INSTITUTE OF ACOUSTICS

IOA CONSULTATION QUESTIONNAIRE FOR

"METHODS FOR RATING AMPLITUDE MODULATION IN WIND TURBINE NOISE"

APRIL 2015

FOREWORD

** PLEASE READ BEFORE PROCEEDING TO THE MAIN DOCUMENT **

This discussion document has been produced by a working group on behalf of the Institute of Acoustics consisting of the following members:

Jeremy Bass		RES Ltd
Matthew Cand		Hoare Lea Acoustics
David Coles		24 Acoustics
Robert Davis		RD Associates
Gavin Irvine	(Chair)	Ion Acoustics
Geoff Leventhall		
Tom Levet		Hayes McKenzie
Sam Miller		
David Sexton		West Devon Borough Council
John Shelton		AcSoft

This questionnaire has been produced specifically to promote discussion of the relevant issues during the consultation on a metric for amplitude modulation (AM) from wind turbines and should be read in conjunction with the "IOA AMWG Discussion Document". Respondents to the consultation are encouraged to provide their comments on the form provided. A word version has been provided to allow respondents to increase box sizes as required.
All comments on the consultation draft should be sent electronically to:

WTAMCONSULT@IOA.ORG.UK

Alternatively, written responses can be sent to:
IOA AMWG Consultation Feedback
Institute of Acoustics
3rd Floor St Peter's House,
45-49 Victoria Street,
St Albans,
Herts.
AL1 3BN.

The closing date for the receipt of comments is **30th June 2015**. Late comments may not be reflected in the deliberations on the choice of the AM metric.

CONTENTS

INTRODUCTION TO THE CONSULTATION

Background

The Institute of Acoustics Amplitude Modulation Working Group (IOA AMWG) has prepared a discussion document on methods for rating amplitude modulation in wind turbine noise, for the purpose of consultation to IOA Members and other interested parties.

The discussion document considers various methods and has proposed three methods for consultation. The intention of the IOA AMWG post-consultation is to recommend one method but at this consultation stage, three candidate methods are proposed. The AMWG will not be proposing a threshold or penalty mechanism for rating the subjective response.

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

Subsequent section numbers refer to the main discussion document.

Section 3 – AM Definition

Do you agree with the Definition of AM? Does it relate to your experience?

Yes, as it encompasses all forms of AM and not just those associated with transient stall conditions. AM has been noted within Northern Ireland from a number of medium scale single wind turbines (250kW) potentially due to building turbulence and downwind rotor designs. The proximity of medium scale single wind turbines to local residents (as close as sub 200m) due to a highly permissive planning policy within Northern Ireland, makes 'normal' AM more prevalent.

Is the Definition of AM applicable to smaller turbines?

For the majority of smaller wind turbines, AM is still related to the blade passing frequency. Only in micro-scale is AM also produced by other factors e.g. sway and flap.

Is it appropriate to measure AM Outside in free-field conditions? If not can you propose alternatives?

From local experiences, AM typically results in complaints of sleep disturbance. Whilst difficulties can arise with gaining access to measure, peak to trough can be more pronounced due to limited attenuation through an open window of AM noise but significant reduction in the under lying noise level. The currently proposed methods could still be used internally, albeit the community adverse response level would need to be amended accordingly.

Section 4 – Literature Review

Are there any other rating methods or important references that the AMWG should consider?

Not aware of any other rating methods or references.

Section 5 – Towards a preferred metric

In principle, which is the best domain for rating and describing amplitude modulation: the time domain; the frequency domain; or is a hybrid method preferred? Can you explain why?

In principle, the Time Domain is the best method for rating and describing amplitude modulation as this best represents the impact on residents, is the most easily understood and visually presentable. However, this is based on the assumption of clean data which is rarely available.

Do you agree with time intervals proposed, that is: 100 millisecond samples, 10 second blocks, 10 minute periods?

Yes. It is especially welcomed that the use of the highest 10% of 10 second samples are used to represent the 10 minute period.

Do you agree with the band-limiting filtering approach for rating AM?

Yes. Data held locally suggests that turbine AM is typically contained within the suggested frequencies, yet birdsong would typically be at the higher frequencies. One potential impact of applying a band-limiting approach would be to reduce the masking effect of background noise that is dominated by noise outside of the suggested frequencies, but this would be site specific and a rare occurrence.

Is the default frequency range appropriate? What other frequency ranges could be considered, taking into account the desirability to characterize the frequency range in which AM occurs, the desirability to exclude spurious noise sources and the need for a consistent approach to avoid differences?

Yes. No data held locally that would suggest the default frequency range as inappropriate. If initial measurements identify AM, the frequency of the AM can be derived and a narrower frequency range could be applied to further reduce any potential extraneous noise sources.

Section 6 – Time Series Method

Do you think the time series method proposed is suitable for rating AM? If not, can you explain why?

If clean data is obtained with limited spurious noise then AM should be captured accurately. The time series method represents the higher peaks and lower troughs and hence better represents impact on residents who don't listen in 10 second blocks but each individual beat. Detrending allows for constant background noise influences to be accounted.

Section 7 – Frequency Domain Method

Do you think the frequency domain method proposed is suitable for rating AM? If not, can you explain why?

The suggested method appears to overcome some of the shortfalls as highlighted by others with respect to the RenewableUK method. Although the energy contained within the harmonics of the fundamental are not appropriately captured and hence may under represent the true impact. It is also a very difficult methodology to explain to lay people/courts or present visually.

Should other parameters be used in the application of this method and why?

Section 8 – Hybrid Method

Do you think the hybrid method proposed is suitable for rating AM? If not, can you explain why?

The hybrid method appears to incorporate the best from the time series and frequency domain methods, in ensuring that the data is appropriately 'cleansed' but equally not reducing the impact of the peak to trough.

Should other parameters be used in the application of this method and why?

Section 9 – Comparison of Methods

Of the three methods proposed, which is your preferred method?

Hybrid.

Is there another alternative method not recommended by the AMWG which would be preferable? Explain why.

Section 10 – Instrumentation

Are the proposed requirements for instrumentation appropriate?

Yes, most local authorities will have access to equipment that fulfils the instrumentation requirements.

Would you like instrument manufacturers to make available an "AM rating" option for sound level meters?

Yes, if easily applied.

Section 11 – Software

Should the IOA make available software for rating AM?

Yes, as undertaking such calculations with Excel would be highly laborious

Do you have any comments on the software released?

No.

Recommendations for Further Study and any other comments

The focus of the discussion document is towards AM produced by wind farms. Consideration should also be given towards AM produced by single wind turbines (currently over 1000 permissions within Northern Ireland), which may typically be located closer to dwellings than wind farms.

Your details

Please provide your name and contact details in case the working group wishes to clarify any of the points raised in your feedback: Can you also indicate if you would like your response to be published anonymously or not published at all by the IOA?

Northern Ireland Environmental Protection Group

Dr Chris Jordan – Secretary
Mid and East Antrim Borough Council
'Ardeevin'
Ballymena
BT42 1AB
03001245000

The IOA AMWG thanks you for your help in completing this document.

Gavin Irvine
AMWG Chair

INSTITUTE OF ACOUSTICS

IOA CONSULTATION QUESTIONNAIRE FOR

"METHODS FOR RATING AMPLITUDE MODULATION IN WIND TURBINE NOISE"

APRIL 2015

FOREWORD

** PLEASE READ BEFORE PROCEEDING TO THE MAIN DOCUMENT **

This discussion document has been produced by a working group on behalf of the Institute of Acoustics consisting of the following members:

Jeremy Bass		RES Ltd
Matthew Cand		Hoare Lea Acoustics
David Coles		24 Acoustics
Robert Davis		RD Associates
Gavin Irvine	(Chair)	Ion Acoustics
Geoff Leventhall		
Tom Levet		Hayes McKenzie
Sam Miller		
David Sexton		West Devon Borough Council
John Shelton		AcSoft

This questionnaire has been produced specifically to promote discussion of the relevant issues during the consultation on a metric for amplitude modulation (AM) from wind turbines and should be read in conjunction with the "IOA AMWG Discussion Document". Respondents to the consultation are encouraged to provide their comments on the form provided. A word version has been provided to allow respondents to increase box sizes as required.
All comments on the consultation draft should be sent electronically to:

WTAMCONSULT@IOA.ORG.UK

Alternatively, written responses can be sent to:
IOA AMWG Consultation Feedback
Institute of Acoustics
3rd Floor St Peter's House,
45-49 Victoria Street,
St Albans,
Herts.
AL1 3BN.

The closing date for the receipt of comments is **30th June 2015**. Late comments may not be reflected in the deliberations on the choice of the AM metric.

CONTENTS

INTRODUCTION TO THE CONSULTATION

Background

The Institute of Acoustics Amplitude Modulation Working Group (IOA AMWG) has prepared a discussion document on methods for rating amplitude modulation in wind turbine noise, for the purpose of consultation to IOA Members and other interested parties.

The discussion document considers various methods and has proposed three methods for consultation. The intention of the IOA AMWG post-consultation is to recommend one method but at this consultation stage, three candidate methods are proposed. The AMWG will not be proposing a threshold or penalty mechanism for rating the subjective response.

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

Subsequent section numbers refer to the main discussion document.

Section 3 – AM Definition

Do you agree with the Definition of AM? Does it relate to your experience?

We do not agree that the definition of AM accurately or adequately defines the perception and harm of AM. The definition does not:

1. clarify or define the intermittency of AM at the receptor location;
2. account for the change in the spectrum from the source location to the receptor location;
3. define for any peaks of the level of AM;
4. include the variability of the conditions that AM could be experienced in, such as 'typical weather conditions and wind direction, and
5. the definition of AM, and indeed all the work on AM, seems to be focused on the audibility of turbines and normal AM and not clarifying sleep disturbance. Audibility and Annoyance are not the reasons for the ETSU-R-97 limits. The work on AM seems to be overly restrictive on wind farm development based on perception rather than harm.

Our experience of AM can vary for different turbines. Older fixed speed turbines operate with closer rotational speeds which seem to form beats and would be more audible. Whilst the newer variable pitch regulated turbines could produce AM at random times based on the specific wind conditions.

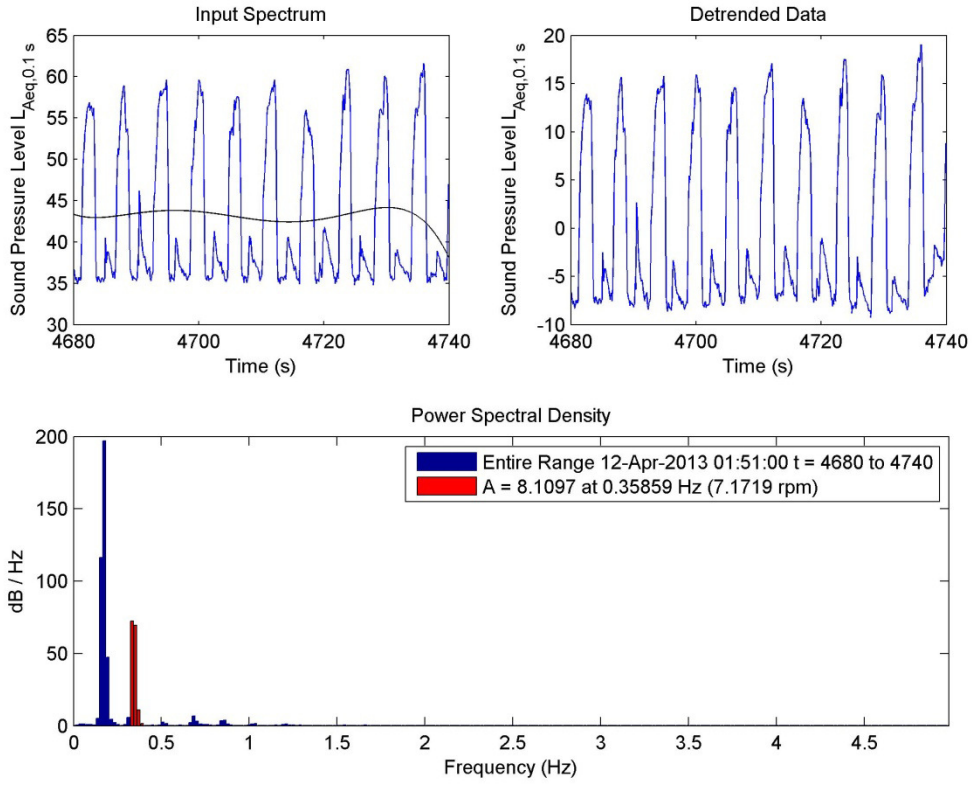
Is the Definition of AM applicable to smaller turbines?

In principle the AM definition could apply to smaller turbines; however, their blade passing frequency would be higher and their character different. Therefore, the metrics proposed would not be adequate.

Is it appropriate to measure AM Outside in free-field conditions? If not can you propose alternatives?

The measurements within a dwelling would indicate what the complainant would experience. However there are difficulties and benefits with measurements inside:

1. each room would have its own characteristics. These would have to be taken into account prior to the assessment of AM. It would also provide a burden on the wind farm developer, to attempt to predict the effect of building acoustics (essentially third party) within a condition. This would run counter to Government Circular 11/95.
2. The AM measured outside may be masked by natural noise, whilst inside the natural masking noise would be attenuated by windows and walls.
3. Other noise sources would contribute to an AM value based on the AM definition. Contamination sources are breathing, snoring, footfalls, washing machines, wind blowing across chimneys, bathroom fans, structure borne vibration from wind or other sources, which occurs within the blade passing frequency of a modern turbine. The figures below shows an AM source, within the range of the operation of a turbine, measured inside a property. Please note there are not wind farms nearby and it uses frequency domain for analysis. The source of the AM is snoring.



There are difficulties and benefits for measuring in free field conditions:

1. Contamination from outside sources, engines, fans, flues and birds.

Perhaps an equivalent frequency filter could be used on free-field measurements to replicate the experience of the occupant within the property.

We consider the outside free-field measurements to be the best option.

Section 4 – Literature Review

Are there any other rating methods or important references that the AMWG should consider?

There are no references we can recommend. However, we do not agree that the existing rating methods have suitable sample size of 100 people. In addition, the values produced by the metric are not comparable with any of the rating methods.

Section 5 – Towards a preferred metric

In principle, which is the best domain for rating and describing amplitude modulation: the time domain; the frequency domain; or is a hybrid method preferred? Can you explain why?

The frequency domain is the preferred method, closely followed by the hybrid method.

If the methods are able to be modified, then our preference would be (1) Hybrid and then (2) Frequency domain.

RWE conducted work at one of our wind farms and found that a hybrid approach was necessary to get any kind of usable result. A time series of AM at blade passing frequency, and used this to *filter* the raw time-series data. An analysis of the time domain data was then made to compare blade passing with and without blade modifications. The method was not perfect, but we doubt it could have been done purely in the time or frequency domains alone.

Problems involving vibrations or oscillations occur frequently in physics and engineering and they are solved using Fourier Series and Fast Fourier Transforms. Therefore, any signal that is periodic signature, such as a tone or AM, will

be analysed quickly and effectively using FFT or hybrid method.

The time domain method is insufficient and would include random noise in the assessment of AM. This would give rise to false positives. One would not use the time domain to calculate the strength of a tone, since it does not discriminate between other frequencies and the one of interest. Therefore, AM is poorly assessed from a theoretical and practical basis using a time domain methodology

We have analysed some simulated AM signals and this confirms that Method 2 provides the most consistent results.

Do you agree with time intervals proposed, that is: 100 millisecond samples, 10 second blocks, 10 minute periods?

The frequency resolution is equal to the inverse of the acquisition time and is 0.1 Hz. The frequency range is 5 Hz. The operation range of the turbine is typically is 5 rpm to 25 rpm, which gives a blade passing frequency of 0.25 Hz to 1.25. To increase the length of the measurement blocks to either 20 or 30 seconds would increase the frequency resolution to 0.05 Hz or 0.033 Hz, respectively. The maximum frequency could be reduced down to 2.5 Hz, without detriment to measuring AM by increasing the sample length to 200 ms.

We agree that the same length of 100 ms is adequate. The analysis blocks should be lengthened, to 30 seconds or 1 minute, to increase the frequency resolution. The average standard deviation in the blade passing frequency, measured over a 10 minute period, is of the order of 0.1 Hz.

The 10 minute period is suitable owing to the SCADA systems producing all data values to 10 minutes. Please note that SCADA systems can produce an average, minimum, maximum and standard deviation of the RPM. This would be compatible with Methods 2 and 3.

Do you agree with the band-limiting filtering approach for rating AM?

No. Band-limiting filtering approach may ignore important frequencies in AM.

Is the default frequency range appropriate? What other frequency ranges could be considered, taking into account the desirability to characterize the frequency range in which AM occurs, the desirability to exclude spurious noise sources and the need for a consistent approach to avoid differences?

The AM frequency range is 0 to 5 Hz. The operation range of the turbine is typically is 5 rpm to 25 rpm, which gives a blade passing frequency of 0.25 Hz to 1.25 Hz. Therefore the range is acceptable. The frequency resolution should be increased, since there are only 12.5 bins over the operational BPF range of the turbine.

Section 6 – Time Series Method

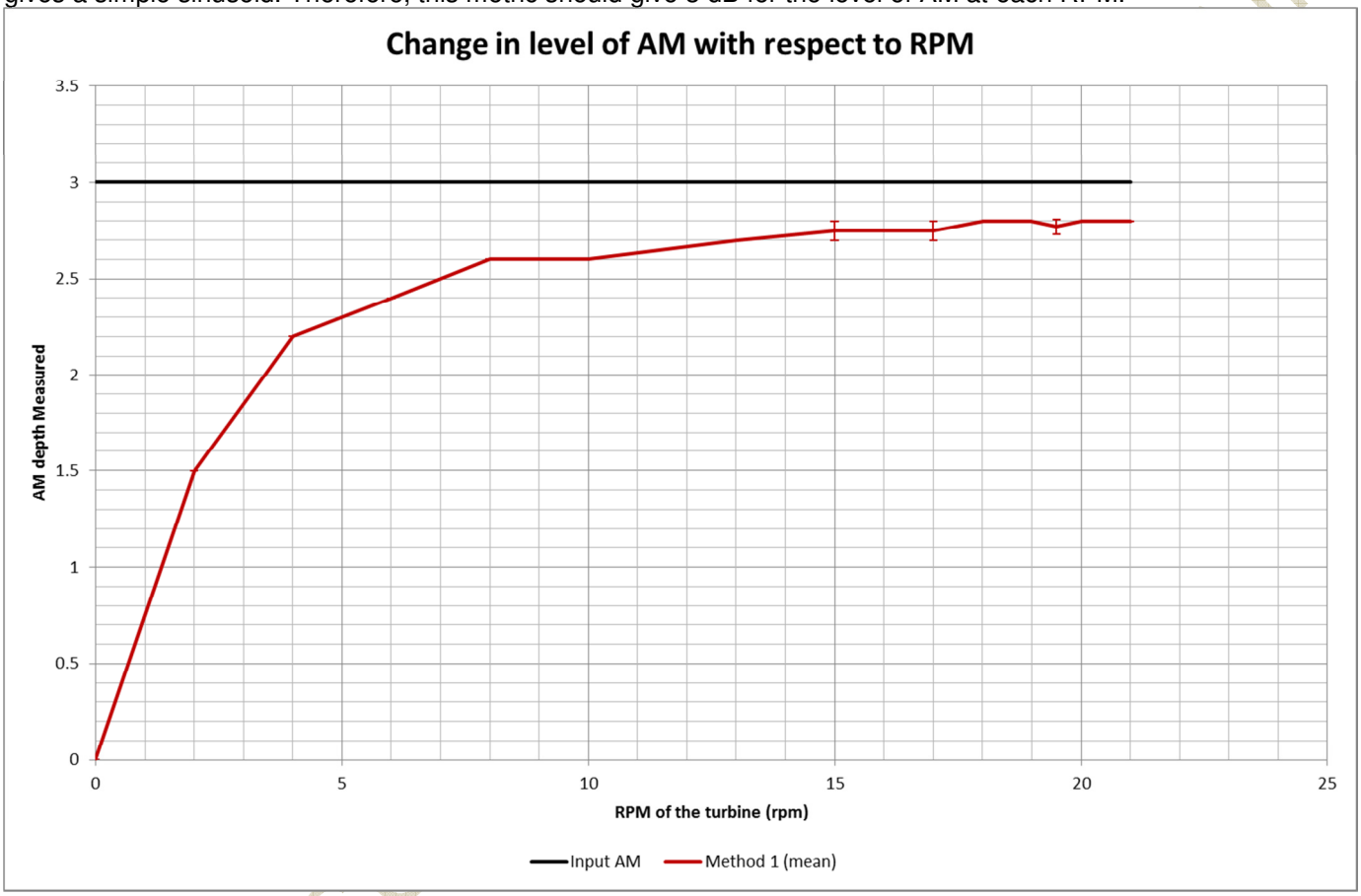
Do you think the time series method proposed is suitable for rating AM? If not, can you explain why?

