



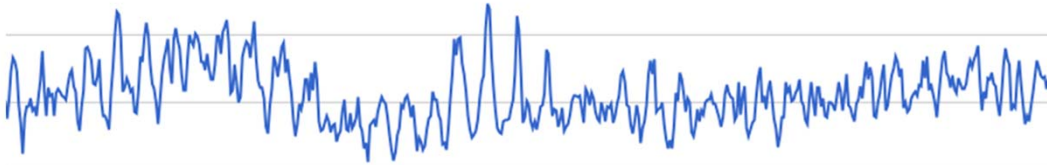
Independent Noise Working Group

Wind Turbine Amplitude Modulation and Planning Control Study

Institute of Acoustics Conference

Harrogate - 15 October 2015

Richard Cox



Today I will provide an overview of the Independent Noise Working Group's AM study and findings.



Independent Noise Working Group

Amplitude Modulation Study

- **Introduction**
- **Methodology**
- **Findings**
- **Recommendations**

INWG report download:

<http://www.heatonharris.com/reports-publications>

INWG contact: wind-noise@tsp-uk.co.uk

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Or by contacting us at this email address: wind-noise@tsp-uk.co.uk and we can provide links to download the INWG reports and reference material

So who and why the independent noise working group?

For many years there has been denial by the wind industry and its acousticians of wind turbine noise problems including:

Excess Amplitude Modulation;

The need for an AM planning condition;

And ill health effects from wind turbine noise;

We have also seen the continued defence of ETSU and its recent Good Practice Guide.

And there has also been a total failure of the planning and legal systems to provide effective protection for those suffering turbine noise and EAM.



Independent Noise Working Group

Amplitude Modulation Study Introduction

- **INWG formed August 2014 by a diverse group of experts and non-experts**
- **To conduct an independent study into AM that is able to credibly challenge the IoA AMWG findings and methodologies**
- **Study objective: To provide reasonable protection for wind turbine neighbours from wind turbine noise including EAM**

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It was the announcement last August by the Institute of Acoustics that it was forming an AM working group with the objective of recommending an AM planning condition that caused great concern with community groups across the country.

It was with a background of memories still fresh from the ETSU Good Practice Guide consultation and the lack of confidence in the integrity of IoA noise working group that the INWG was formed.

It was recognised that an essential requirement of the INWG was that must be able to credibly challenge the AMWG findings and recommendations.

To achieve this the INWG brings together a wide range of expertise, not just in acoustics but physics, health & sleep, legal and planning with relevant qualifications and experience that not only equal but exceed that of the AMWG.



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Amplitude Modulation Study Introduction

- **Sponsored by**
 - Chris Heaton-Harris MP
 - National Alliance of Wind Farm Action Groups
- **Target customers:**
 - Department of Communities & Local Government (DCLG)
 - Department of Energy and Climate Change (DECC)
 - Department for Environment, Food and Rural Affairs (DEFRA)
 - Department of Health

Total independence from the wind industry

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The INWG also brings strong political and community support and the study findings have already been presented to government ministers.

The INWG is also differentiated from the AMWG by being totally independent from the wind industry with our work being funded by the individual group members.



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Amplitude Modulation Study Methodology

The INWG study investigated:

- **How AM affects people**
- **Legal remedies**
- **Community experience**
- **Science behind AM**
- **Control of AM**
- **Wind industry response**

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After more than 12 months work the study has covered all aspects of wind turbine noise and amplitude modulation.



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Amplitude Modulation Study Methodology

Work packages for completion summer 2015

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	Draft AM planning condition	Sarah Large
6.1	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	Report summary	Richard Cox

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The study developed into 12 work packages plus an overall summary report.

Most work packages have already been released.

Now to the key findings.



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Amplitude Modulation Study Findings

How AM affects people: Occurrence

- WP2.1 , WP2.2 and the LPA survey at WP3.1 show that **EAM is a frequent occurrence, often for long periods of time**
- The LPA survey results presented at WP3.1 shows that progress in resolving complaints is inconclusive with inconsistent approaches to dealing with it across the country
- 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

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Firstly Occurrence

The LPA survey was launched by Chris Heaton-Harris MP who wrote to the Chief Executives of 265 LPAs in England and the results were analysed by Trevor Sherman at WP 3.1. The survey showed that 47% of LPAs with turbines in their districts reported receiving complaints.

