities living near wind farms.

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. 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 Cotton Farm wind farm noise data, including audio recordings, can be accessed on line at: http://www.masenv.co.uk/~remote_data/ The experience pioneered by the local community around the Cotton Farm wind farm proves this is both essential and practical.

3.6 The Wind Industry Response to AM

At WP8 Richard Cox reviews the activities of the Institute of Acoustics and its Noise Working Groups with respect to wind turbine noise amplitude modulation. This chronology of the activities of the IoA shows that its NWG and specialist subgroup the AMWG devoted to the study of excess amplitude modulation have continued to operate for the benefit of the UK onshore wind industry and to the detriment of local communities hosting wind turbines. This is arguably against both the IoA Code of Ethics and that of the Engineering Council. Whether or not this behaviour is carried forward into the future remains to be seen (August 2015).

4 CONCLUSIONS

After conducting a comprehensive twelve month study into 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 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. 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[4] provides a robust noise assessment methodology. This conclusion is supported by the recent Northern Ireland Assembly report[7], January 2015, 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.

- The practice of establishing shell companies to run wind farms should mean that insurance is required to cover claims for nuisance.

- 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. 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 a similar 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. 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.

- Serious scientific errors in publications masquerading as objective academic research are exposed at WP1 demonstrating the paucity of truly independent competent research that has been available to or sought by government. 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 for control of AM were tested as part of WP5. The methods were tested with a large library of data including single turbines, wind farms, different turbine models and different sizes of turbines. Significant problems were found with methods based primarily on FFT analysis. These methods (ReUK and RES) frequently failed to identify periods of AM (false negatives) and in some cases identified periods of AM where there was not AM (false positives). The wording of the condition in both cases (RES and ReUK) presented significant problems in interpretation and implementation of the condition including manual checks and a penalty system that failed to prevent adverse impact in some of the worst cases. Other non-automated methods were found to work well. The DAM and Den Brook methods successfully identified and distinguished between adverse EAM and AM that might be considered acceptable. These methods benefit from simplicity of implementation and whilst potentially susceptible to extraneous noise, third octave filtering and post processing checks can quickly separate extraneous noise from non-extraneous noise. BS4142:2014 was found to successfully identify periods of adverse impact and has the benefit of a holistic approach accounting for context, noise character and the general level of wind farm noise. However, it does not address low frequency noise contribution.

- WP 5 recommends that where wind farm noise level and character require simultaneous assessment, BS4142: 2014 or a procedure based on the true principles of BS4142: 2014 could be used with, for example a control that the rated wind farm noise level should not exceed +10dB above the background noise level. Where wind farm noise EAM only requires assessment then the Den Brook condition could be used.

- The complicated nature of impact where different contributing character features arise, require separate methods of identification and different methods for identification of distinct character features, indicates the need for a Code of Practice (CoP). A CoP could address priority and approach to the evaluation of impact in different cases. A way forward for planning control based on implementing a scheme using CoP procedures is to be explored in an addendum report to WP5 to be released at a later date.

- All three of the methodologies for assessing AM being proposed by the IoA AMWG in their 2015 consultation document[6] 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 noise working groups 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 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 (August 2015).

5 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[4] 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[2] 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 backed by insurance 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[2] 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[7], January 2015. This should be funded by the wind turbine operator but controlled by the LPA with the noise and SCADA 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[7], January 2015.

6 REFERENCES

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5. INWG (Oct 2014) Wind turbine amplitude modulation & planning control study terms of reference
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7. Lo, A (Jan 2015) Northern Ireland Assembly, Report on the inquiry into wind energy
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