We conducted a simple test for the three methodologies. We used a simple model:

$$L_i = \frac{AM}{2}\sin\left(\frac{R\pi t_i}{10}\right) + L_{BG} + \mathrm{RAND}\,(L_N),$$

where AM is the level of Amplitude modulation, R is the RPM of the turbine, t is the time in seconds, L_{BG} is the general background level, RAND(L_n) is a random number between ± Ln per unit time and L_i is the sound pressure level at unit time t_i.

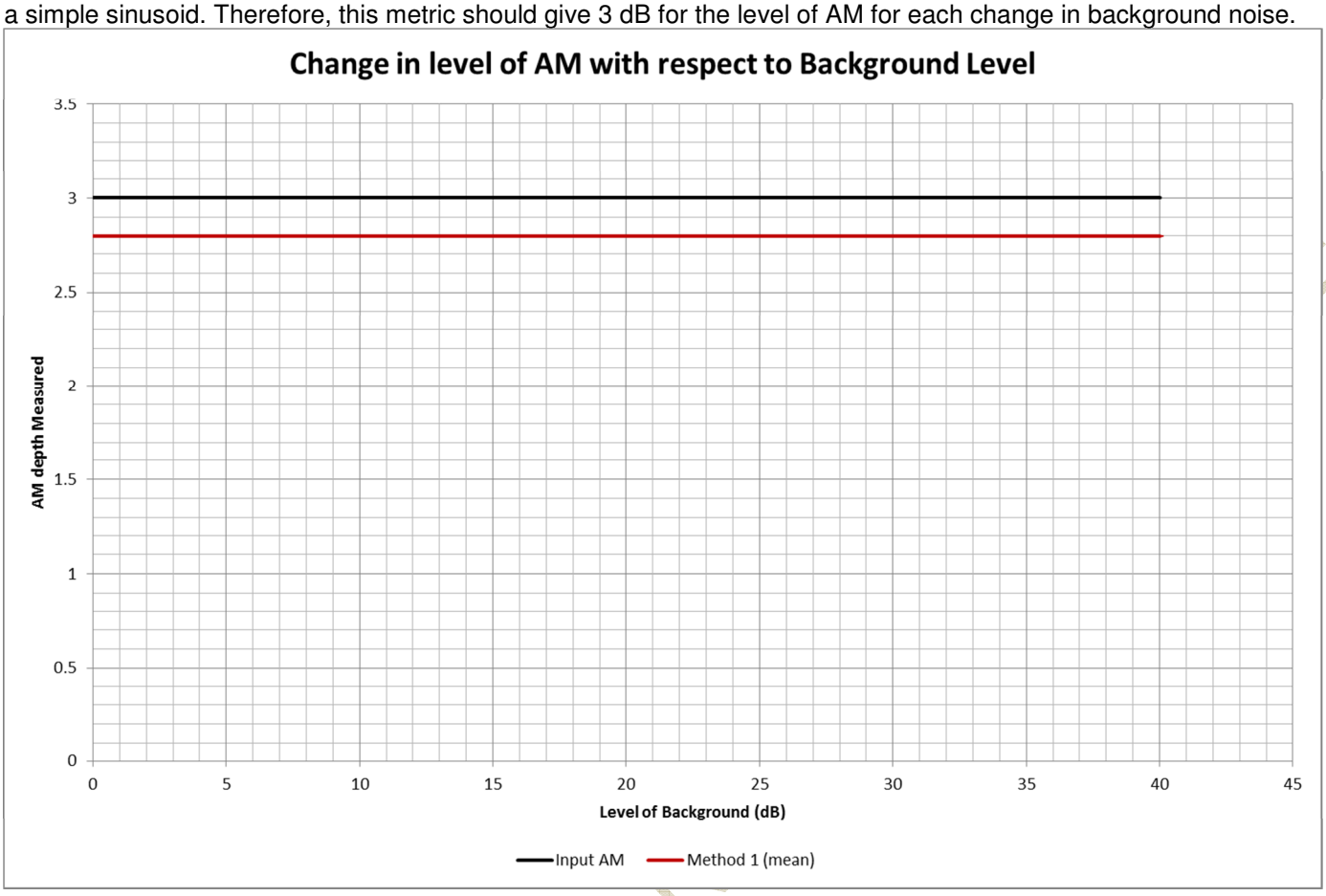
Case 1: Rpm varies between 0 and 21 revolutions per minute, AM is 3 dB, L_{BG} is equal to 35 dB and L_n is zero. This gives a simple sinusoid. Therefore, this metric should give 3 dB for the level of AM at each RPM.



The method under evaluates the level of AM from the simple model at all rpm. The measured AM at an rpm of 6 the evaluated AM is 2.4 dB and then tends to 2.8 dB at 20 rpm. Therefore, the method can evaluate AM for a simple model for the operational range of a turbine; however, it under estimates at all rpm.

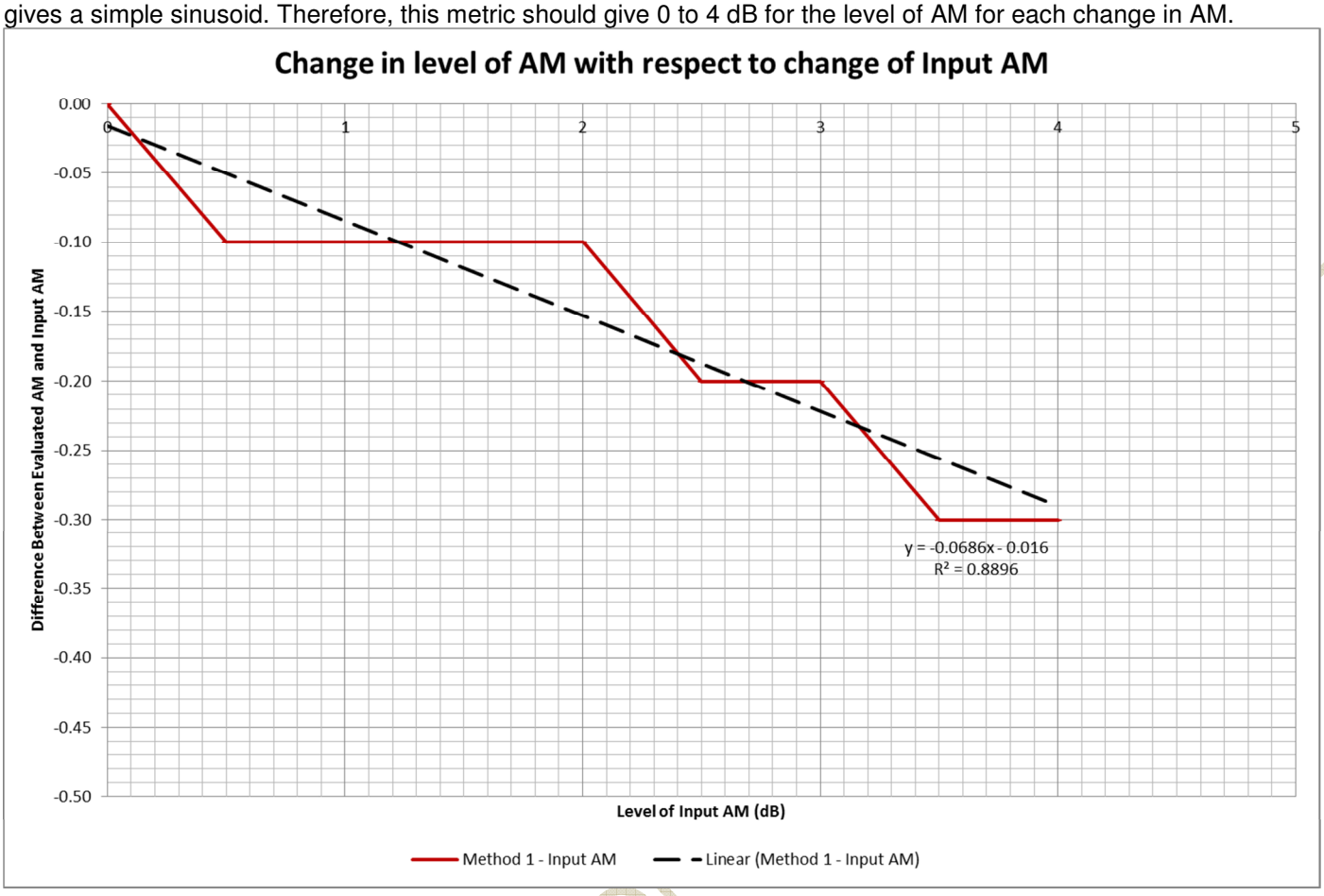
The average AM depth measured seems to produce a standard variation at 15 to 19.5 rpm, which should not occur. This means that the method intrinsically introduces uncertainty in the results.

Case 2: Rpm equals 18 revolutions per minute, AM is 3 dB, L_{BG} varies between 0 and 40 dB and L_n is zero. This gives a simple sinusoid. Therefore, this metric should give 3 dB for the level of AM for each change in background noise.



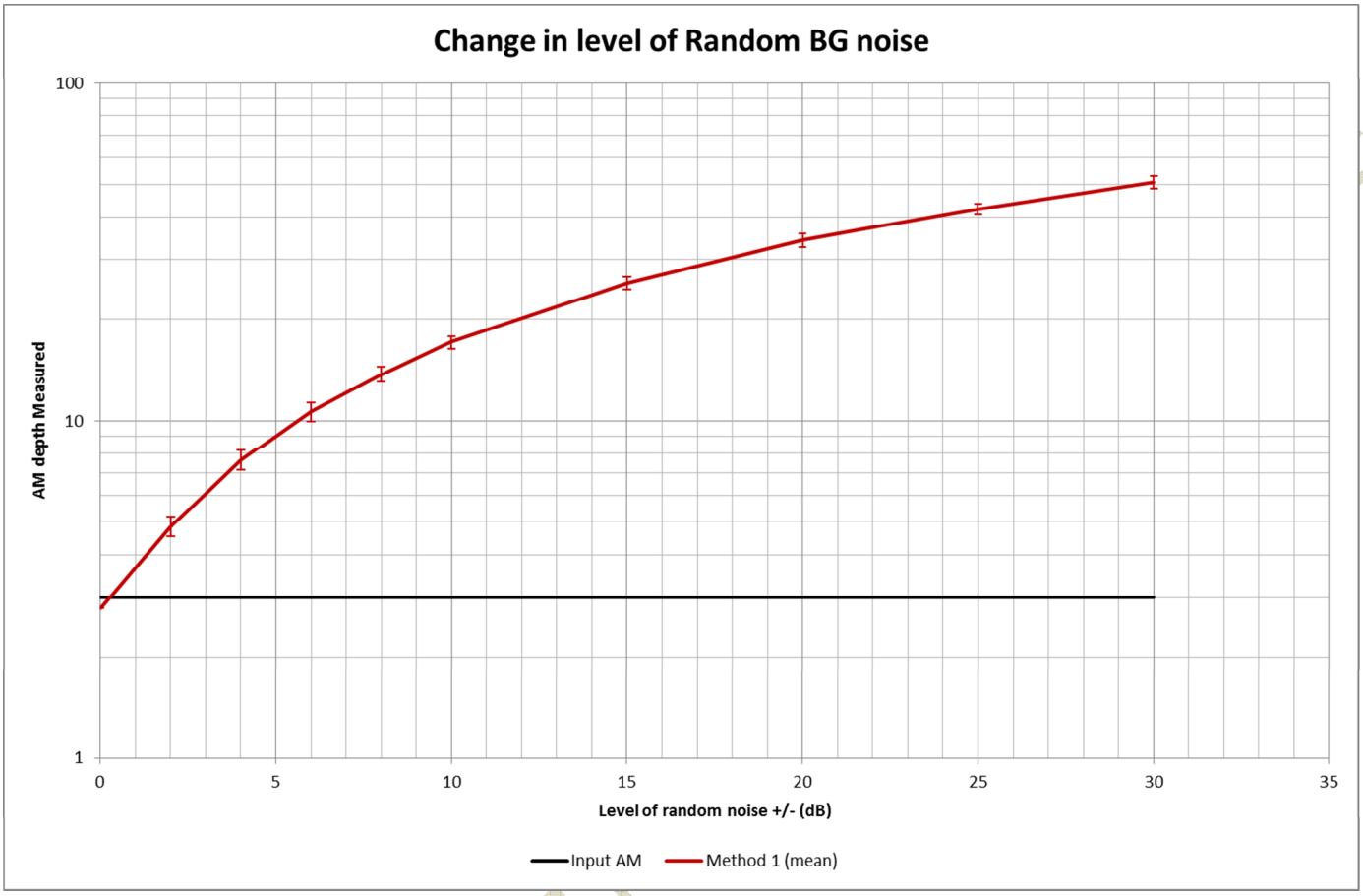
The level of AM evaluated is underestimated value of 2.8 dB at all background levels. The method underestimates the level of AM.

Case 3: Rpm equals 18 revolutions per minute, AM varies between 0 and 4 dB, L_{BG} equals 35 dB and L_n is zero. This gives a simple sinusoid. Therefore, this metric should give 0 to 4 dB for the level of AM for each change in AM.



The method underestimates the level of AM with the change of input AM. The evaluated AM decreases as the level of Input AM increases. Therefore, this method underestimates the levels of AM.

Case 4: Rpm equals 18 revolutions per minute, AM equals 3, L_{BG} equals 35 dB and L_n varies between 0 and 40 dB. This gives a simple sinusoid with additional noise to mimic the nature of external noise sources. We expect standard deviation in the mean level of measured AM to increase with increasing noise. It is expected that random noise of > ±10 dB, will reduced the effectiveness of detecting AM.



The y-axis of the above graph is logarithmic. The method vastly over estimates the level of AM with small additions of random noise.

We investigated two real world sites with two scenarios for each site. Site 1 is an active wind farm with measurements conducted when the wind farm was (a) not operating and (b) operating. Site 2 is an residential location without a wind farm measured (a) outside in a garden and (b) inside in a living room.

	Method 1 – Average AM level over the measurement period ± 1 standard deviation.
Site 1 Turbines Not operating	3.4 ± 4.5 dB
Site 1 Turbines operating	2.9 ± 0.6 dB
Site 2 Outside	3.0 ± 2.4 dB
Site 2 Inside	9.6 ± 1.8 dB
Comments	Sensitive to background noise. Would produce a false positive.

Using the criteria of success stated in Section 2.1:

Achievability: This method is achievable with the tools available to acousticians.
Reality: The method produces very large values of AM when an AM source is not present. The levels of uncertainty are very high.
Robustness: This method is not robust and is extremely sensitive to spurious noise sources.
Location: External measurements only
Objectivity: Gives a number, but with a high level of uncertainty. Based on the simple model, the final number will vary with respect to the level of AM and the rpm of the turbine.
Repeatability and reproducibility: Given the level of variance for the simple model at 15 to 19.5 for a clean AM signal, it is unlikely that this method would give repeatable and reliable results.
Specificity: This method is not specified enough to measure AM owing to the significant probability to produce false positives.
Automation: This method would not be able to discriminate AM in large datasets. It will need a subjective analysis.
Relativity: This does not relate to the AM dose response in the RUK work.

Section 7 – Frequency Domain Method

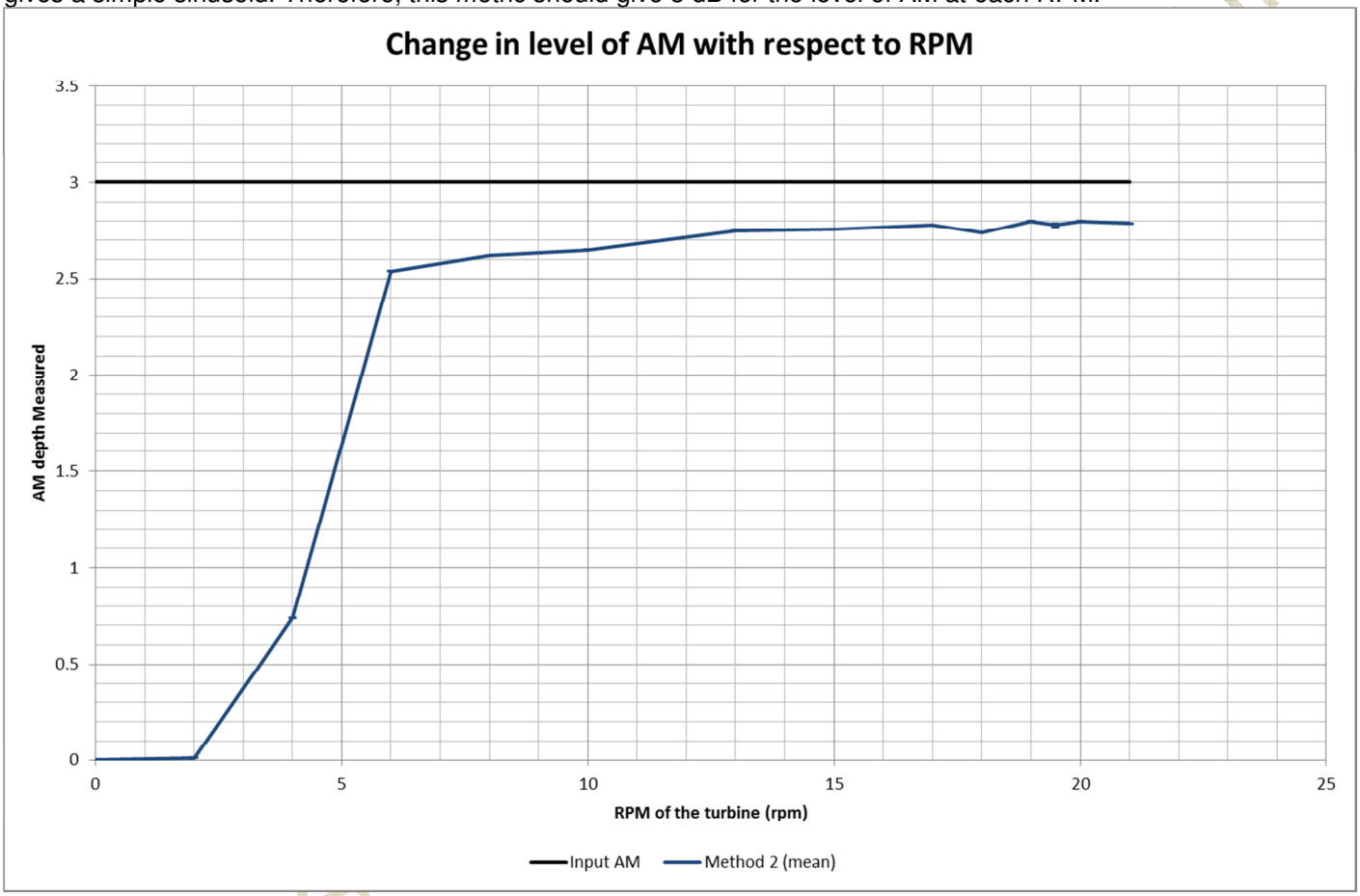
Do you think the frequency domain method proposed is suitable for rating AM? If not, can you explain why?