So not only are incidents of EAM more frequent than the wind industry has admitted, we find 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 sadly anecdotal evidence of a 'silent majority' who suffer in silence without knowing how to complain, not wanting to complain or to get 'involved' .

We believe we are only seeing the tip of the iceberg.



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Amplitude Modulation Study Findings

How AM affects people: Health effects

- It is 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 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

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Now health effects

WP3.2 has been produced by Dr Chris Hanning, a recognised sleep specialist, published researcher of wind turbine noise effects and expert witness. He has summarized 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.

His report discusses ETSU's ability to protect noise sensitive receptors from sleep disruption and harm to their health, and in this context to consider the contribution of EAM.

The evidence shows that wind turbine noise adversely affects sleep and health at the setback distances and noise levels permitted by ETSU .

The Government & Planning Inspectorate's current position regarding the health impacts arising from wind turbine noise is based on a lack of awareness or misinformation and is not borne out by the evidence presented by Dr Hanning.

This work package is required reading for anyone not yet convinced of the ill health effects of wind turbine noise.



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Amplitude Modulation Study Findings

Legal remedies: AM planning condition

- **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**

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Next legal remedies

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 legal arguments presented by Richard Cowen at WP6.1. This conclusion is also supported by the evidence shown at WP3.1 and WP6.2.

It is shown that without an AM planning condition, nuisance action typically requires substantial financial resources, is a prolonged process and can be circumvented by the turbine operator in a number of ways. As far as we are aware there has not been to date a successful nuisance action against a turbine operator.

Additionally, 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.

This Bill highlighted the widespread practice by developers of setting up a shell company with limited assets to operate the wind farm. This way the parent company may be able to insulate itself from legal responsibility for any nuisance it may cause, further complicating any legal remedy.



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Amplitude Modulation Study Findings

Community experience: Statutory nuisance

- No requirement for WT operators to monitor noise or prove ETSU compliance except occasionally at the start of a development
- WP6.2 demonstrates the need to monitor wind farm noise to provide the evidence to pursue noise complaints and ensure ETSU compliance
- Long term monitoring is a recommendation of the Northern Ireland Assembly report, Jan 2015: *"the Department should bear responsibility for ensuring that arrangements be put in place for on-going long-term monitoring of wind turbine noise"*

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And at WP6.2 and based on residents experience with the Cotton Farm turbines, Bev Gray clearly demonstrates the need to monitor wind farm noise to provide the evidence to pursue noise complaints.

There have been hundreds of resident noise complaints from the Cotton Farm turbines for nearly 3 years with now proven ETSU breaches and EAM recorded on over 50% of nights yet still the noise continues.

Noise monitoring is now one of the key recommendations of the Northern Ireland Assembly report.



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Amplitude Modulation Study Findings

Community experience: Cotton Farm monitor

- WP9 provides a review of a rural community's experience setting up long term noise monitoring of wind farm noise
- Has provided a huge amount of data
- The wind farm noise data, including audio recordings can be accessed on line at:
http://www.masenv.co.uk/~remote_data/

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Again at Cotton Farm, at WP9 Bev Gray describes the resident funded noise monitor.

The recordings can be accessed at this web address and it is providing highly valuable data for use locally as evidence in their discussions with their LPA and also helping to better understand WT noise and EAM.



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Amplitude Modulation Study Findings

Community experience: Den Brook

- **WP4 details the enormous effort RES, the developer for Den Brook has gone to over the last 8 years to oppose having an AM planning condition applied**
- **Den Brook became a test case for the wind industry to prevent the AM condition becoming the 'standard'**
- **Den Brook will be subjected to a Cotton Farm type community noise monitoring**

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Now Den Brook

At WP4 Mike Hulme details the enormous effort RES, the developer for Den Brook has gone to over the last 8 years to ensure first that an AM planning condition is not applied, then to have the applied condition removed, and finally to have it sufficiently weakened presumably to ensure it prioritises operation of the wind farm rather than the intended protection against EAM.