We conducted a simple test for the three methodologies. We used a simple model:

$$L_i = \frac{AM}{2}\sin\left(\frac{R\pi t_i}{10}\right) + L_{BG} + \mathrm{RAND}\,(L_N),$$

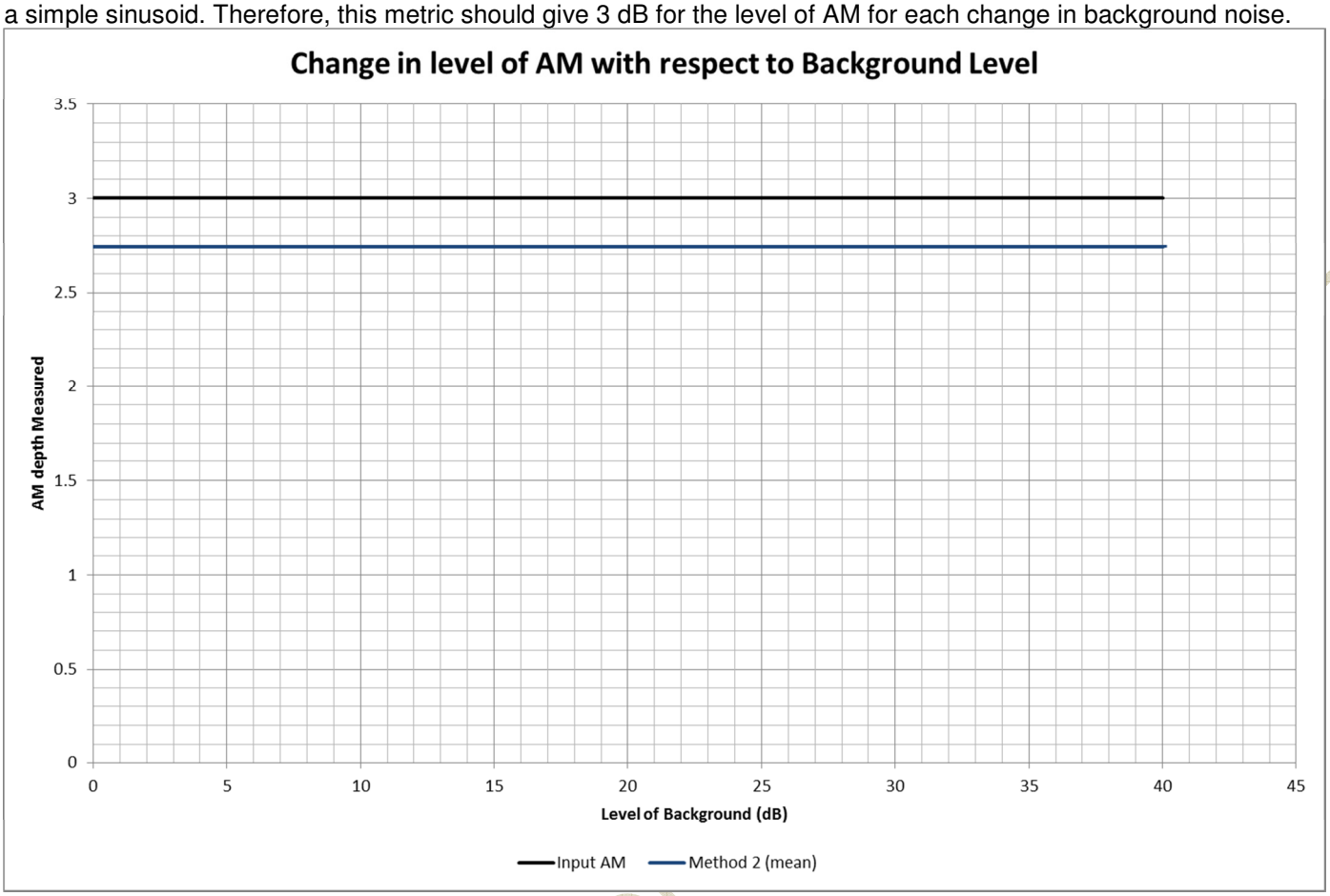
where AM is the level of Amplitude modulation, R is the RPM of the turbine, t is the time in seconds, L_{BG} is the general background level, RAND(L_n) is a random number between ± Ln per unit time and L_i is the sound pressure level at unit time t_i.

Case 1: Rpm varies between 0 and 21 revolutions per minute, AM is 3 dB, L_{BG} is equal to 35 dB and L_n is zero. This gives a simple sinusoid. Therefore, this metric should give 3 dB for the level of AM at each RPM.



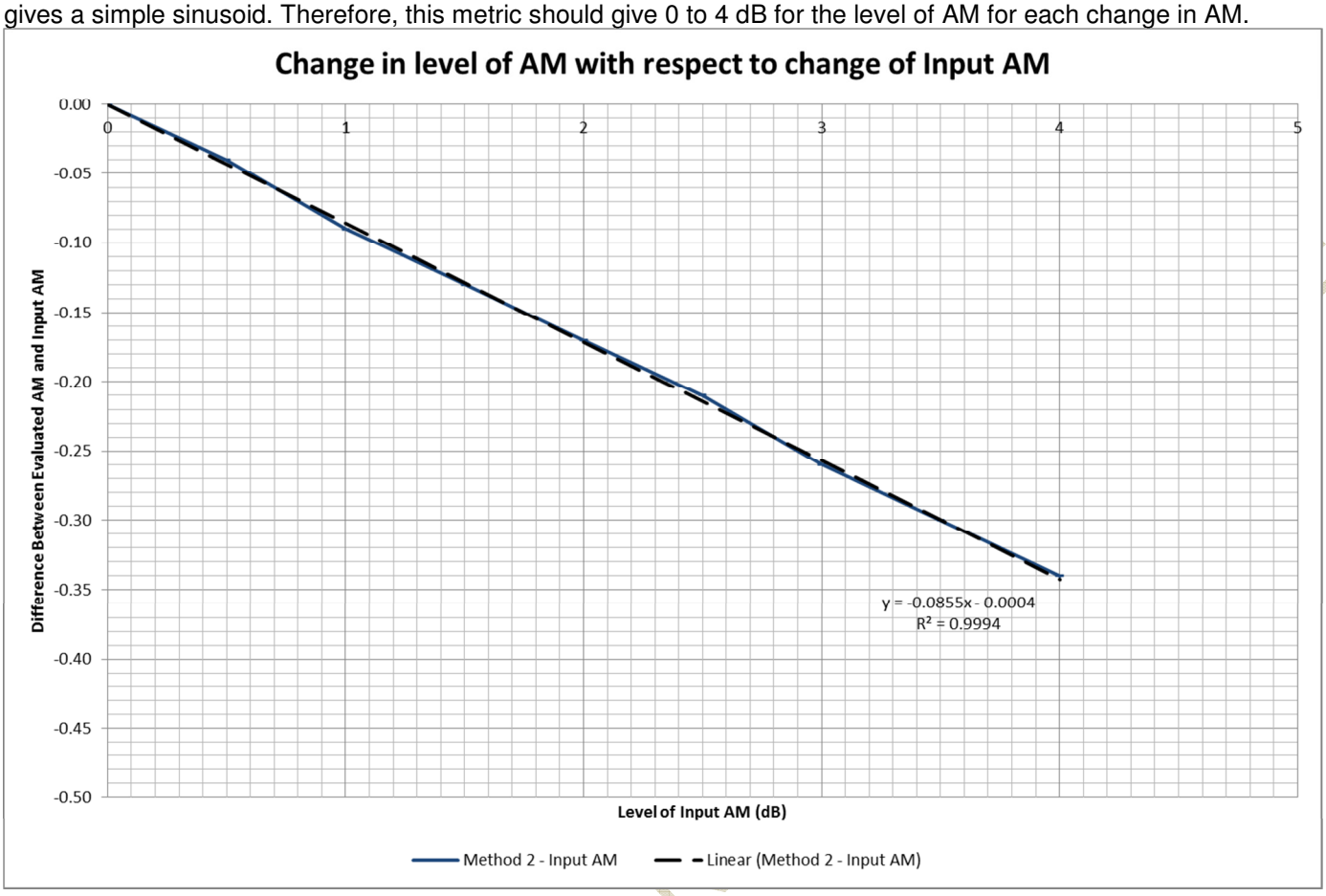
The method under evaluates the level of AM from the simple model at all rpm. The measured AM at an rpm of 6 the evaluated AM is 2.5 dB and then tends to 2.8 dB at 20 rpm. Therefore, the method can evaluate AM for a simple model for the operational range of a turbine; however, it underestimates at all rpm.

Case 2: Rpm equals 18 revolutions per minute, AM is 3 dB, L_{BG} varies between 0 and 40 dB and L_n is zero. This gives a simple sinusoid. Therefore, this metric should give 3 dB for the level of AM for each change in background noise.



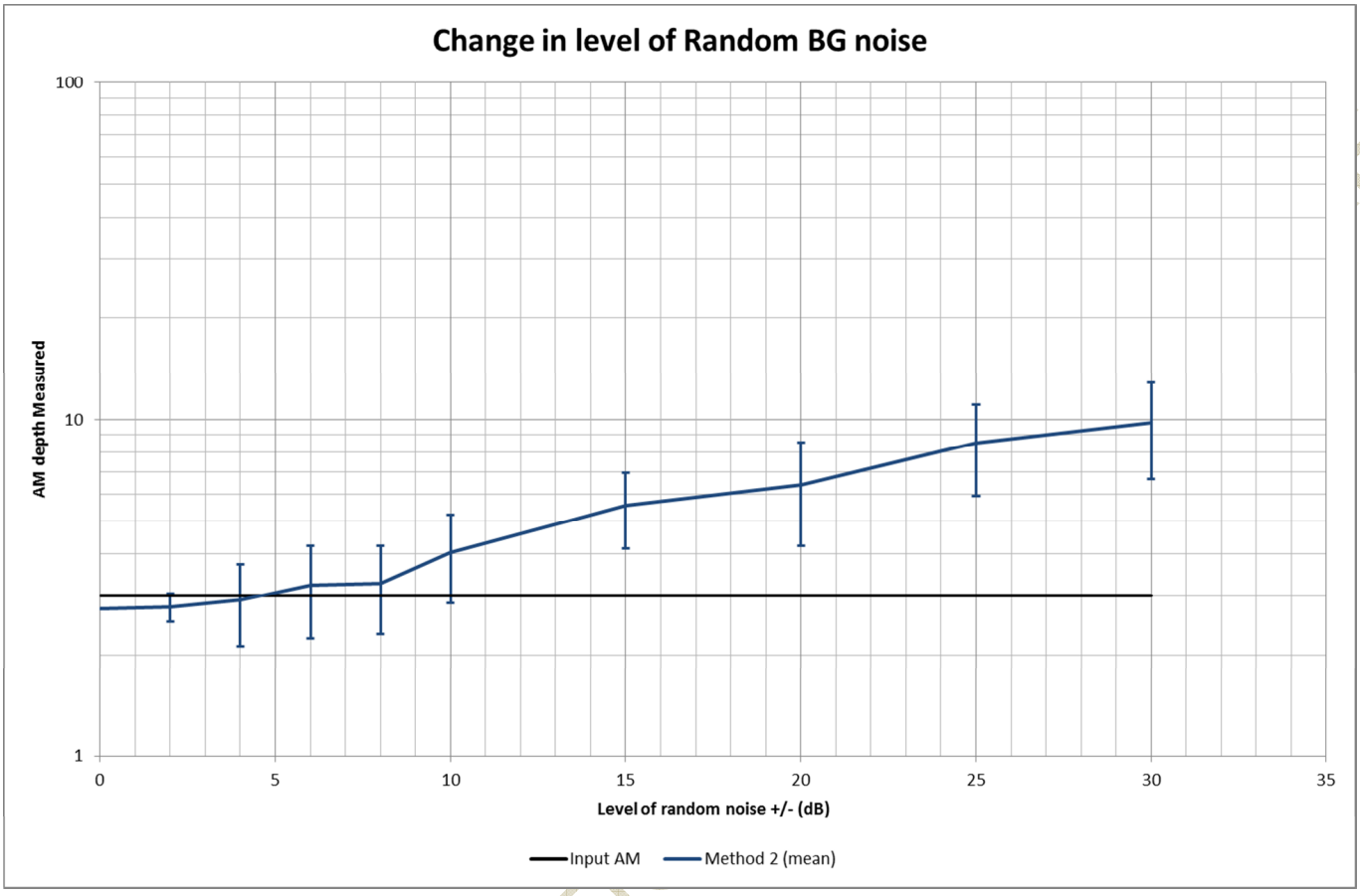
The level of AM evaluated is underestimated value of 2.7 dB at all background levels. The method underestimates the level of AM.

Case 3: Rpm equals 18 revolutions per minute, AM varies between 0 and 4 dB, L_{BG} equals 35 dB and L_n is zero. This gives a simple sinusoid. Therefore, this metric should give 0 to 4 dB for the level of AM for each change in AM.



The method underestimates the level of AM with the change of input AM. The evaluated AM decreases as the level of Input AM increases. Therefore, this method underestimates the levels of AM.

Case 4: Rpm equals 18 revolutions per minute, AM equals 3, L_{BG} equals 35 dB and L_n varies between 0 and 40 dB. This gives a simple sinusoid with additional noise to mimic the nature of external noise sources. We expect standard deviation in the mean level of measured AM to increase with increasing noise. It is expected that random noise of > ±10 dB, will reduced the effectiveness of detecting AM.



The y-axis of the above graph is logarithmic. The average level of AM increases and the level of uncertainty increases with random noise. The evaluated level of AM falls outside of 1 standard deviation above ± 10 dB.

We investigated two real world sites with two scenarios for each site. Site 1 is an active wind farm with measurements conducted when the wind farm was (a) not operating and (b) operating. Site 2 is an residential location without a wind farm measured (a) outside in a garden and (b) inside in a living room.

	Method 2 - Average AM level over the measurement period ± 1 standard deviation.
Site 1 Turbines Not operating	0.85 ± 1.0 dB
Site 1 Turbines operating	1.2 ± 0.4 dB
Site 2 Outside	0.9 ± 0.6 dB
Site 2 Inside	3.4 ± 1.4 dB
Comments	Generally consistent and is reasonable robust against background noise, but not very good inside.

Using the criteria of success stated in Section 2.1:

Achievability: This is achievable.

Reality: The results from this method produce a value of AM when an AM source is present and a low number when AM is not. If AM is not present, the level of uncertainty is of the order of the AM value.

Robustness: This method is robust, but can generate false positives in its current form.

Location: Measurements will have to be conducted in free-field conditions. The measurements inside a property produces an AM value. This may be owing to wind blowing across the chimney.
Objectivity: It does provide a value, but it does vary with respect to the rpm of the turbine.
Repeatability and reproducibility: The method is stable when analysing the simple model. It is expected that the results are repeatable; although, uncertainty would be introduced by the selection of the rpm range of the turbine.
Specificity: This method is specific for the definition of AM, but would need some modifications.
Automation: This method is good for measuring AM, but all sources of AM. This method may produce false positives and would not be able to discriminate from other sources of AM, such as breathing, snoring, bird song, footfalls etc.
Relativity: This is covered under the RUK report. We feel that further study is required and with a larger sample base.

There is a **significant error** in the methodology. The frequency resolution is 0.1 Hz not 5/128 Hz. Modern FFT routines can perform an FFT on data even if the total number does not correspond to a 2^x integer. Therefore, Method 2 needs to be corrected to reflect the resolution of 0.1 HZ. Currently the method introduces oversampling, a smoothing, which is introducing a systematic error into the results.

Should other parameters be used in the application of this method and why?

The single value obtained from the Power Spectral Distribution does not account for continuum and the variation in this continuum.

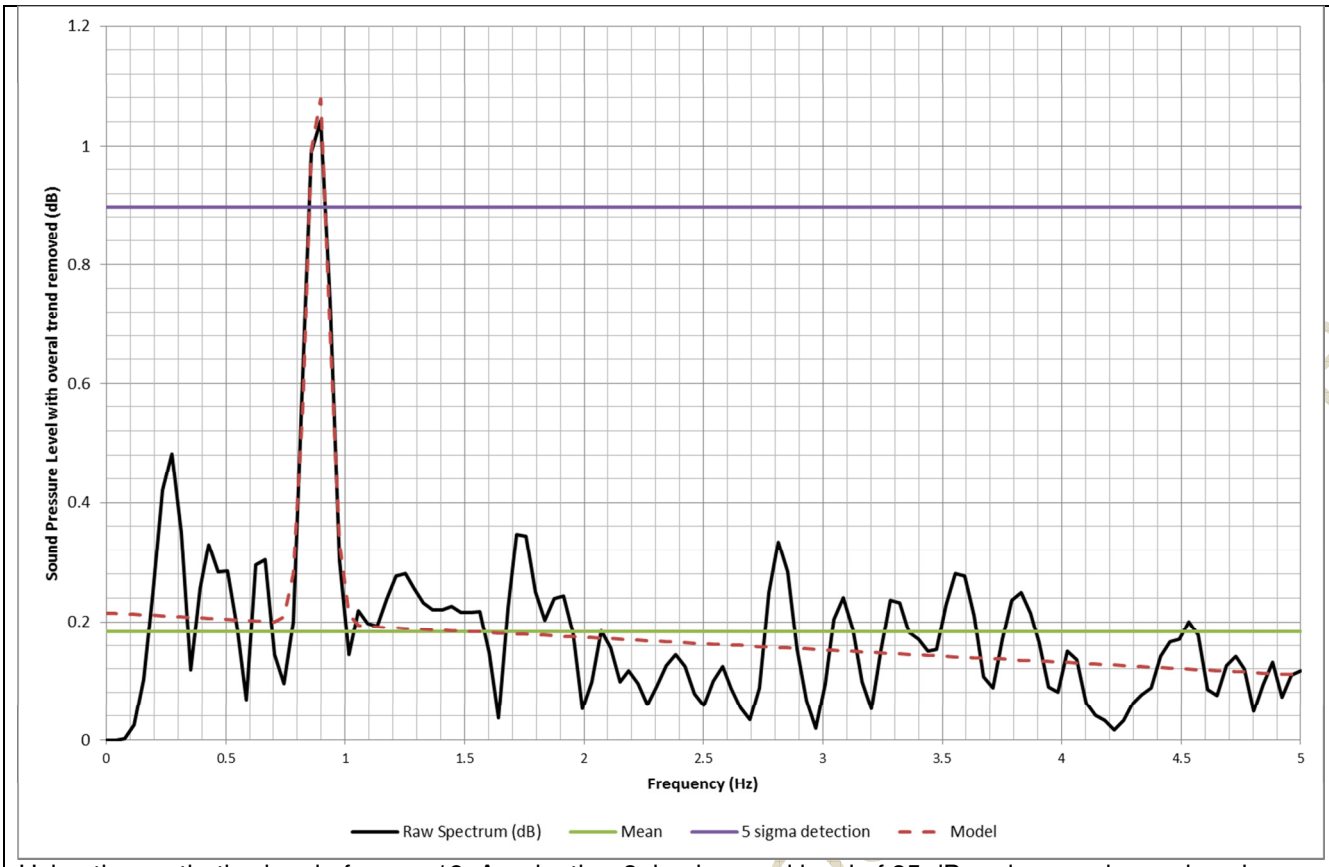
The average level should be determined via a simple mean. In addition, the standard deviation shall also be obtained. A peak of greater than the mean value plus 5 times the standard deviation indicates a possible AM peak.

A relationship of

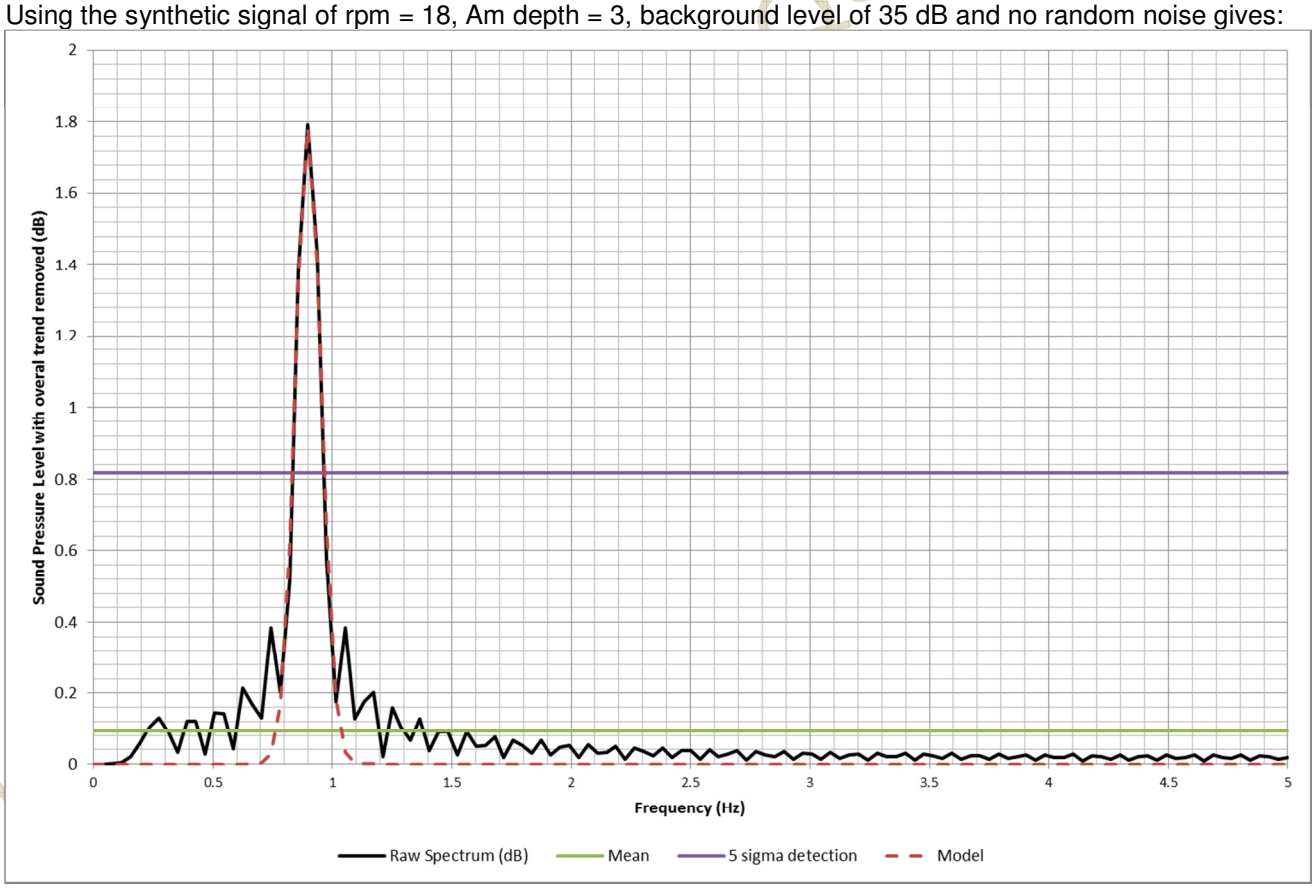
$$Y(f) = mf + c + Ae^{\frac{-(f-f_{peak})}{2\sigma^2}},$$

shall be iteratively fitted to these data, using least squares method, where y(f) is the result to be compared with the raw spectrum, m is the gradient of the continuum, f is the frequency, c is the level of continuum, A is the height of the peak of AM, f_{peak} is the frequency that the peak occurs and σ is the width of the peak. This process can be automated in Excel, using Solver, and other programming languages.

The sample below shows the fitting for one 10 second period for Site 1. The height of the peak, A, is 0.92 dB and correcting for the window function (not explained in IOA guidance) gives an peak, A of 1.54 dB.



Using the synthetic signal of rpm = 18, Am depth = 3, background level of 35 dB and no random noise gives:



The height of the Gaussian is 1.79 dB and correcting for the window function gives an value of 3.0 dB

All values produced by Method 2 should have an uncertainty stated in the results and a correction for the continuum.

Section 8 – Hybrid Method

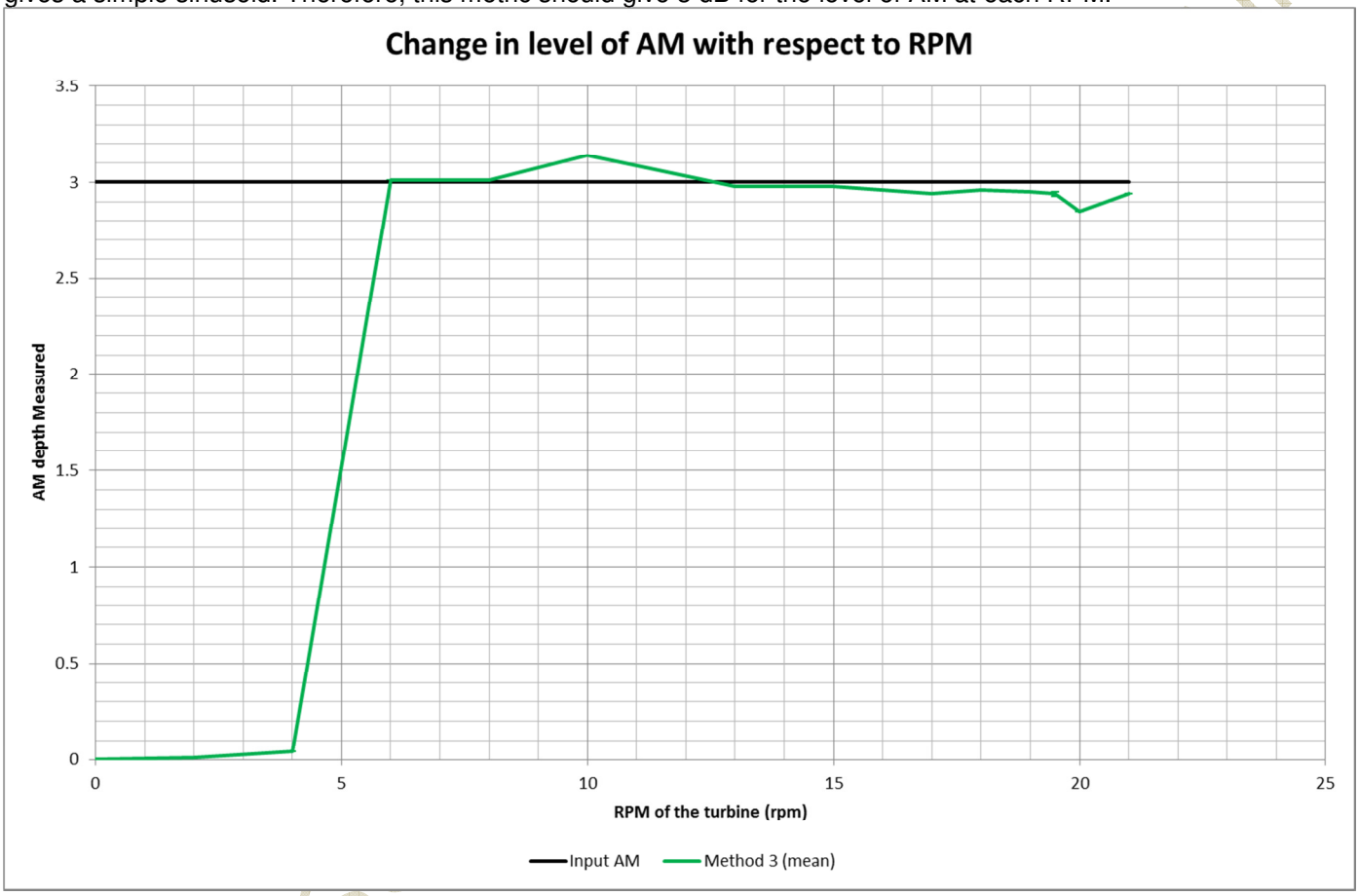
Do you think the hybrid method proposed is suitable for rating AM? If not, can you explain why?

We conducted a simple test for the three methodologies. We used a simple model:

$$L_i = \frac{AM}{2}\sin\left(\frac{R\pi t_i}{10}\right) + L_{BG} + \mathrm{RAND}\,(L_N),$$

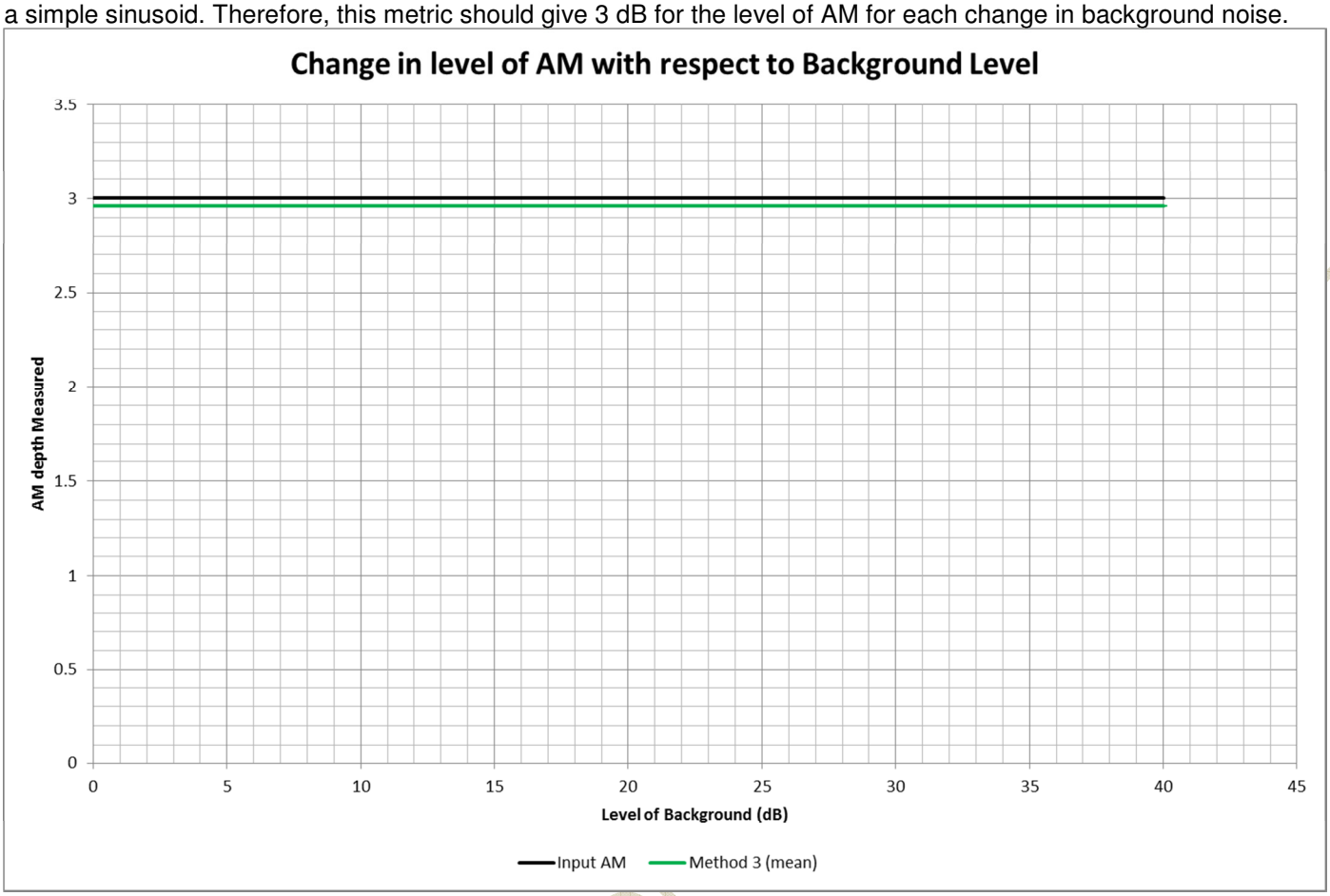
where AM is the level of Amplitude modulation, R is the RPM of the turbine, t is the time in seconds, L_{BG} is the general background level, RAND(L_n) is a random number between ± Ln per unit time and L_i is the sound pressure level at unit time t_i.

Case 1: Rpm varies between 0 and 21 revolutions per minute, AM is 3 dB, L_{BG} is equal to 35 dB and L_n is zero. This gives a simple sinusoid. Therefore, this metric should give 3 dB for the level of AM at each RPM.



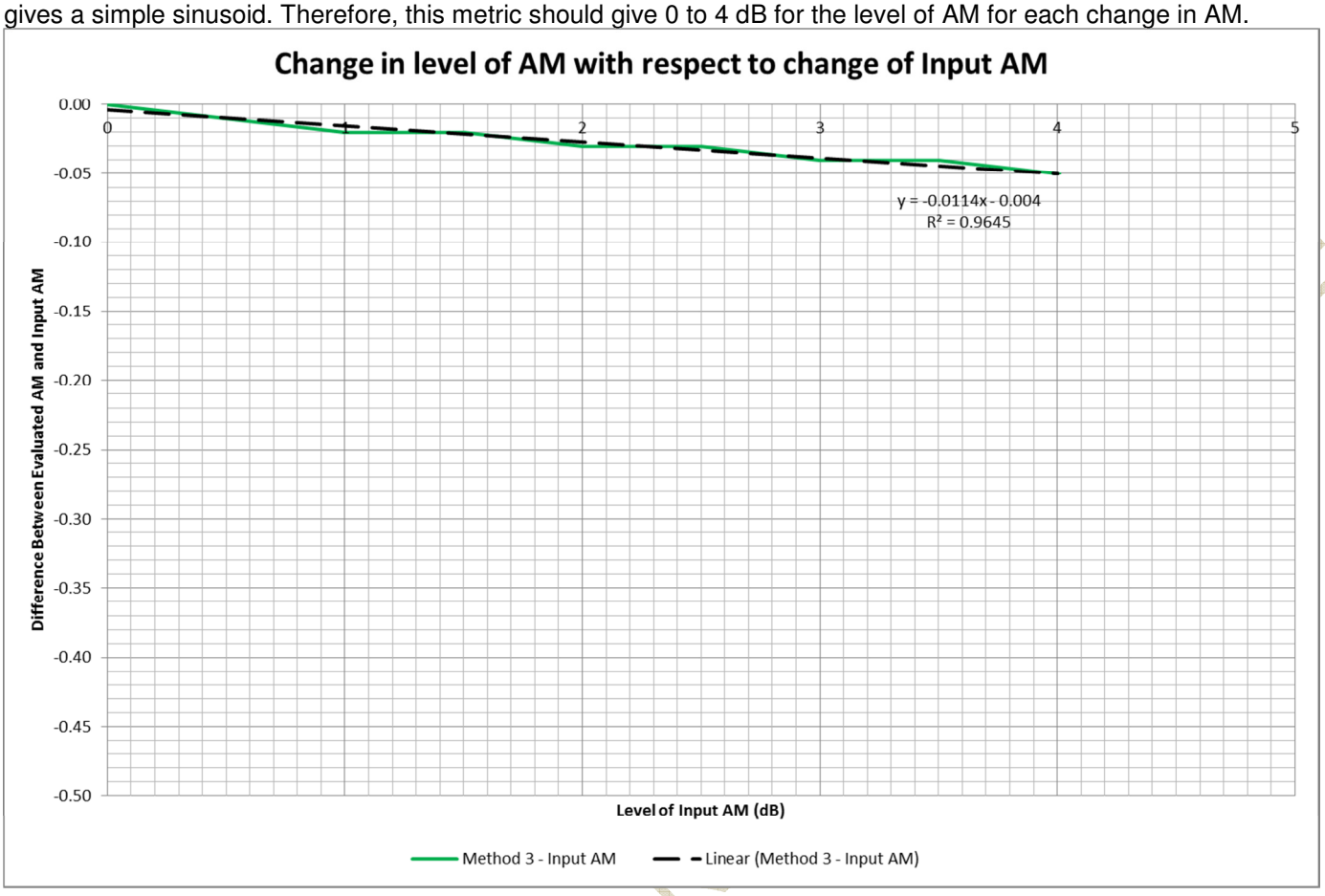
The method under evaluates the level of AM from the simple model at an less than 6 rpm. The measured AM at 10 rpm over estimates of AM to 3.1 and under estimates at and above 13 rpm. Therefore, the method can evaluate AM for a simple model for the operational range of a turbine; however, it under estimates at most rpm and over estimates at 10 rpm.

Case 2: Rpm equals 18 revolutions per minute, AM is 3 dB, L_{BG} varies between 0 and 40 dB and L_n is zero. This gives a simple sinusoid. Therefore, this metric should give 3 dB for the level of AM for each change in background noise.



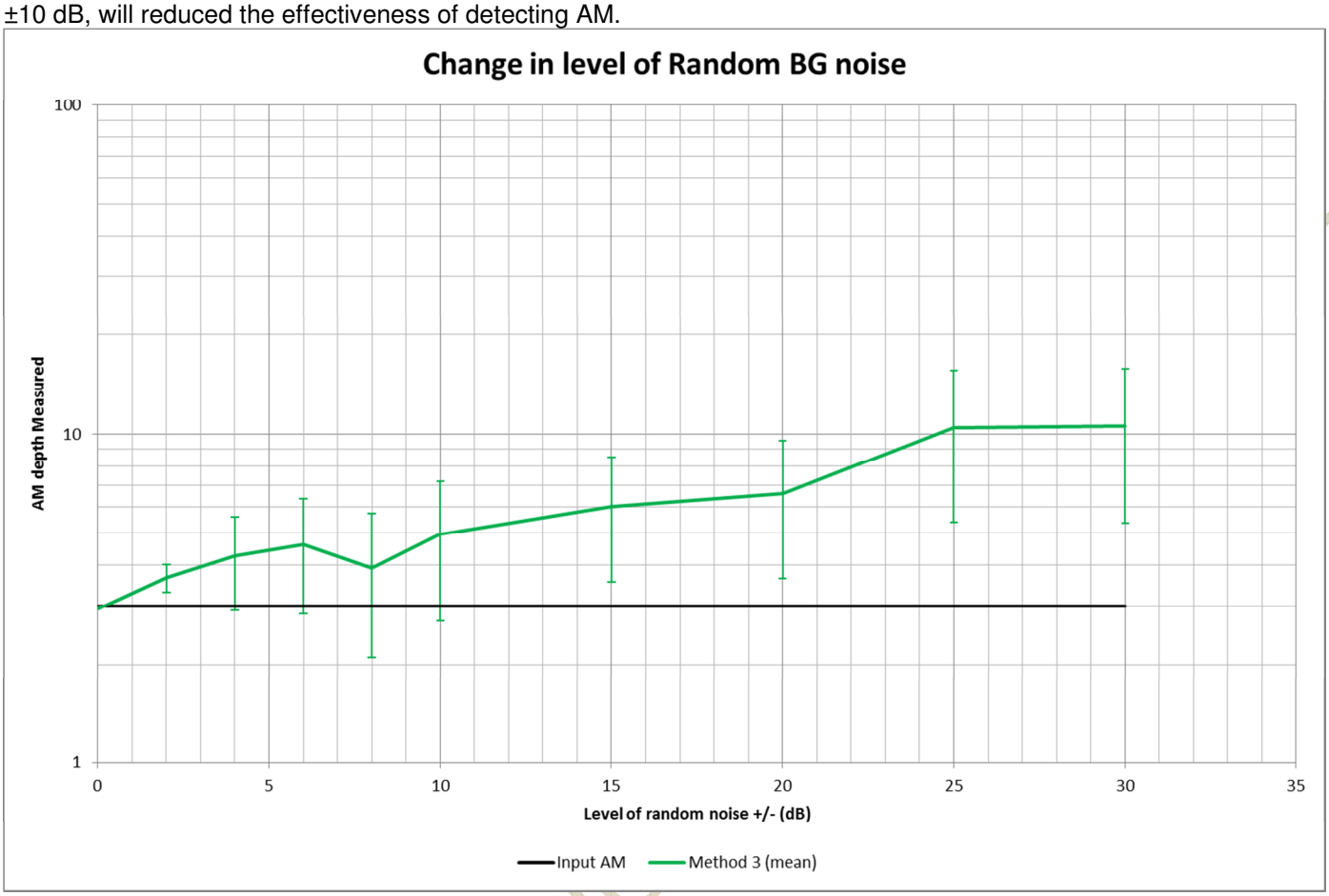
The level of AM evaluated is underestimated value of 2.95 dB at all background levels. The method underestimates the level of AM, but within 0.1 dB.