It should also be noted that since the 2011 Court of Appeal judgment ratifying the Den Brook AM condition, the wind industry has taken active steps to avoid its effect even though this is a judgment of the second highest court in the land and so sets a judicial precedent.

Also Den Brook will be subjected to a Cotton Farm type of community noise monitoring once the turbines commence operation.

Amplitude Modulation Study Findings

Science behind AM: Literature review

- WP2.1 reviews over 160 documents, of which at least 85 are technical. **Note: the IoA AMWG literature review lists a total of just 35 documents**
- The evidence confirms that EAM can and does occur frequently and often for lengthy periods for most, if not all wind turbines
- **The evidence regarding LFN being a significant component of WTN including AM, is compelling**

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The study included a thorough literature review.

Evidence reviewed spanning the past 30 years shows a clear evolution of knowledge relating both to the science behind WTN and the effects on people.

Starting with the NASA research in the USA during the 1980s through to the Northern Ireland Assembly inquiry report of January this year, the key scientific aspects of WTN including AM are now well understood and defined. This is now challenging the status quo imposed by the wind industry for the last two decades.

The evidence confirms that EAM is a frequent occurrence for most if not all turbines. It is amazing how much was known about EAM from the NASA research during the 1980s but had been conveniently forgotten and only recently rediscovered.

Also the evidence regarding LFN being a significant component of EAM is compelling.

However, it is recognised that further research is required especially regarding the effects on health from LFN. It is also apparent that despite a wealth of evidence indicating adverse health effects from audible noise, the wind industry has no plans to investigate this or amend its practices.



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Amplitude Modulation Study Findings

Science behind AM: Literature review - ETSU-R-97

- There is irrefutable evidence presented at WP3.2 and WP2.1 to discredit claims that ETSU provides a robust noise assessment methodology
- This conclusion is supported by the Northern Ireland Assembly report, (Jan 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”*

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We did not set out to produce an ETSU bashing study but the evidence is clear and conclusive that ETSU is not fit for purpose.

The Northern Ireland Assembly report is also very clear on this calling for its urgent replacement.



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Amplitude Modulation Study Findings

Science behind AM: Literature review

- Noise complaints are often characterised by '*sensation*' as being the major form of disturbance.
- Measurement using 'A' weighting may be unsuitable for WTN where low frequency components are present;
- Measurements should be made inside homes when investigating noise complaints;
- IEC 61672 compliant 'Class 1', instrumentation may be unsuitable for LFN measurement or where background noise levels are low as in typical rural areas

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The literature review also highlights that:

Noise complaints are often characterised by '*sensation*';

That A weighting may be unsuitable where there are significant LFN components;

That measurements should be made inside homes when investigating complaints;

and that Class 1 instrumentation may be unsuitable in low noise environments or where there are significant LFN components.



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Amplitude Modulation Study Findings

Science behind AM: Evidence review

- **WP2.2 looks primarily for evidence of audible AM in support of its existence and prevalence**
- **This typically relates to audible AM typically up to around 1000Hz, with the higher frequencies being more dominant in earlier studies, smaller turbines and / or near field**

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At WP2.2 Sarah Large investigates noise data for evidence of audible AM, typically up to around 1,000 Hz.



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Amplitude Modulation Study Findings

Science behind AM: Evidence review

- This evidence based report is conclusive that EAM exists and shows EAM is being 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
- The evidence supports the prevalence of lower frequency AM and AM in infrasonic frequencies, including that which does and does not relate to blade pass frequency
- Whilst meteorology may not be the sole determinant, under certain meteorological conditions adverse AM can occur for long periods

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This work package again confirms that EAM is being generated by most turbines.

There is also 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. However this is discussed elsewhere in the study being beyond the scope of WP2.2.



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Amplitude Modulation Study Findings

Science behind AM: Blade stall at zenith

- **Stall at blade zenith has been declared by the wind industry to be the primary cause of EAM. This hypothesis is attractive and persuasive as dynamic control of the blade pitch to maintain the optimum angle of attack throughout the 360° of rotation would be an obvious solution**
- **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 Dec 2013 AM study. It is of great concern that the ReUK report's interpretation draws the opposite conclusion**

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At WP1 John Yelland conducts an investigation into the science behind wind turbine noise and AM and explores the characteristics of EAM investigating its likely sources.