Case 3: Rpm equals 18 revolutions per minute, AM varies between 0 and 4 dB, L_{BG} equals 35 dB and L_n is zero. This gives a simple sinusoid. Therefore, this metric should give 0 to 4 dB for the level of AM for each change in AM.



The method underestimates the level of AM with the change of input AM. The evaluated AM decreases as the level of Input AM increases. Therefore, this method underestimates the levels of AM.

Case 4: Rpm equals 18 revolutions per minute, AM equals 3, L_{BG} equals 35 dB and L_n varies between 0 and 40 dB. This gives a simple sinusoid with additional noise to mimic the nature of external noise sources. We expect standard deviation in the mean level of measured AM to increase with increasing noise. It is expected that random noise of > ±10 dB, will reduced the effectiveness of detecting AM.



The y-axis of the above graph is logarithmic. The average level of AM increases and the level of uncertainty increases with random noise. The evaluated level of AM falls outside of 1 standard deviation above ± 10 dB.

We investigated two real world sites with two scenarios for each site. Site 1 is an active wind farm with measurements conducted when the wind farm was (a) not operating and (b) operating. Site 2 is an residential location without a wind farm measured (a) outside in a garden and (b) inside in a living room.

	Method 3 - Average AM level over the measurement period ± 1 standard deviation.
Site 1 Turbines Not operating	0.75 ± 1.0 dB
Site 1 Turbines operating	1.5 ± 0.7 dB
Site 2 Outside	0.7 ± 0.5 dB
Site 2 Inside	4.1 ± 1.5 dB
Comments	Generally consistent and is reasonable robust against background noise, but not very good inside.

Using the criteria of success stated in Section 2.1:

Achievability: This is achievable.
Reality: The results from this method produce a value of AM when an AM source is present and a low number when AM is not. If AM is not present, the level of uncertainty is of the order of the AM value.
Robustness: This method is robust, but can generate false positives in its current form.
Location: Measurements will have to be conducted in free-field conditions. The measurements inside a property produces an AM value. This may be owing to wind blowing across the chimney.
Objectivity: It does provide a value, but it does vary with respect to the rpm of the turbine.
Repeatability and reproducibility: The method is stable when analysing the simple model. It is expected that the results are repeatable; although, uncertainty would be introduced by the selection of the rpm range of the turbine.
Specificity: This method is specific for the definition of AM, but would need some modifications.
Automation: This method is good for measuring AM, but all sources of AM. This method may produce false positives and would not be able to discriminate from other sources of AM, such as breathing, snoring, bird song, footfalls etc.
Relativity: We feel that further study is required and with a larger sample base.

Should other parameters be used in the application of this method and why?

All values produced by Method 3 should have an uncertainty stated in the results and a correction for the continuum. In addition, a 'goodness of fit' should also be stated, to ensure that the AM result is credible.

Section 9 – Comparison of Methods

Of the three methods proposed, which is your preferred method?

We find that all methods do not fulfil the success criteria stated in section 2.1. All methods would require listening to the sample to subjectively assess, if the source of AM is originating from a wind turbine.

Method 1 is influenced by simple background noise variation as shown in the simple model tests and the real world data. We find this method unsuitable to analysing Amplitude Modulation, regardless of source. This method fails on: Reality, Robustness, Objectivity, Repeatability, Reproducibility, Specificity, Automation and Relativity (score: 2/9).

Method 2
Has systematic errors in the methodology; however, the general principle is sound once these errors have been fixed. The method does not fulfil all of the success criteria and fails on: Objectivity and Automation (score: 7/9). **This is our preferred method.**

Method 3
This is essentially method 2, but using three sinusoidal components. This method fails on: Objectivity, Automation and Relativity (score: 6/9).

Is there another alternative method not recommended by the AMWG which would be preferable? Explain why.

We would recommend a modification of method 2. Using the correct frequency resolution of 0.1 Hz. A correction for the sampling window, Fitting a continuum to these data with Gaussians fitted at the BPF, $^1/_3$ x BPF (contribution from a single blade), 2 x BPF and 3 x BPF to the peaks. The uncertainty reported in the fit and the final AM value.

This may be an effective model of wind turbine AM.

As no method is able to fully exclude the potential for false positives, any methodology must retain the option for the assessor to listen to periods identified as containing AM, and discount these if the source is clearly not a wind turbine.

Section 10 – Instrumentation

Are the proposed requirements for instrumentation appropriate?

The requirements for instrumentation are appropriate

Would you like instrument manufacturers to make available an "AM rating" option for sound level meters?

It is unlikely that they would produce such a feature. In addition, if the AM method is modified, then this would require upgrading the software and considerable expense. We cannot see any value to this proposal.

Section 11 – Software

Should the IOA make available software for rating AM?

The IOA software should be developed as open source and that can be offered free. A group that works on the software can introduce more features over time.

Do you have any comments on the software released?

The software was a black box. It would be useful if the python source code was released.

The software will need to be verified. Therefore, I propose a round robin, using example data, of interested parties (I volunteer) to test the software against the metrics. This will give an indication of the variation for people using different software, programming languages and implementation.

Recommendations for Further Study and any other comments

We feel that deciding on a method of measuring AM is redundant, owing to the lack of study of the effect of AM on sleep disturbance and its subsequent significance. The focus on annoyance is entirely subjective and is predicated on bias against wind farms. The existing studies are too limited and require larger sample sizes. We would very much encourage DECC to sponsor further work in this regard.

Your details

Please provide your name and contact details in case the working group wishes to clarify any of the points raised in your feedback: Can you also indicate if you would like your response to be published anonymously or not published at all by the IOA?

The IOA AMWG thanks you for your help in completing this document.

Gavin Irvine
AMWG Chair

INSTITUTE OF ACOUSTICS

IOA CONSULTATION QUESTIONNAIRE FOR

"METHODS FOR RATING AMPLITUDE MODULATION IN WIND TURBINE NOISE"

APRIL 2015

FOREWORD

** PLEASE READ BEFORE PROCEEDING TO THE MAIN DOCUMENT **

This discussion document has been produced by a working group on behalf of the Institute of Acoustics consisting of the following members:

Jeremy Bass	RES Ltd
Matthew Cand	Hoare Lea Acoustics
David Coles	24 Acoustics
Robert Davis	RD Associates
Gavin Irvine (Chair)	Ion Acoustics
Geoff Leventhall	
Tom Levet	Hayes McKenzie
Sam Miller	
David Sexton	West Devon Borough Council
John Shelton	AcSoft

This questionnaire has been produced specifically to promote discussion of the relevant issues during the consultation on a metric for amplitude modulation (AM) from wind turbines and should be read in conjunction with the "IOA AMWG Discussion Document". Respondents to the consultation are encouraged to provide their comments on the form provided. A word version has been provided to allow respondents to increase box sizes as required.
All comments on the consultation draft should be sent electronically to:

WTAMCONSULT@IOA.ORG.UK

Alternatively, written responses can be sent to:
IOA AMWG Consultation Feedback
Institute of Acoustics
3rd Floor St Peter's House,
45-49 Victoria Street,
St Albans,
Herts.
AL1 3BN.

The closing date for the receipt of comments is **30th June 2015**. Late comments may not be reflected in the deliberations on the choice of the AM metric.

CONTENTS

INTRODUCTION TO THE CONSULTATION

Background

The Institute of Acoustics Amplitude Modulation Working Group (IOA AMWG) has prepared a discussion document on methods for rating amplitude modulation in wind turbine noise, for the purpose of consultation to IOA Members and other interested parties.

The discussion document considers various methods and has proposed three methods for consultation. The intention of the IOA AMWG post-consultation is to recommend one method but at this consultation stage, three candidate methods are proposed. The AMWG will not be proposing a threshold or penalty mechanism for rating the subjective response.

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

Subsequent section numbers refer to the main discussion document.

Section 3 – AM Definition

Do you agree with the Definition of AM? Does it relate to your experience?

The definition of AM seems appropriate, in the context of AM being defined in this case as amplitude modulated noise generated by wind turbines. It does not seem necessary for the purposes of defining an AM metric to distinguish between “normal” and “other” / “excess” AM.

Is the Definition of AM applicable to smaller turbines?

The definition of AM also seems appropriate for small turbines, and it would seem sensible for AM to be defined in the same way for all turbine sizes for consistency, however it should perhaps be noted in any guidance that if AM is measured from a small turbine, it may indicate problems other than aerodynamic amplitude modulation (e.g. a repetitive rattle, squeak etc.). It would, however, seem sensible to set an upper limit of turbine rpm / blade passing frequency for which the selected method is applicable to guard against the chosen method being used inappropriately (for instance, see comments below regarding vertical axis turbines).

Is it appropriate to measure AM Outside in free-field conditions? If not can you propose alternatives?

Yes, outside measurements are appropriate. Whilst it is possible that internal levels of AM may be increased by room effects or by filtering of the building envelope and may be of more importance to residents, internal measurements are likely to be much less repeatable / reproducible due to room effects and the influence of internal noise sources. Whilst in principle these effects could be mitigated, e.g. by shutting off internal noise sources such as fridges, freezers, central heating etc. for the duration of the measurements and using, for instance, a boom mounted moving microphone to reduce the influence of individual room modes in causing in very localised increases in noise levels, in reality these measures are unlikely to be practical. In addition, the assessment of all other aspects of wind turbine noise (i.e. absolute levels and tonality) are based on external measurements, therefore it would not be possible to measure AM at the same location or with the same measurement equipment as the other measures of wind turbine noise, which is clearly undesirable.

For the same reason, it seems sensible for AM to be measured at free-field (rather than façade or other) locations, as other compliance measurements for overall level and tonality of wind turbine noise are required to be carried out at free-field locations.

Section 4 – Literature Review

Are there any other rating methods or important references that the AMWG should consider?

We have no comments on the literature review.

Section 5 – Towards a preferred metric

In principle, which is the best domain for rating and describing amplitude modulation: the time domain; the frequency domain; or is a hybrid method preferred? Can you explain why?

The method must be a frequency domain or hybrid method, as pure time domain methods are more susceptible to corruption by extraneous noise sources (although all methods will suffer from this problem to an extent). In addition, it is difficult to robustly define a modulation depth using only a time domain method for a modulated time domain signal which is also varying in level (either decreasing or increasing), which is common for wind turbine noise. Whilst in principle it is possible to remove variations in level whilst retaining the modulation, in practice, for real signals, it is very difficult to remove this type of variation in level completely without affecting the modulation in the signal, if solely working in the time domain.

We would also point out that time domain methods are also affected by the underlying background noise level, as this underlying background noise will “fill in” the troughs in turbine noise modulation, whereas the peaks in the modulation will tend not to be affected by consistent sources of backgrounds noise.

It is also our view the results obtained by manually determining the peak to trough height are often considered the ‘right answer’ against which objective methods are to be compared. The purely time-domain time series should not be considered the baseline against which other methods should be compared, as this could include influences from factors unrelated to modulation at the blade passing frequency, as discussed above.

For the above reasons, measuring a peak to trough height in a pure time series will not provide an accurate measure of turbine noise modulation, unless the average level of noise from the turbine is considerably above the prevailing background noise level (at least 12 dB in order to measure a 4 dB modulation depth, for example) and the level of both background and turbine noise are constant over the time period being considered. Hybrid methods address some, but not all, of the potential problems with purely time domain methods.

Frequency domain analysis, by definition, will separate out the measured noise levels into the constituent frequencies, allowing modulation from the turbines to potentially be identified during periods where other sources of noise may mask the turbine AM if a time series approach was applied, thereby avoiding many of the disadvantages of time domain analysis.

Do you agree with time intervals proposed, that is: 100 millisecond samples, 10 second blocks, 10 minute periods?

100ms samples seem appropriate, as this is the smallest sample period that is commonly available and is a small enough sampling period in order to adequately represent the range of likely modulation frequencies from the range of horizontal axis wind turbines currently available. It may not be sufficient for vertical axis wind turbines which run at much higher rpms, however, so perhaps it would be advisable to clarify that the current method applies only to horizontal axis wind turbines, or wind turbines within a particular range of rpms / blade passing frequencies. It would seem preferable not to use a "Fast" time weighting instead of the 100 ms L_{eq}, as the time constant of the "Fast" weighting will act to reduce the modulation depth.

There may be an argument to reduce the block period slightly in order to more accurately to reflect rapid changes in AM, however the block length should be longer than 5 seconds, otherwise AM at a modulation frequency of 0.4 Hz is unlikely to be reliably detected, due to only few (i.e. less than 3) full modulation cycles being included in each block. On this basis, a block length of 10 seconds seems a reasonable compromise between detecting the lower range of possible modulation frequencies from large turbines and allowing the detection of short term variations in AM.

It seems desirable for the overall AM metric to be over a time period that is relatable to conventional meteorological measurements, as this would allow the possibility of identifying possible variations in amplitude modulation with wind direction, wind speed, atmospheric turbulence etc. As such, a 10 minute period seems most appropriate.

Do you agree with the band-limiting filtering approach for rating AM?

In principle, band-limiting the input data seems to be an appropriate choice, given that it is desirable to reduce, as far as possible, the influence of any non-wind turbine related noise sources prior to any AM analysis.

We would also note that it is not desirable to consider a very narrow range of frequencies (i.e. single third octave bands or narrower), as this may result in the modulation being under-estimated, as the modulated signal envelope is, in effect, sampled by the broadband aerodynamic wind turbine noise, so considering a very narrow frequency range could result in errors in estimating the modulation.

We would also suggest that the working group considers whether or not there is likely to be a difference between the summation of adjacent third octave bands, as compared to a true band pass filter over the same frequency range, and if so, if this difference is likely to influence the AM rating obtained. Since there will be some overlap between adjacent third octave band filters, it seems likely that there will be some difference between the two, however whether or not this will affect the AM rating (using whichever of the proposed analysis methods) is unclear.

We would also suggest that the working group investigates the effect of using the linear third octave band / band limited data as the basis of the assessment, rather than the A-weighted data. There are two reasons for this; firstly, from a practical point of view, some sound level meters do not provide A-weighted frequency band data but only provide linearly weighted frequency information, so an additional processing step would be required in analysing the data. Secondly, from experience of analysing measurements of amplitude modulation available to us, the linearly weighted frequency band data appears, at least in some circumstances, to be less sensitive to spurious noise sources and have a reduced "noise floor" (i.e. there is less background variation in, for instance, the calculated power spectral density). The explanation for this is likely to be that A-weighting the data effectively reduces the frequency range that is being considered, as the A-weighting deliberately puts more weight on the higher frequencies in the range that are being considered here. This is likely to be particularly apparent if a band pass range of up to 800 Hz is used, as the A-weighting filter will significantly reduce the influence of frequency bands below around 200 Hz, and

the output is likely to be dominated by frequencies between 400 and 800 Hz.

Is the default frequency range appropriate? What other frequency ranges could be considered, taking into account the desirability to characterize the frequency range in which AM occurs, the desirability to exclude spurious noise sources and the need for a consistent approach to avoid differences?

As suggested in the discussion document, it is probably desirable to allow the band-pass filtering to cover differing frequency ranges depending upon the type of turbine being assessed, however we would suggest that definite advice is provided as to which frequency range applies under different scenarios (e.g. non-overlapping frequency ranges apply for different non-overlapping rotor diameter ranges, for instance) to avoid the possibility of two parties measuring AM using different frequency ranges and therefore arriving at different measures of AM.

We would therefore strongly urge that whatever the final decision with regard to band limiting of the input data, and for that matter all other aspects of the methodology, are set out in the final document in the form of a technical specification and not in terms of a discussion document, and should not be reliant upon engineering judgement to select an appropriate range of frequencies (or other parameters) to include in the analysis. The working group should explicitly specify the appropriate range of input frequencies for the selected rating method.

Section 6 – Time Series Method

Do you think the time series method proposed is suitable for rating AM? If not, can you explain why?

We would note that, strictly speaking, the time series method (Method 1) does not measure modulation per se, but is more a measure of the rapidity of the variation in the 100 ms measurements. This will include modulation, but will also include all other sources of variation. Without performing some form of frequency domain analysis (as was done by the Japanese team who developed this method), it is not possible to know whether the measured variation is likely to be due to AM or whether it is due to other sources of noise (e.g. birdsong etc.).

The discussion document notes that the auto-correlation can be determined from the de-trended time series data, and this can be used to determine the modulation frequency. It is not clear from the discussion document how the modulation frequency is intended to be determined from the auto-correlation (presumably by taking the Fourier transform of the auto-correlation) and this should be explicitly stated if this method is adopted. In addition, it is not clear what should be done if there is some influence from wind turbine noise modulation, but also a clear effect from other noise sources resulting in modulation not at the blade passing frequency. Since the rating determined from this method is based on a statistical assessment of the variation in the noise level over an individual block, it is not possible to say whether the 5^{th} and 95^{th} percentile are controlled by modulation or by spurious sources, even if modulation does occur in the time period. Method 1 therefore fails to properly advise how the output results obtained from the auto-correlation are used to moderate the results from the $5^{th}/95^{th}$ percentile difference, and if this method is adopted, specific requirements on how to achieve this should be provided.

We would also note that calculating the Fourier transform of the auto-correlation provides an estimate of the power spectral density. As such, if it is necessary to calculate this Fourier transform, the time domain method (Method 1) is essentially providing an estimate of the frequency domain method (Method 2) result. In other words, if calculating the Fourier transform of the auto-correlation is a necessary step in order to identify AM (which seems to be the case), the time domain and frequency domain methods are essentially the same (albeit Method 1 uses a different method of detrending the data to Method 2).

The proposed time series method is, as described in the discussion document, highly dependent on the input data being "clean" (or at least that turbine modulation is the dominant form of modulation in the measured data) in order to provide results that correspond to the actual level of AM. At most locations near to UK wind farms there is likely to be significant influence from birdsong which will be picked up as modulation by the proposed time domain method. As such, if this method is implemented, significant filtering is likely to be needed in order to remove data corrupted by non-wind farm modulation. Inevitably this filtering will be, to a degree, subjective and therefore there is the potential for different practitioners to obtain different results from the same data set if this method is implemented. A possible alternative would be to only analyse data during night-time periods, as these are the periods that are likely to be most sensitive from the point of view of residents and are also least likely to be affected by noise from other sources of modulation, however this could lead to very little data being available per day during the summer months.

A further alternative would be to band-filter the data prior to processing it with the time domain method, as is proposed with the frequency domain and hybrid methods. Applying this filtering, whilst likely to reduce the influence of spurious noise sources, will not address the fundamental problems with a purely time domain method described above (i.e., it does not measure modulation per se, and seems to require a Fourier transform of the auto-correlation to be calculated in order to determine whether or not the modulation is at the turbine blade passing frequency).

As such, the proposed time domain method (Method 1) seems to have major limitations and is not in our view fit for purpose.

Section 7 – Frequency Domain Method

Do you think the frequency domain method proposed is suitable for rating AM? If not, can you explain why?

In principle, the frequency domain method as described is suitable for rating AM, however there are some points that should be noted with the proposed procedure. Firstly, it should be noted that there are 5 spectral lines in the proposed integration interval of 0.16 Hz, not four as noted in the footnote on page 38 of the discussion document. The frequency resolution of the power spectral density as calculated using the specified parameters is 0.0390625 Hz (which rounds to 0.04 Hz as stated in the discussion document), i.e. the interval between adjacent spectral lines in the power spectral density is slightly less than 0.04 Hz. The proposed integration interval of 0.16 Hz therefore contains just over 4 complete intervals between spectral lines, therefore there are 5 spectral lines in an interval of 0.16 Hz.

It is also perhaps worth noting that, in one sense, the proposed frequency domain method can be seen as a hybrid method as, in theory, the power spectral density of a signal can be interpreted as the Fourier transform of the autocorrelation of the signal (i.e. a time domain process, followed by a frequency domain process, as noted above in the discussion of Method 1). This suggests a possible method of allowing the harmonics to be included in the frequency domain analysis by adding them to the fundamental in this method, as calculating the Fourier transform of the autocorrelation will allow calculation of both the phase and magnitude at each spectral line. There are, however, likely to be errors introduced to the estimate of the power spectral density using this alternative method of calculating the power spectral density, due to the limited time period over which the Fourier transform and autocorrelation can be calculated, therefore whether or not this is a feasible approach in practice would need further investigation.

With regard to identifying the modulation peak, we would note that the method described in section 7.2.2 may not be particularly reliable if applied to individual 10 second spectra (although it is not clear if this is what is intended from the description in the discussion document). It is just as likely that a spurious peak could occur in the modulation spectrum within the expected range of blade passing frequencies as at any

other frequency. To reduce the likelihood of spurious peaks in individual 10 second spectra affecting the modulation frequency, one possible method is calculate an average spectrum over all of the calculated 10 second spectra in a particular 10 minute period. Whilst the signal to noise ratio in this average spectrum will be the same as in any individual 10 second spectrum (assuming the signal and noise are relatively constant), the variance of the noise will be reduced, and so large peaks in the average spectrum are not likely to be due to short-lived events. The modulation frequency can then be determined by looking for a peak in this average spectrum which is in the expected range of modulation frequencies. Note that the modulation depth should not be determined from this average spectrum, only the modulation frequency. Whilst this method is not immune to being affected by spurious noise sources, experience suggests it gives a better estimate of the fundamental modulation frequency than trying to determine the modulation frequency within individual 10 second spectra.

It would also be advisable to investigate whether inputting unweighted data into this method gives better results that using A-weighted data, as recommended in the discussion document. Experience suggests that using A-weighted third octave bands increases the noise floor in the calculated modulation power spectral density – this is likely to be due to the fact that the A-weighting effectively reduces the frequency range of the input data by reducing the influence of the lower frequency third octave bands, and this narrowing of the frequency range may introduce errors, as described above.

Should other parameters be used in the application of this method and why?

Generally, the parameters as suggested seem appropriate, however as described above, there may be the opportunity to include the influence of harmonics if the power spectral density is calculated in an alternative way, however the reliability of this alternative method would need to be investigated further.

Section 8 – Hybrid Method

Do you think the hybrid method proposed is suitable for rating AM? If not, can you explain why?

Whilst the proposed hybrid method is reasonable in theory, in practice it should be noted that if the fundamental modulation frequency is determined from a Fourier transform method (as will be the case if no SCADA data is available), then the frequencies of the first and second harmonic are not likely to be integer multiples of the fundamental. This is due to the fact that any Fourier transform method only provides a measure of the frequency content of the signal at discrete frequencies, which will generally not align exactly with the fundamental frequency of the modulation, therefore there will be some error in the estimation of the fundamental frequency. The addition of noise into the modulation spectrum is likely to make this error greater, especially if the fundamental frequency is estimated from individual 10 second spectra (see above regarding a more accurate method for calculating modulation frequencies using the average of the 10s spectra in a 10 minute period). Multiplying the fundamental frequency by multiples of 2 and 3 to determine the first and second fundamental will increase this error for these harmonics, and therefore the third octave band filters at the first and second harmonic frequencies will not be centred at the correct frequencies.

An alternative method of identifying the harmonic frequencies is to use a peak search method on some form of Fourier transformed data (e.g. the power spectral density) in a range of possible frequencies, which are determined from the identified fundamental frequency. For example, if the identified fundamental frequency is identified to be 0.78125 Hz, the frequency of the first harmonic could be identified by applying a peak search method in the range of frequencies between 1.48 Hz and 1.64 Hz (twice the fundamental, plus or minus 10% of the identified fundamental frequency). A similar method could be used to identify the second harmonic.

We would also note that the proposed hybrid method is rather complex and computationally intensive (in many cases, a power spectral density, at least two peak search algorithms and three 1/3 octave band filters will need to be computed for every 10 s period). Whilst this is not in itself a problem, in many cases the power spectral density will need to be calculated in order to determine the frequencies of the fundamental and the harmonics of the modulation in order to set the filter centre frequencies. It therefore seems unnecessary to perform all of the remaining steps in the proposed hybrid method when the power spectral density can be used to estimate the level of modulation directly.

The justification for the increased complexity of Method 3 apparently stems from the need to account for the magnitude of the harmonics. As set out above there is an alternate approach to doing so which would warrant further study. Not accounting for the magnitude of the harmonics is not a fatal flaw but would be accounted for when relating the objective metric to subjective impression.

We do, however, recognise that the hybrid method results in a time series output, and if this is desirable for a particular reason, then Method 3 would be preferred ahead of Method 1 (the purely time series method).

Should other parameters be used in the application of this method and why?

We would note that, if this method is adopted, multiple descriptors could be used analogous to L_{50}, L_{max}, L_{90} etc., as the peak to trough levels can be determined for each individual peak and trough within each data block. Since the aim of the current work is to identify an objective method of rating AM, this raises the possibility that a set of objective descriptors could be defined, which allows greater flexibility for future work (i.e. the DECC project that is currently out to tender) to select a descriptor or combination of descriptors against which to set penalties.

Section 9 – Comparison of Methods

Of the three methods proposed, which is your preferred method?

Method 2 (the “frequency domain” method) would be our preferred choice, as this seems to strike an appropriate balance between being resistant to the effect of spurious noise sources and closely matching the subjective response to modulation, whilst keeping complexity of the method reasonably low.

We would stress that whichever method is chosen, this should be prescriptive and involve as little user intervention as possible, for instance in excluding certain data based on user judgement, manual selection of filter frequencies etc. It is, in our view, vitally important that the selected method is reproducible, i.e. different individuals will get exactly the same AM rating given the same data set.

Is there another alternative method not recommended by the AMWG which would be preferable? Explain why.

Section 10 – Instrumentation

Are the proposed requirements for instrumentation appropriate?

The instrumentation proposed seems reasonable (however see comments below regarding measurement parameters).

Would you like instrument manufacturers to make available an "AM rating" option for sound level meters?

This is not a relevant consideration for the IOA and is for SLM makers to decide. Based on past experience of the ETSU-R-97 tonal method, there is unlikely to be sufficient market for a device which implements the analysis within the instrument.

Section 11 – Software

Should the IOA make available software for rating AM?

This is not a relevant consideration at this time.

Do you have any comments on the software released?

As discussed above, the integration interval of 0.16 Hz contains 5 spectral lines, not 4 as described above. We understand that, since 4 spectral lines (hence an integration interval of 0.12 Hz) has been used in the supplied software, this has required the frequencies in the integrated spectrum to be shifted from the frequencies in the original, raw spectrum, since the centre point of the 4 spectral lines lies in the interval between 2 spectral lines. The shifting in frequencies has not been performed in a consistent manner across the spectrum however, with the interval between spectral lines at the beginning and end of the spectrum being shorter than the remaining intervals.

We would note that, if the integration interval remains at 4 spectral lines, the integrated spectrum can simply be calculated at each of the frequencies that are in the raw spectrum, shifted up in frequency by half the frequency resolution of the raw spectrum. This has the benefit of retaining the interval between adjacent data points in the integrated spectrum to the same as that in raw spectrum. Clearly, if this shift is applied, the final data point in the integrated spectrum will be outside the frequency range of the raw spectrum. This point can be removed (which will result in the integrated spectrum being 1 point shorter in length than the raw spectrum) or, to keep the raw and integrated spectra the same length, this point can be left in the integrated spectrum, as this point will represent a frequency of around 5.04 Hz, which is a long way above the range of modulation frequencies of horizontal axis wind turbines and as such has no relevance to the assessment of AM. The alternative and our preference is to base the integration on 5 spectra lines so that the resulting spectral line frequencies match those in the original raw PSD. Lines at the beginning and end of the integration spectrum would include less than 5 spectral lines, but these centre frequencies are

outside of the range of frequencies of interest.

Recommendations for Further Study and any other comments

On page 61 of the discussion document, several optional measurements are listed that could be measured as part of an AM assessment. It's not clear, however, what relevance the L_{Aeq} and L_{A90} measured over 10 minute periods, or the L_{A90} measured over 10 s periods, has to the assessment of amplitude modulation. Whilst 10 minute L_{Aeq} and L_{A90} measurements are clearly relevant to the assessment of overall noise levels from wind turbines, they cannot provide any information in relation to modulation depth, whichever of the three proposed methods are adopted.

We would therefore suggest that references these optional measurements are removed from the final methodology, as they are not relevant to the measurement of AM.

Your details

Please provide your name and contact details in case the working group wishes to clarify any of the points raised in your feedback: Can you also indicate if you would like your response to be published anonymously or not published at all by the IOA?

The IOA AMWG thanks you for your help in completing this document.

Gavin Irvine
AMWG Chair

INSTITUTE OF ACOUSTICS

IOA CONSULTATION QUESTIONNAIRE FOR

"METHODS FOR RATING AMPLITUDE MODULATION IN WIND TURBINE NOISE"

APRIL 2015

FOREWORD

** PLEASE READ BEFORE PROCEEDING TO THE MAIN DOCUMENT **

This discussion document has been produced by a working group on behalf of the Institute of Acoustics consisting of the following members:

Jeremy Bass		RES Ltd
Matthew Cand		Hoare Lea Acoustics
David Coles		24 Acoustics
Robert Davis		RD Associates
Gavin Irvine	(Chair)	Ion Acoustics
Geoff Leventhall		
Tom Levet		Hayes McKenzie
Sam Miller		
David Sexton		West Devon Borough Council
John Shelton		AcSoft

This questionnaire has been produced specifically to promote discussion of the relevant issues during the consultation on a metric for amplitude modulation (AM) from wind turbines and should be read in conjunction with the "IOA AMWG Discussion Document". Respondents to the consultation are encouraged to provide their comments on the form provided. A word version has been provided to allow respondents to increase box sizes as required.
All comments on the consultation draft should be sent electronically to:

WTAMCONSULT@IOA.ORG.UK

Alternatively, written responses can be sent to:
IOA AMWG Consultation Feedback
Institute of Acoustics
3rd Floor St Peter's House,
45-49 Victoria Street,
St Albans,
Herts.
AL1 3BN.

The closing date for the receipt of comments is **30th June 2015**. Late comments may not be reflected in the deliberations on the choice of the AM metric.

CONTENTS

INTRODUCTION TO THE CONSULTATION

Background

The Institute of Acoustics Amplitude Modulation Working Group (IOA AMWG) has prepared a discussion document on methods for rating amplitude modulation in wind turbine noise, for the purpose of consultation to IOA Members and other interested parties.

The discussion document considers various methods and has proposed three methods for consultation. The intention of the IOA AMWG post-consultation is to recommend one method but at this consultation stage, three candidate methods are proposed. The AMWG will not be proposing a threshold or penalty mechanism for rating the subjective response.

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

Subsequent section numbers refer to the main discussion document.

Section 3 – AM Definition

Do you agree with the Definition of AM? Does it relate to your experience?

Yes.

Is the Definition of AM applicable to smaller turbines?

No experience of smaller turbines.

Is it appropriate to measure AM Outside in free-field conditions? If not can you propose alternatives?

Definitely the best approach. Impractical to measure indoors due to; lack of access, extraneous noise, issues of privacy when recording audio indoors (audio is required and invaluable to check source of AM).

AM is a difference in level between the peak and trough – this peak to trough difference will not be significantly altered by a façade if a relatively narrow frequency range is considered.

Section 4 – Literature Review

Are there any other rating methods or important references that the AMWG should consider?

No.

Section 5 – Towards a preferred metric

In principle, which is the best domain for rating and describing amplitude modulation: the time domain; the frequency domain; or is a hybrid method preferred? Can you explain why?

Frequency / Hybrid. The time domain is impractical on large data sets. Modern turbines have variation in rotational speed.

In my opinion frequency analysis is needed to determine the rotational speed of the turbines. This needs to be determined through analysis of the measurements, as rotational speed data from the turbines does not accurately provide this information (not always the nearest 1 or 2 turbines that are dominant).

Do you agree with time intervals proposed, that is: 100 millisecond samples, 10 second blocks, 10 minute periods?

Yes.

However, is it necessary to exclude the period if 12 10 second samples have extraneous noise? Extraneous noise and turbine noise constantly rise and fall. Turbine noise may still be pretty annoying even with 12 10 second periods of extraneous noise. Suggest a higher limit on exclusion of the period is considered – maybe 24 or 30 10 second periods??

How exactly are the periods with 12 10-second periods of extraneous noise going to be identified + removed.

Do you agree with the band-limiting filtering approach for rating AM?

Yes, excellent method. Focuses on the frequencies imported for OAM, and also ditches the extraneous noise.

Is the default frequency range appropriate? What other frequency ranges could be considered, taking into account the desirability to characterize the frequency range in which AM occurs, the desirability to exclude spurious noise sources and the need for a consistent approach to avoid differences?

I suspect a good choice, based on OAM resulting in a shift in noise to lower frequencies.

Normal AM seems to be easily detected over 250 – 1000 kHz, at distances of about 1500 m – 2000 m, but my experience is 800 Hz and above is often contaminated by other sources.

Overall A-weighted 100 ms levels are pretty rubbish due to extraneous noise.

Section 6 – Time Series Method

Do you think the time series method proposed is suitable for rating AM? If not, can you explain why?

For brief spot checks of at a moment in time, yes suitable, as it's very simple to do.

For a rigorous assessment of AM; pretty useless due to the susceptibility to extraneous noise.

Section 7 – Frequency Domain Method

Do you think the frequency domain method proposed is suitable for rating AM? If not, can you explain why?

Frequency domain should work, with an acceptability criterion specifically derived to suit the method. However, likely to attract criticism from some parties for assuming a sinusoidal wave, which turbine noise is not.

How exactly is the requirement for the periods with 12 10-second periods of extraneous noise (Section 5.2.3 of the discussion paper) going to be achieved? Surely the idea is this will be automated, to allow application to large data sets? My following comments are assuming these periods are to be automatically found based on the detected frequency not matching the plausible rotational turbine speed.

My experience is that rotational speed data is pretty useless for determining the blade pass frequency on large sites with variable speed turbines, as large variations in speed occur and it's unclear which turbines are controlling noise levels at the residence. But I'm sure at small sites it could work very well (and obviously a non-issue on sites with fixed rotational speed turbines). Selecting the range of operating speeds as possible blade pass frequency has not previously worked for me, due to extraneous noise.

In our assessment (Cooper and Evans 2013) we started by trying both of the above methods, but they provided a significantly incorrect blade pass frequency far more often than the correct frequency. Wind turbine levels at this house were only about 35 dB(A), and so often affected by extraneous noise. It could perhaps be argued that at our site the levels are so low that AM is a bit irrelevant, and not going to change the compliance outcome – therefore possibly no need for a method to cater for this much extraneous noise. The methods I used to deal with the extraneous noise are not pretty, but significantly improved the accuracy of frequency detection.

The inspection of the waterfall plot and manual selection of blade pass frequency suggested in the discussion paper would definitely work to find blade pass, but does take away the automation of the method. I suggest considering including some aspects of our extraneous noise rejection, to avoid manual setting of the frequency based on use of the waterfall plot.

Should other parameters be used in the application of this method and why?

Section 8 – Hybrid Method

Do you think the hybrid method proposed is suitable for rating AM? If not, can you explain why?

This is definitely the best approach – deals well with the non-sine wave AM. Should also be far better than the time series methods for rejecting extraneous noise.

Comments from Section 7 on finding the blade pass frequency are relevant to this method.

Should other parameters be used in the application of this method and why?

Section 9 – Comparison of Methods

Of the three methods proposed, which is your preferred method?

Hybrid, but with some more effort to find the actual blade pass frequency.

Is there another alternative method not recommended by the AMWG which would be preferable? Explain why.

Section 10 – Instrumentation

Are the proposed requirements for instrumentation appropriate?

Fine.

Would you like instrument manufacturers to make available an “AM rating” option for sound level meters?

Have my doubts this is feasible, due to the likely need to set blade pass frequency from waterfall plot.

Section 11 – Software

Should the IOA make available software for rating AM?

Optional, but some parties would be incapable of implementing the frequency domain or hybrid methods without it. That would probably not be a bad outcome.

Strongly prefer some flexibility so that it's not a requirement that IOA software must be used, to allow tailoring of the assessment as needed / much greater automation.

Do you have any comments on the software released?

I've not had the time to run it. Looks pretty easy from the motes provided.

Recommendations for Further Study and any other comments

Your details

Please provide your name and contact details in case the working group wishes to clarify any of the points raised in your feedback: Can you also indicate if you would like your response to be published anonymously or not published at all by the IOA?

Jon Cooper
jon.cooper@resonateacoustics.com
Resonate Acoustics, Australia

The IOA AMWG thanks you for your help in completing this document.

Gavin Irvine
AMWG Chair

INSTITUTE OF ACOUSTICS

IOA CONSULTATION QUESTIONNAIRE FOR

"METHODS FOR RATING AMPLITUDE MODULATION IN WIND TURBINE NOISE"

APRIL 2015

FOREWORD

** PLEASE READ BEFORE PROCEEDING TO THE MAIN DOCUMENT **

This discussion document has been produced by a working group on behalf of the Institute of Acoustics consisting of the following members:

Jeremy Bass		RES Ltd
Matthew Cand		Hoare Lea Acoustics
David Coles		24 Acoustics
Robert Davis		RD Associates
Gavin Irvine	(Chair)	Ion Acoustics
Geoff Leventhall		
Tom Levet		Hayes McKenzie
Sam Miller		
David Sexton		West Devon Borough Council
John Shelton		AcSoft

This questionnaire has been produced specifically to promote discussion of the relevant issues during the consultation on a metric for amplitude modulation (AM) from wind turbines and should be read in conjunction with the "IOA AMWG Discussion Document". Respondents to the consultation are encouraged to provide their comments on the form provided. A word version has been provided to allow respondents to increase box sizes as required.
All comments on the consultation draft should be sent electronically to:

WTAMCONSULT@IOA.ORG.UK

Alternatively, written responses can be sent to:
IOA AMWG Consultation Feedback
Institute of Acoustics
3rd Floor St Peter's House,
45-49 Victoria Street,
St Albans,
Herts.
AL1 3BN.

The closing date for the receipt of comments is **30th June 2015**. Late comments may not be reflected in the deliberations on the choice of the AM metric.

CONTENTS

INTRODUCTION TO THE CONSULTATION

Background

The Institute of Acoustics Amplitude Modulation Working Group (IOA AMWG) has prepared a discussion document on methods for rating amplitude modulation in wind turbine noise, for the purpose of consultation to IOA Members and other interested parties.

The discussion document considers various methods and has proposed three methods for consultation. The intention of the IOA AMWG post-consultation is to recommend one method but at this consultation stage, three candidate methods are proposed. The AMWG will not be proposing a threshold or penalty mechanism for rating the subjective response.

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

Subsequent section numbers refer to the main discussion document.

Section 3 – AM Definition

Do you agree with the Definition of AM? Does it relate to your experience?

Is the Definition of AM applicable to smaller turbines?

Is it appropriate to measure AM Outside in free-field conditions? If not can you propose alternatives?

It is but the background sound condition must be low enough not to cause major masking effect of AM. Thus it means that evening-night-early morning measurement periods need to be used primarily.

Section 4 – Literature Review

Are there any other rating methods or important references that the AMWG should consider?

Section 5 – Towards a preferred metric

In principle, which is the best domain for rating and describing amplitude modulation: the time domain; the frequency domain; or is a hybrid method preferred? Can you explain why?