Local blade stall has been promoted by the wind industry as the root cause of EAM and this is an attractive answer the 'what causes it' question but the numbers simply do not add up.

They appear to have looked for evidence to support their theory rather than examine all the scientific possibilities or contradictory or unexplored explanations found by others.



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Amplitude Modulation Study Findings

Science behind AM: Blade stall at zenith

- **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**
- **However this falls short of the measured EAM modulation depths ranging from 10 dBA recognised by Oerlemans and values of 15dBA frequently occurring as reported by others**

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In the ReUK study Oerlemans shows that local blade stall accounts for only an additional 3dB of modulation depth.

There clearly has to be another mechanism behind the high levels of EAM being regularly experienced.



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Amplitude Modulation Study Findings

Science behind AM: Mechanical resonances

- Blade and tower resonances pose significant problems for the manufacturers of modern wind turbines but the concern has previously been structural integrity, not noise. WP1 shows how flexible and elastic turbine blades are and how tower resonances can be excited when synchronised to blade passing frequencies or their subharmonics
- WP1 also shows how vortex shedding can excite 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

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WP1 then discusses mechanical resonances.

It shows how flexible turbine blades are and how tower and blade resonances are excited.

It is important therefore that these mechanisms are examined and the contribution to EAM quantified. The theory indicates significant low frequency noise but we suspect the AMWG have not investigated this sufficiently.



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Amplitude Modulation Study Findings

Science behind AM: Is there nothing below 100Hz?

- The wind industry has long ignored 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 the only references to lower frequencies are emphatic assertions of their irrelevance
- 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

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We now find with the emergence of the EAM problem that instead of ignoring noise below 20Hz, generally perceived to be around the lowest frequency we can hear, it is now proposed to ignore noise below 100Hz.

And we see Salford University going to extraordinary lengths to remove frequencies below 100Hz from real wind turbine sound recordings during their listening tests.

We have clear evidence 100Hz is too high a cut off as we have many cases where noise below 100Hz is the primary or one of the primary components of EAM complaints.

Although we can show that LFN is an integral component of EAM there is still further research required to determine to what extent the LFN that we are not able to hear is harmful.

However, there is clear evidence harm is caused by audible EAM and that control of EAM can be achieved via the route of measuring audible noise using the (A) weighting. This leads to the core task of the INWG study being how best to effectively control EAM.



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Amplitude Modulation Study Findings

Control of AM: WP5

Five methods were tested:

- **ReUK template planning condition**
- **RES proposal for Den Brook**
- **Original Den Brook condition**
- **Japanese DAM rating method**
- **BS4142:2014**

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At WP5 Sarah Large reports on the testing of the available options for EAM control utilising what is probably the largest database in the UK, or globally of wind turbine noise data.

After a review of options, five methods were selected for testing.



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Amplitude Modulation Study Findings

Control of AM: ReUK template planning condition

- The ReUK template planning condition was found to be significantly flawed including imprecise wording, 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
- **Concluded that the ReUK method is unfit for purpose**

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The ReUK planning condition was found to be significantly flawed and the simple decibel penalty applied to the ETSU limits failed to enforce control in even the most serious cases of EAM.

As a result the ReUK planning condition is declared to be unfit for purpose.



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Amplitude Modulation Study Findings

Control of AM: RES proposal

- **Methodology proposed by RES for Den Brook like the ReUK method is flawed 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 relate to the A weighted modulation depth or subjective impression**
- **Concluded the RES method is unfit for purpose**

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Similarly the RES proposal was also found to be similarly flawed and is also declared to be unfit for purpose.

Both these methods are based on a Fast Fourier Transform and propose an algorithm that can be transferred to an automated process. However, both algorithms present significant problems, they both require manual input and both provide values that bear little relation to the impact being experienced.



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Amplitude Modulation Study Findings

Control of AM: Original Den Brook condition

- 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
- Success depends on its interpretation and implementation. 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
- This is consistent with other UK planning noise controls and guidance on enforcement policy

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The original Den Brook EAM condition, a time series method was found to work well with the data from all six sites tested and could be used as a stand-alone control for EAM.