This depends of the scope of the work! If it is a short term measurement with known EAM problems, it seems that envelope based methods give a more accurate answer to the AM depth question. If it is a long term measurement without knowing the situation beforehand, the hybrid method may be more appropriate method to choose.

Do you agree with time intervals proposed, that is: 100 millisecond samples, 10 second blocks, 10 minute periods?

Yes, proposed intervals should be 10 minutes since the wind data (Sodar, Scada) typically has the same interval. The 10 s period may sound short and 15 s has been used also (C.Larsson, Sweden), but AM or EAM may be also produced by 4-5 instantaneous pulses (e.g. during wind gusts) and thus the 10s proposed interval seems to be reasonable. 100 ms sample interval is better than 0.125 as it takes account the peak values with more accuracy. I believe that overall the proposed intervals are valid and should be used as a reference.

Do you agree with the band-limiting filtering approach for rating AM?

The band-limiting frequency range gives typically the strongest indication of AM (or EAM) but we have done case-by-case pre-assessment to the data to find the most suitable frequency limits. I guess if you have to choose one band-limit, 100-400 should be it, since partial stalling effect seems to occur mostly between those bands.

Is the default frequency range appropriate? What other frequency ranges could be considered, taking into account the desirability to characterize the frequency range in which AM occurs, the desirability to exclude spurious noise sources and the need for a consistent approach to avoid differences?

see above.

Section 6 – Time Series Method

Do you think the time series method proposed is suitable for rating AM? If not, can you explain why?

I think it is suitable for short term measurement analysis where AM is knows to occur. It gives more realistic results in terms of AM depth than frequency domain methods.

Section 7 – Frequency Domain Method

Do you think the frequency domain method proposed is suitable for rating AM? If not, can you explain why?

It seems that the method 2 underestimates AM depth a bit (see annexes) although it follows methods 1 and 3 results in every 10s period but generally with a slightly lower AM depth values.

Should other parameters be used in the application of this method and why?

Section 8 – Hybrid Method

Do you think the hybrid method proposed is suitable for rating AM? If not, can you explain why?

From the frequency domain methods, this seems to give more realistic AM depth results than Method 2 but still somewhat underestimates AM depth even in calibration signals, which had a 1.5s peak to peak modulation frequency (equalling 13.333.. r.p.m.). Maybe by fixing it a bit (?) it would give more correct AM depth results. 0.7 -1.3 dB modulation depth differences were calculated.

Should other parameters be used in the application of this method and why?

Section 9 – Comparison of Methods

Of the three methods proposed, which is your preferred method?

Method 1 for short term measurements and method 3 for long term measurements with caution.

Is there another alternative method not recommended by the AMWG which would be preferable? Explain why.

Section 10 – Instrumentation

Are the proposed requirements for instrumentation appropriate?

Would you like instrument manufacturers to make available an “AM rating” option for sound level meters?

Section 11 – Software

Should the IOA make available software for rating AM?

Do you have any comments on the software released?

Recommendations for Further Study and any other comments

- AM depth calibrations for frequency domain methods

Your details

Please provide your name and contact details in case the working group wishes to clarify any of the points raised in your feedback: Can you also indicate if you would like your response to be published anonymously or not published at all by the IOA?

Carlo Di Napoli
Pöyry Finland Oy
carlo.dinapoli@poyry.com
+358405857674

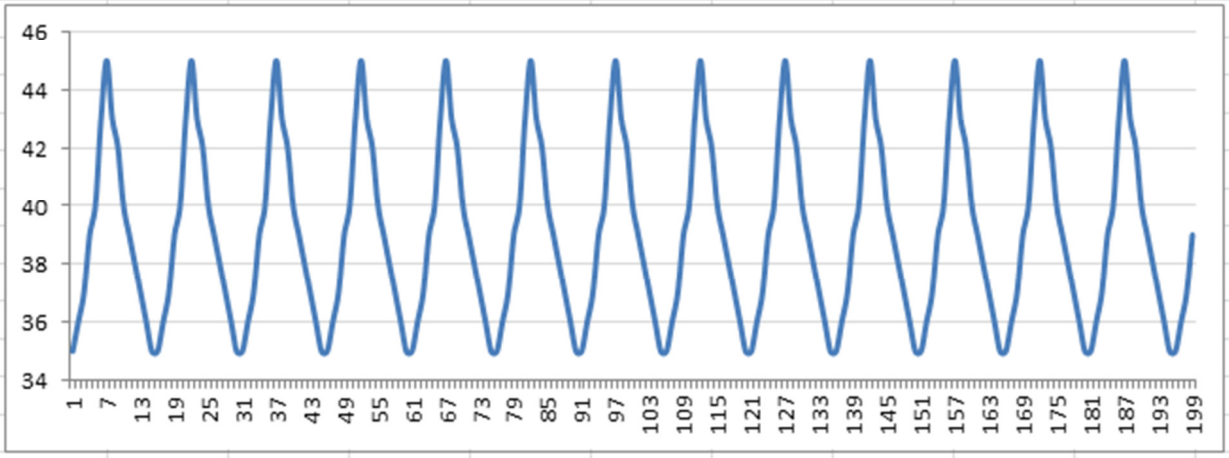
The IOA AMWG thanks you for your help in completing this document.

Gavin Irvine
AMWG Chair

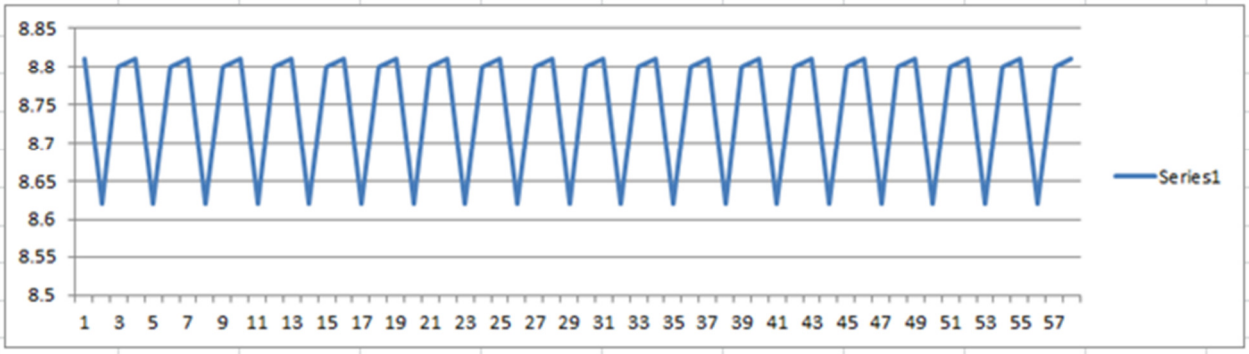
Annex 1. Some calibration signal tests

Modulation depth 10 dB (35-45 dB) , 13.33 r.p.m. AM frequency 0.666…Hz

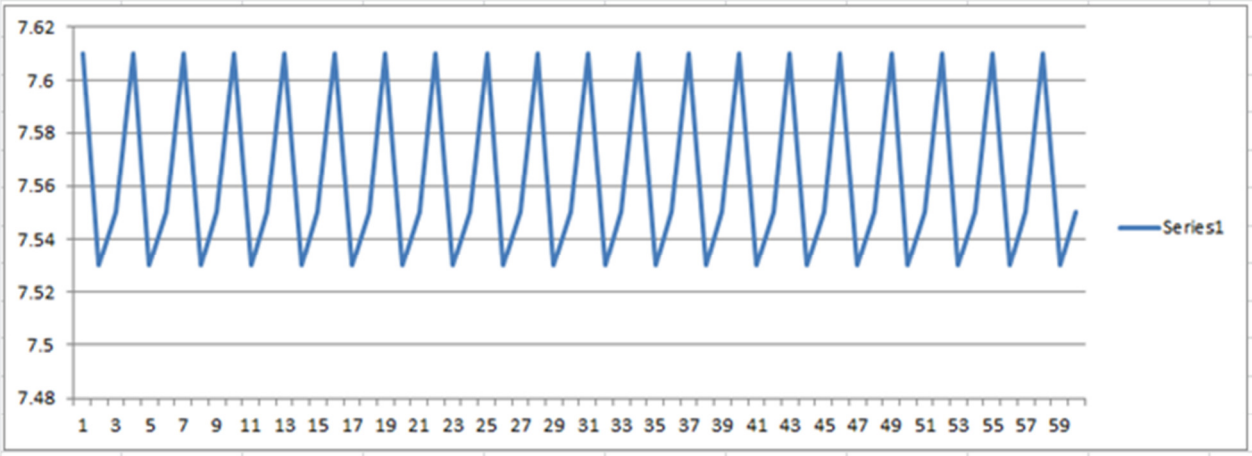
data1



Method 3



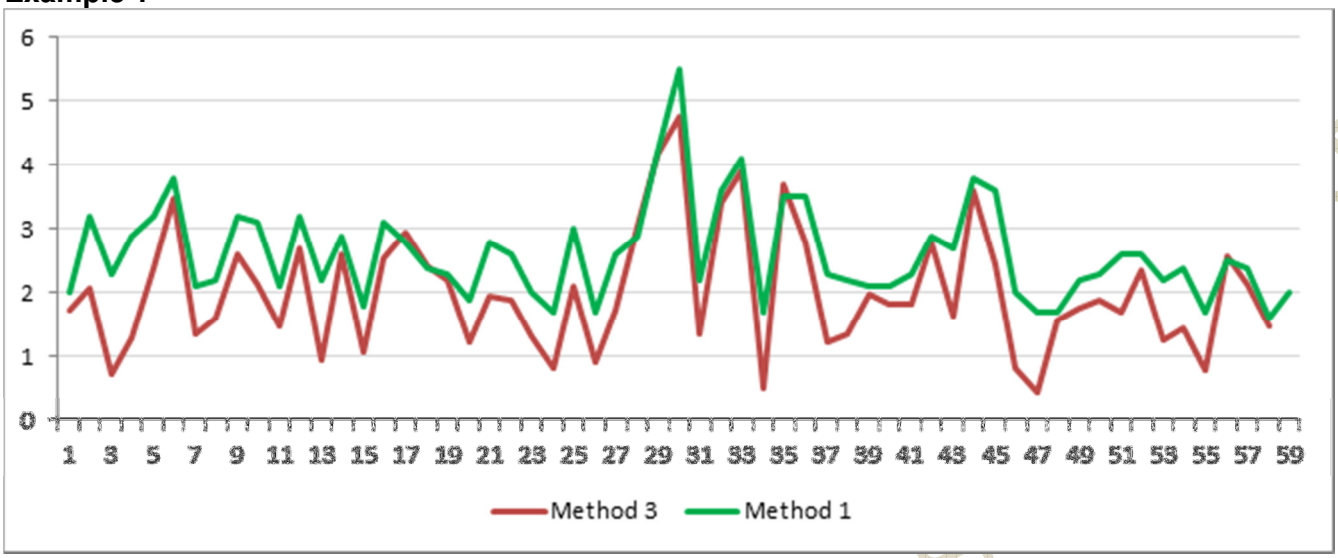
Method 2



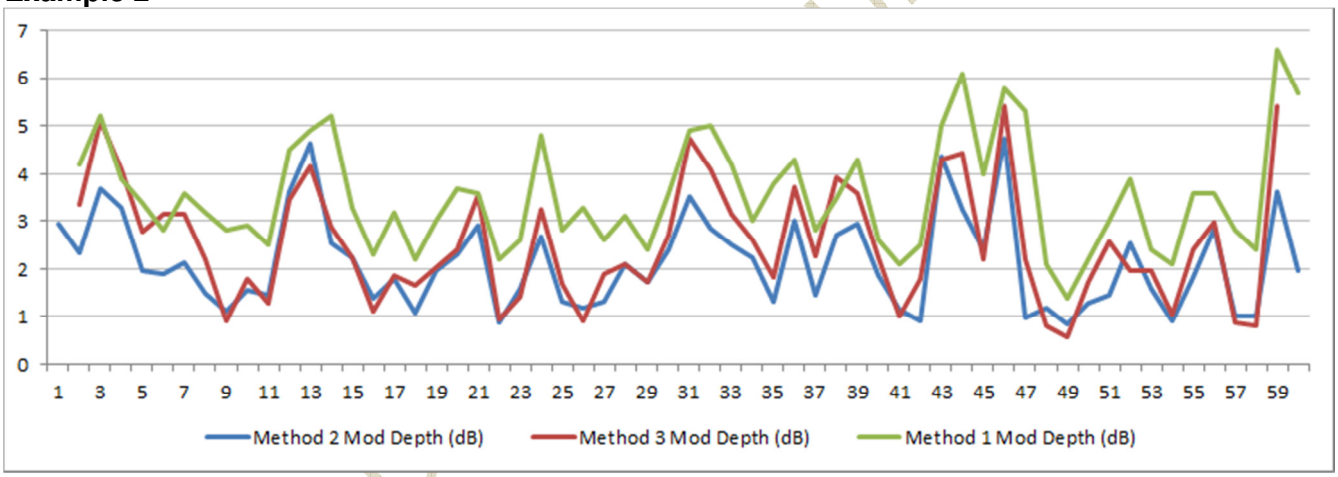
Annex 2. Tests with real signals from WTN measurements

Methods 2-3 are from band pass filtered data (100-400Hz). Method 1 with non-filtered data.

Example 1



Example 2



INSTITUTE OF ACOUSTICS

IOA CONSULTATION QUESTIONNAIRE FOR

"METHODS FOR RATING AMPLITUDE MODULATION IN WIND TURBINE NOISE"

APRIL 2015

FOREWORD

** PLEASE READ BEFORE PROCEEDING TO THE MAIN DOCUMENT **

This discussion document has been produced by a working group on behalf of the Institute of Acoustics consisting of the following members:

Jeremy Bass	RES Ltd
Matthew Cand	Hoare Lea Acoustics
David Coles	24 Acoustics
Robert Davis	RD Associates
Gavin Irvine (Chair)	Ion Acoustics
Geoff Leventhall	
Tom Levet	Hayes McKenzie
Sam Miller	
David Sexton	West Devon Borough Council
John Shelton	AcSoft

This questionnaire has been produced specifically to promote discussion of the relevant issues during the consultation on a metric for amplitude modulation (AM) from wind turbines and should be read in conjunction with the "IOA AMWG Discussion Document". Respondents to the consultation are encouraged to provide their comments on the form provided. A word version has been provided to allow respondents to increase box sizes as required.
All comments on the consultation draft should be sent electronically to:

WTAMCONSULT@IOA.ORG.UK

Alternatively, written responses can be sent to:
IOA AMWG Consultation Feedback
Institute of Acoustics
3rd Floor St Peter's House,
45-49 Victoria Street,
St Albans,
Herts.
AL1 3BN.

The closing date for the receipt of comments is **30th June 2015**. Late comments may not be reflected in the deliberations on the choice of the AM metric.

CONTENTS

INTRODUCTION TO THE CONSULTATION

Background

The Institute of Acoustics Amplitude Modulation Working Group (IOA AMWG) has prepared a discussion document on methods for rating amplitude modulation in wind turbine noise, for the purpose of consultation to IOA Members and other interested parties.

The discussion document considers various methods and has proposed three methods for consultation. The intention of the IOA AMWG post-consultation is to recommend one method but at this consultation stage, three candidate methods are proposed. The AMWG will not be proposing a threshold or penalty mechanism for rating the subjective response.

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

Subsequent section numbers refer to the main discussion document.

Section 3 – AM Definition

Do you agree with the Definition of AM? Does it relate to your experience?

I'm an acoustics and technical expert at MAS Environmental, tasked with processing noise data on a daily basis and programming software tools to assist my colleagues in doing the same. I am in charge of the Cotton Farm permanent online monitor and I have personally analysed many months of recorded data, assessing the occurrence of AM in the data to determine how often it occurs. I was tasked with understanding the FFT method which I have followed through the various iterations (RenewablesUK, Proposed Den Brook Condition 21 and here). I have assisted my colleagues in understanding the technical side of this method.

My own comments are quite short and are mostly the same as those that I raised during the Newcastle workshop. I wanted to include them in written form as I feel they are important. I have highlighted them in blue.

Is the Definition of AM applicable to smaller turbines?

Is it appropriate to measure AM Outside in free-field conditions? If not can you propose alternatives?

Section 4 – Literature Review

Are there any other rating methods or important references that the AMWG should consider?

Section 5 – Towards a preferred metric

In principle, which is the best domain for rating and describing amplitude modulation: the time domain; the frequency domain; or is a hybrid method preferred? Can you explain why?

Do you agree with time intervals proposed, that is: 100 millisecond samples, 10 second blocks, 10 minute periods?

Do you agree with the band-limiting filtering approach for rating AM?

Is the default frequency range appropriate? What other frequency ranges could be considered, taking into account the desirability to characterize the frequency range in which AM occurs, the desirability to exclude spurious noise sources and the need for a consistent approach to avoid differences?

Section 6 – Time Series Method

Do you think the time series method proposed is suitable for rating AM? If not, can you explain why?

Section 7 – Frequency Domain Method

Do you think the frequency domain method proposed is suitable for rating AM? If not, can you explain why?

Should other parameters be used in the application of this method and why?

Section 8 – Hybrid Method

Do you think the hybrid method proposed is suitable for rating AM? If not, can you explain why?

Should other parameters be used in the application of this method and why?

Section 9 – Comparison of Methods

Of the three methods proposed, which is your preferred method?

Method 1 is my preferred method for the simple reason that you are attempting to create a metric, a way of measuring the depth of modulation as a single figure, and methods 2 and 3 understate the peak-to-trough of real world AM data measured by us and experienced by complainants significantly more than method 1.

I understand the argument about method 1 introducing more " extraneous noise", but I think that this is something that occurs with all metrics as there will always be other environmental noise sources that will result in a high AM value. This was shown by Tom Levet in his presentation and I demonstrated an example of this to David Coles at the workshop where aircraft noise gave the same AM value as 5dB+ peak-to-trough wind farm noise for all three methods.

I can see that with methods 2 and 3 there is a significant reduction in "extraneous noise" due to using the FFT analysis focusing on a single peak of modulating sound level, however this also results in a significant reduction in AM value for real world data compared with method 1. The AM values taken from data we have recorded and analysed are only close to being representative of the overall peak-to-trough activity during periods of consistent AM for the entire 10 second period. When AM behaves like a perfect sine wave, the FFT method does a better job of representing the modulation depth as a single figure and could potentially be a useful metric.

Our experience with monitoring data at many locations and wind farms across the country is that AM does not behave in this consistent way when measured at distances at and greater than 400-500m. What we see more often is AM comes and goes very quickly, multiple turbines go in and out of sync and during extreme cases you have large individual peaks of 10-15dB in a 10 second period that methods 2 and 3 equate in value to a period of consistent sinusoidal AM of around 5dB.

Methods 2 and 3 are appropriate metrics for determining how consistent AM is, however they are commonly not representative of how extreme it is. I think this is a real problem when using the methods to determine acceptability or nuisance. Despite what Matthew Cand said in the Newcastle workshop, I'm not convinced that consistent AM of a lower depth is of equal or greater annoyance to complainants than inconsistent AM with greater depth of peaks.

Is there another alternative method not recommended by the AMWG which would be preferable? Explain why.

Section 10 – Instrumentation

Are the proposed requirements for instrumentation appropriate?

Would you like instrument manufacturers to make available an “AM rating” option for sound level meters?

Section 11 – Software

Should the IOA make available software for rating AM?

Do you have any comments on the software released?

Recommendations for Further Study and any other comments

I'd just like to note that the example of the FFT processing for figure 7.1 and 7.2 has me concerned. The "10 second time history graph" is actually 20 seconds - it shows it along the bottom and has too many peaks to be 0.8Hz if it's 10 seconds. Additionally, it does not appear to be from the part of the "100ms time history" graph illustrated with the two red lines, as the traces don't match. So the images don't actually show what they're implying they do, which could be misleading and confusing to those trying to understand the methods.