It is implicit that it works as a simple trigger control and cannot assess frequency and duration. This is common with planning conditions generally and it follows its application requires assessment of the rules for enforcement including expediency as in all other limit type conditions. Qualification and quantification of the frequency and duration of impact could be incorporated if necessary.



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Amplitude Modulation Study Findings

Control of AM: DAM method

- 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

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The Japanese DAM method, also a time series rating method but not a condition, worked quite well to identify EAM.



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Amplitude Modulation Study Findings

Control of AM: BS4141:2014

- 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 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**

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BS4142:2014 was found to work very well and has the advantage over separate EAM methods as it assesses both noise level and character simultaneously and in context with the character of the area.

Importantly, the arguments made against the use of earlier versions of BS4142 have now been addressed with this latest version.

However, BS4142 in common with other methodologies does not address LFN so an additional mechanism would be required where there is significant LFN.

The complicated nature of impact where different character features arise, each requiring separate methods of identification, indicates the need for a Code of Practice that would address priority and approach to the evaluation of impact in different cases.

A way forward for planning control based on implementing a scheme using Code of Practice procedures, is to be explored in an addendum report to WP5 to be released later.



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Amplitude Modulation Study Findings

Control of AM: IoA AMWG proposal

- WP7 (**to be released later**) tests the effectiveness of the AM rating methodology proposed by the IoA AMWG
- Despite acknowledging numerous characteristics of EAM that determine psycho-acoustical response including, modulation depth, rise time, frequency content, the AMWG have focused only on modulation depth
- **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

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At WP7 Sarah Large reports on the testing of the AM rating methodologies being proposed by the AMWG.

Method 1 is a time series method being a variation of the Japanese DAM method.

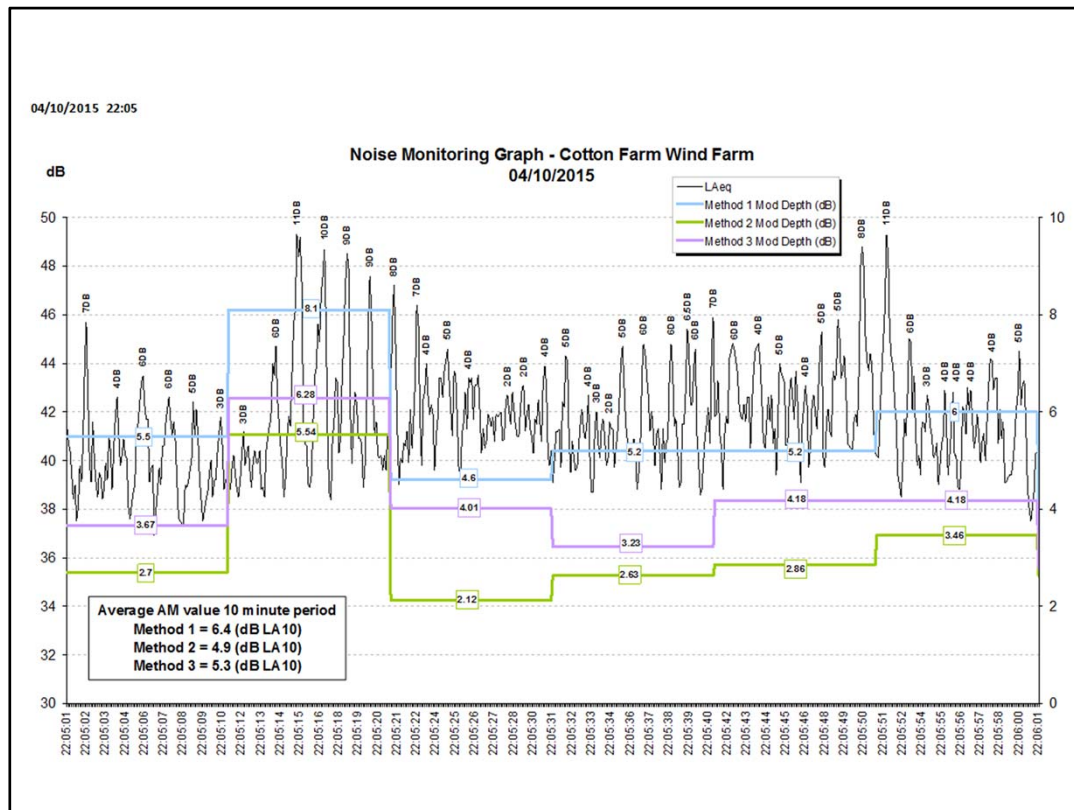
Method 2 is a FFT method similar to the ReUK and RES methods

Method 3 is a hybrid method also incorporating FFT analysis

Preliminary testing shows that all three methods present significant problems and are not fit for purpose.

With this we see again the problem arising from the AMWG assuming rather than taking an evidence based approach to impact by only considering modulation depth.

WP7 will also test in more detail the final AMWG AM rating proposal once it has been released.



This chart of data taken from the Cotton Farm noise monitor illustrates how the AMWG proposed metrics perform with real data. This shows a clear lack of consistency with significantly varying AM producing the same or similar results.

In this case the actual modulation depth is varying up to 11 dB.

Method 1 based on the Japanese DAM method significantly under reports the actual impact value showing typically values of only 6dB.

Method 2 based on the ReUK and RES method is even worse showing only 4.18dB.

Method 3 the hybrid is even worse than Method 2 showing only 3.46dB.



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Amplitude Modulation Study Findings

Wind industry response

- WP8 reviews the activities of the IoA Noise Working Groups with respect to WT noise AM
- Clear evidence that for two decades the NWGs now under the IoA have continued to operate for the benefit of the 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 (Oct 2015)

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WP8 reviews the activities of the Institute of Acoustics noise working groups.

However, there is insufficient time here to discuss in detail our many concerns other than to state that for two decades the NWGs and its small group of acousticians have continued to operate for the benefit of the wind industry and to the detriment of local communities hosting wind turbines.

The effect has been to both obfuscate and hide problems related to wind turbine noise assessment from government and from the Planning Inspectorate.



Independent Noise Working Group

Amplitude Modulation Study Recommendations

- **ETSU noise guidance to be replaced with a code of practice based on BS4142:2014**
- **Independent research is required into the health effects of wind turbine noise including EAM and LFN**
- **An effective AM planning condition required for every wind turbine planning approval**

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To conclude, the INWG recommendations already made to government are:

That the ETSU noise guidance to be replaced with a code of practice based on the principals of BS4142:2014 setting out how to implement and apply controls from measurement to enforcement.

That independent research is required into the health effects of wind turbine noise including EAM and LFN

That an effective AM planning condition is required for every wind turbine planning approval



Independent Noise Working Group

Amplitude Modulation Study Recommendations

- **Continuous noise monitoring (with data transparency) should be required for every medium & large wind turbine planning approval**
- **Effective remedy required for retrospectively dealing with noise nuisance including EAM from existing wind turbines**
- **Government should disassociate itself from the IoA until the conflict of interest and ethics issues are resolved and full transparency restored**

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That continuous noise monitoring should be required for every medium & large wind turbine planning approval, funded by the turbine operator and with open access to the data for transparency.

That an effective legal remedy is urgently required for retrospectively dealing with noise nuisance including EAM from existing wind turbines.

That Government should disassociate itself from the IoA until the conflict of interest and ethics issues are resolved and full transparency restored.

In fact we are unable to see where ReUK ends and the IoA starts since they involve the same people. The IoA has effectively become a part of the wind industry.

It is very clear to those communities affected by turbine noise and also to several IoA members that the IoA needs to get its house in order.



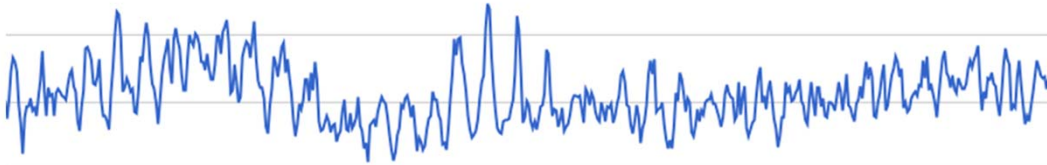
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