Also, the "Modulation spectrum" graph in Figure 7.1 has a harmonic that does not appear in the LAeq trace above, that it is apparently derived from. I believe that the only way that the spectrum graph potentially matches that trace is if the "10s" (actually 20s) trace is actually still unfiltered and the filtered trace peak-to-trough is both much higher in depth and with the added harmonic (peaks between the main peaks would appear). This seems unlikely as I haven't seen the filtering introducing or increasing the harmonics as significantly as would be required here.

I sincerely doubt these graphs are anything more than illustrative and I feel it is misleading to suggest that Figure 7.1 and 7.2 represent a real example of the use of the method. We rarely have the AM value come out this close to the overall peak-to-trough level. It certainly only occurs with the FFT method when the peak-to-trough acts as a near perfect sine wave, meaning there is no harmonic. Even when there are no significant harmonics, the AM value usually understates the overall peak-to-trough. This is what we see when we analyse AM data, time and time again.

My recommendation for the future is to be more transparent with your testing of the methods providing access to your data and not just providing misleading screenshots of graphs.

Your details

Please provide your name and contact details in case the working group wishes to clarify any of the points raised in your feedback: Can you also indicate if you would like your response to be published anonymously or not published at all by the IOA?

Duncan Stigwood
MAS Environmental
14 South Road
Impington
CB24 9PB

01223 510430
duncan@masenv.co.uk

The IOA AMWG thanks you for your help in completing this document.

Gavin Irvine
AMWG Chair

INSTITUTE OF ACOUSTICS

IOA CONSULTATION QUESTIONNAIRE FOR

"METHODS FOR RATING AMPLITUDE MODULATION IN WIND TURBINE NOISE"

APRIL 2015

FOREWORD

** PLEASE READ BEFORE PROCEEDING TO THE MAIN DOCUMENT **

This discussion document has been produced by a working group on behalf of the Institute of Acoustics consisting of the following members:

Jeremy Bass		RES Ltd
Matthew Cand		Hoare Lea Acoustics
David Coles		24 Acoustics
Robert Davis		RD Associates
Gavin Irvine	(Chair)	Ion Acoustics
Geoff Leventhall		
Tom Levet		Hayes McKenzie
Sam Miller		
David Sexton		West Devon Borough Council
John Shelton		AcSoft

This questionnaire has been produced specifically to promote discussion of the relevant issues during the consultation on a metric for amplitude modulation (AM) from wind turbines and should be read in conjunction with the "IOA AMWG Discussion Document". Respondents to the consultation are encouraged to provide their comments on the form provided. A word version has been provided to allow respondents to increase box sizes as required.
All comments on the consultation draft should be sent electronically to:

WTAMCONSULT@IOA.ORG.UK

Alternatively, written responses can be sent to:
IOA AMWG Consultation Feedback
Institute of Acoustics
3rd Floor St Peter's House,
45-49 Victoria Street,
St Albans,
Herts.
AL1 3BN.

The closing date for the receipt of comments is **30th June 2015**. Late comments may not be reflected in the deliberations on the choice of the AM metric.

CONTENTS

INTRODUCTION TO THE CONSULTATION

Background

The Institute of Acoustics Amplitude Modulation Working Group (IOA AMWG) has prepared a discussion document on methods for rating amplitude modulation in wind turbine noise, for the purpose of consultation to IOA Members and other interested parties.

The discussion document considers various methods and has proposed three methods for consultation. The intention of the IOA AMWG post-consultation is to recommend one method but at this consultation stage, three candidate methods are proposed. The AMWG will not be proposing a threshold or penalty mechanism for rating the subjective response.

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

Subsequent section numbers refer to the main discussion document.

Section 3 – AM Definition

Do you agree with the Definition of AM? Does it relate to your experience?

No. ETSU did not envisage any AM in the far field and so even AM defined as 'normal AM' should not be considered 'normal' at residential dwellings. From experience, OAM may be one feature of far field AM but it does not describe or relate to the whole picture. OAM is described in the Renewable UK document as rare / infrequent. In this document occurrences are described as 'occasional'. This is simply not the case and does not relate to any of the many sites that I have looked at. The long term monitoring station at Cotton Farm has been well publicised and should be a very useful resource for this project. I am surprised that it is not referenced and has not been used to inform your work. It is a missed opportunity. A brief review of the Cotton Farm data shows that EAM is a very serious, frequent and persisting problem. (http://www.masenv.co.uk/~remote_data/plot.php) The work in Japan, led by Tachibana et al, also leads to a description of AM as a "common occurrence".

Is the Definition of AM applicable to smaller turbines?

How are you defining smaller turbines? AM from turbines with rated power of around 50kW or less is very different to that from larger turbines. Whilst a very loose definition (modulation, related to blade pass frequency) might be appropriate for all turbines, their characteristics are very different. Small turbine AM can be much more variable. Where AM from larger turbines does not result in a very high impulse rating smaller turbine AM can be much more impulsive and can result in a higher impulse rating. Smaller turbine AM is also very variable, it comes and goes much more than larger turbine AM. I have found that this makes it difficult to derive a reliable or representative average or typical value of AM for a 10 minute period. In my experience I think it would be difficult to have a definition of AM or a rating method for AM that adequately deals with the differences in character between larger and smaller turbines.

Is it appropriate to measure AM Outside in free-field conditions? If not can you propose alternatives?

Yes, as long as the appropriate location is used. We still see many monitoring locations 20m from the house, on drive ways, exposed field type locations. The monitoring locations rarely relate to locations closer to the dwelling where residents experience noise. Internal noise measurements are also needed depending on the complaint but particularly (and obviously) where complaints also relate to internal impact.

Section 4 – Literature Review

Are there any other rating methods or important references that the AMWG should consider?

I think you could have considered other methods currently used to enforce noise with character. There are long established principles / tried and tested methods for assessing noise character, such as those used in BS4142 and in music noise assessment, that have not been considered. I also think there is merit in the Cooper and Evans (2013) method for assessing AM and think this should be tested further with real world data.

Section 5 – Towards a preferred metric

In principle, which is the best domain for rating and describing amplitude modulation: the time domain; the frequency domain; or is a hybrid method preferred? Can you explain why?

I don't think you should be limited to only one domain where taking a holistic approach might be more beneficial. The frequency domain has obvious benefits in that it is easy to spot periods with a strong BPF, but other than this it does not work very well for identifying / rating EAM. The frequency domain methods work the least well and do not appear to relate to impact. It is perhaps only useful for identifying periods where there is EAM and then leaving the analysis to the time domain. The time domain method has obvious advantages in that it is very easy to see what is going on in the data and the human eye is a much better judge of patterns, and small changes in those patterns, than an automated, rigid algorithm.

Do you agree with time intervals proposed, that is: 100 millisecond samples, 10 second blocks, 10 minute periods?

Agree with 100ms for now, though shorter time intervals might be needed depending on the nature and character of the EAM and particularly if you start looking at smaller turbines. To date 100ms has worked well. 10s blocks don't always seem to work, particularly where you have isolated very high peak to trough EAM, it just gets averaged with lesser EAM. I don't understand why you are focused on 10 minute periods unless you want to derive a metric that relates to ETSU-R-97 and application of a penalty. I am very opposed to such an approach as I have shown with numerous sites and where there is significant EAM that this will do absolutely nothing to enforce impact.

Do you agree with the band-limiting filtering approach for rating AM?

Yes and no. The band limiting helps derive better AM values in some cases and allows the DAM method to be less influenced by extraneous noise, but it is still subject to problems, i.e. what limits to use and whether these are appropriate for all cases.

Is the default frequency range appropriate? What other frequency ranges could be considered, taking into account the desirability to characterize the frequency range in which AM occurs, the desirability to exclude spurious noise sources and the need for a consistent approach to avoid differences?

No. It misses EAM with significant components in the 80Hz 1/3rd octave band and also in the 500Hz / 630Hz third octave band. NB I found EAM from the same turbine model which sometimes had significant 80Hz EAM and sometimes 500Hz EAM. It may also miss EAM with significant energy lower than 80Hz, as suggested by others at the Newcastle meeting. This is a difficult one, if you broaden the range the methods will again be susceptible to bird noise / extraneous noise. If you narrow the range your method will not work for many turbines. If you allow those using the methods to select a range that they consider appropriate you will get different answers for your AM value and debate (contrary to the purpose of deriving a standardised metric).

Section 6 – Time Series Method

Do you think the time series method proposed is suitable for rating AM? If not, can you explain why?

Yes and no. It works the best out of all the methods but is susceptible to extraneous noise, though this is much improved if you band limit the data. It best relates to actual peak to trough values; however, it still cannot relate to erratic and highly changeable periods of EAM, for example where there are occasional irregular peaks of up to 15dB peak to trough.

Section 7 – Frequency Domain Method

Do you think the frequency domain method proposed is suitable for rating AM? If not, can you explain why?

Method 2 definitely not. It fails in nearly all of the cases that I have tested. The AM values that result do not relate to the peak to trough values of EAM, the range is very limited, i.e. all values tend to be between around 1 and 4. It is not very responsive to changes in EAM. It misses periods of EAM (giving values between 0 and 1) and gives similar results when there is no EAM. Method 3 also has problems though they are not as extensive.

Should other parameters be used in the application of this method and why?

Not sure what you are suggesting and what other parameters might be used. It is assumed you are only looking at modulation depth i.e. only one factor relevant to AM impact.

Section 8 – Hybrid Method

Do you think the hybrid method proposed is suitable for rating AM? If not, can you explain why?

Method 3 works slightly better than method 2 (not as good as method 1) but still seems subject to the flaws of a frequency domain method. I.e. it does not relate very well to the EAM values, the range is better and it is more responsive, but AM values are very significantly influenced as soon as the EAM time trace is not clean and clear (this is also the case for method 2).

Should other parameters be used in the application of this method and why?

Not sure what you are implying and what other parameters might be used. See answer to section 7.

Suggested at the Newcastle meeting that individual peak to trough values could be derived and I wonder whether this could be used to better the method. Don't know how well the calculated peak to trough values relate to the original peak to trough values of the EAM in the original time trace...

Section 9 – Comparison of Methods

Of the three methods proposed, which is your preferred method?

The DAM method, method 1, though this is still far from perfect and I don't think an adequate solution has yet been reached. If I were to incorporate / adapt any of the methods in to my own method it would be the DAM method.

Is there another alternative method not recommended by the AMWG which would be preferable? Explain why.

The testing I have done so far indicates that the automated methods are still subject to significant problems. They also still require pre filtering steps / manual processing and checks and as such this does not really save all that much time compared to just looking at the data. I think these automated methods can be useful tools to help identify periods of EAM but that you can't beat (or haven't yet convincingly shown that the proposed methods are better than) the human eye and ear for assessing EAM.

Section 10 – Instrumentation

Are the proposed requirements for instrumentation appropriate?

If you are going to apply this method to smaller turbines then the noise floor of the meters might start to be a problem, particularly where peaks and troughs fall within 5-10dB of the noise floor. Problems still arise in these cases as background noise levels are very low and the turbine is the dominating source. Also 100ms does not always work for

some small turbines.

I think you should record audio for 10 minutes. I have processed a lot of EAM data and it is really annoying when you see really interesting periods of EAM in the middle of a 10 minute period that you want to analyse / listen to but no-one working for the wind industry appears to ever record more than the first two minutes.

Would you like instrument manufacturers to make available an “AM rating” option for sound level meters?

No. Firstly the automated methods don't yet work well to rate EAM. Secondly, surely you would have huge problems with false positives etc. Seems more of a gimmick that anything that could be really useful.

Section 11 – Software

Should the IOA make available software for rating AM?

If the IoA recommended method for rating AM needs software then it should definitely be made available, open access etc. The code should also be transparent so that those who want to understand what is going on can.

Do you have any comments on the software released?

It works very quickly which is great and is very easy to use. Need a better naming system so that if you are processing a lot of data you don't need to rename each file. It would also help to have better large scale file processing, so for example you can select several 10 min files to be processed at once.

Recommendations for Further Study and any other comments

I have a lot of comments on the discussion document, which I have listed below with reference to the paragraph numbering and also some general comments. I think you should have made a pdf available that people can comment on this work freely without set questions - otherwise you are determining the feedback you get. Surely you should allow reviewers to comment on all aspects of the project, otherwise it appears from consultation that some areas have been completely unquestioned, which is unlikely to be the case.

General comments:

It is unclear from the document which methods you have actually tested with data (for yourselves, not other peoples results) and which you have just thought about. For example "various time domain approaches have been evaluated in this study". Have you actually tested them or just thought about them and decided that they are no good?

You have made the recommendation that an overall 10 minute value can be derived by taking the L10 of the AM values. Why have you chosen this? Have you tested it on real world data to see what sort of 10 min values you get? How does that relate to the impact in the 10 min period? My testing indicates that the L10 values from method 2 significantly undervalue EAM and are very unresponsive. Do you have any evidence that shows that the L10 values derived relate well to subjective response to EAM?

In deriving AM values for methods 2 and 3, why have you not included the first and second harmonic or energy in other harmonics? This might improve the values / make them more representative of what is going on in the time trace and could give you a better range of values. We have found that inclusion of harmonics can increase the success rate of these types of methods.

I have raised this point before, but I do not think that Government should be deciding on what is or is not acceptable EAM. Surely that is for us (acousticians / EHOs etc), those with an actual understanding of acoustics / psycho-acoustics and those with understanding of community response, to try to define. Related to this point, how can you define an acceptable / appropriate metric without knowing how it will be used? If the metric is to be converted to a penalty, then your method needs to be able to reflect a range of EAM values and also show that it is sufficiently responsive. The penalty that results from the AM value must also actually stop intrusive periods of impact. What if the AM value does not enable this?

Whilst the graphs shown at the Newcastle meeting, the AM metrics seemed to follow the variation in peak to trough level quite well, in many cases that I have tested they do not. The metrics therefore do not always consistently rate AM, i.e. in some cases AM with a peak to trough range of 6-8 might give you an AM value of 4 and in some cases you will get an AM value of 2. These basic errors need to be removed before you can decide on whether the metric is appropriate, then how the metric relates to subjective response and then how it might be used in a planning condition.

Para 0.3.1.

Time domain methods can discriminate (you say cannot) between periodic variations in noise occurring at BPF and resulting from other sources. You can use your eyes, listen to the audio data and also look at the 1/3rd octave band levels. Bird noise is pretty obvious when looking at 1/3rd octave band data.

" In most real cases, the data needs to be checked (by listening to audio recordings or visual inspection) to identify 'clean' data where AM is audible and there is no significant contamination by other sources."
So do frequency domain methods. If you look at both the Renewable UK condition and the RES Den Brook scheme they both require extraneous noise to be removed and they both require audio checks to confirm it is actually wind farm noise.

Para 0.4
I have not found a clear correlation between modulation depth and the proposed metrics, perhaps with the exception of the DAM method. At one site (a 275kW turbine) EAM modulated by around 8-13dB peak to trough but method 2 gave AM values of between 1 and 3.

Para 3.3
"The applicability of the metric to smaller turbines will be reviewed when recommending a preferred metric."
Surely this should be done now? If you come up with a metric it will undoubtedly be used for smaller turbines. My testing has shown that the metrics (potentially with the exception of the DAM method) will not work for smaller

turbines.

Para 4.1.
" However, it is self-evident that when applied to any measurement of an episode of AM, a robust metric should deliver a value that generally relates to the subjective response to that episode – and that a higher value of the metric would result in a greater adverse response."
I think this is a very important point. It's not clear whether you have tested the metrics against subjective response and if you have then how? You could argue you have compared it to the Renewable UK Salford study results, but these were all artificial wind farm noise excerpts experienced over short periods and unlike many cases of real life EAM. As such they do not relate to the actual EAM to which residents are exposed. It also can't account for other character features that were absent the Salford study, for example intermittency of EAM, unpredictability of EAM, different frequency content of EAM (including lower frequency EAM) etc.

Para 4.7.
Here you highlight all of the different character features that contribute to the psycho-acoustical aspects of EAM perception. Modulation depth is only one of them. Why have you chosen to focus only on modulation depth for your metric? (probably because it is the most investigated and easiest to look at, but they are not necessarily good scientific reasons) Are you going to consider any of the other factors? How might these other factors contribute to a response / rating of EAM and how do they interrelate?

Para 4.8.

"Frequency domain methods in contrast provide objective evidence of the modulation occurring at a certain rate..."
How are the other methods not objective? I think this is misleading to those who do not fully understand how each of the methods work. It implies that other methods are subjective, i.e. you just listen and make your own judgement. The DAM and Den Brook methods are objective, they are both based on values and numerical descriptors of EAM. You cannot get different results from the DAM / Den Brook methods between assessors (unless you do something wrong). All the methods tested are objective.

Para 5.2.
"It is also necessary to analyse data as a function of wind speed in 10-minute periods."
This is only necessary if you want to derive an average value of AM that can be applied to an ETSU-R-97 noise limit at certain wind speeds. How the metric is to be used is (I thought) beyond the scope of this work package. As such, you should be concerned only with having a metric that describes AM, not what you do with this metric. It might be used as a trigger value or a penalty, but with reference to your scope of work the metric should not predetermine how it is to be used.

" It is proposed that if more than 12 such 10 second samples are contaminated, then the 10 minute sample should be excluded."
How do you define contaminated?

Para 7.0
" provides an objective measure of how much the level of the noise varies at a regular rate when AM... This provides an objective measure..."
As above, how are the other methods not objective? Seems like the use of the word objective is intended to make this method sound more robust when if anything my testing shows it is the least robust.

Para 7.4

"Where spurious sources remain despite the filtering undertaken, this is clearly identifiable as vertical lines in the waterfall spectrum of Figure 7.5, with values over a wide range of frequencies not associated with the BPF. These periods can therefore be discarded from the analysis."
How is this manual inspection of the data any different from looking at the time trace as per the Den Brook method or as might be needed for the DAM method? It is another manual check that seems to undermine the desire for an automated method.

Para 7.5
"The amplitude of the fundamental of the signal is retained as a meaningful measure of the modulation as it was determined that this parameter scaled with the amplitude of the rest of the signal for typically observed AM signals."

We have not found this including in the results of testing a lot of data with the Renewable UK condition methodology. In the majority of cases the value derived from the amplitude of the fundamental significantly underestimates the peak to trough value observed in the time series. It would be nice to see some results so that we can see how you come to these conclusions.

Section 9
This whole section I find quite unhelpful. All it tells you is how well the metrics relate to the Salford study ratings (which were based on artificial samples) and then how well the metrics relate to the FFT band limited method. You can't really tell what is going on with any of the methods. It would be helpful to have a lot more information. The graphs presented in Tom Levet's presentation at the Newcastle meeting were the most interesting part of the day and actually provided us with some meaningful information. I.e. showing the original time trace, how each of the metrics rated the AM, the spectogram of the time trace etc. It would be so much more informative to have this sort of data presented. As was apparent at the Newcastle meeting, many do not have the data we do to enable testing of the methods and / or have not spent the time testing these methods. As such the results need to be available for open interpretation rather than reliant on others interpretation of the results and conclusions.

Your details

Please provide your name and contact details in case the working group wishes to clarify any of the points raised in your feedback: Can you also indicate if you would like your response to be published anonymously or not published at all by the IOA?

Sarah Large
MAS Environmental Ltd
sarah@masenv.co.uk

I am happy for my response to be published.

The IOA AMWG thanks you for your help in completing this document.

Gavin Irvine
AMWG Chair

INSTITUTE OF ACOUSTICS

IOA CONSULTATION QUESTIONNAIRE FOR

"METHODS FOR RATING AMPLITUDE MODULATION IN WIND TURBINE NOISE"

APRIL 2015

FOREWORD

** PLEASE READ BEFORE PROCEEDING TO THE MAIN DOCUMENT **

This discussion document has been produced by a working group on behalf of the Institute of Acoustics consisting of the following members:

Jeremy Bass		RES Ltd
Matthew Cand		Hoare Lea Acoustics
David Coles		24 Acoustics
Robert Davis		RD Associates
Gavin Irvine	(Chair)	Ion Acoustics
Geoff Leventhall		
Tom Levet		Hayes McKenzie
Sam Miller		
David Sexton		West Devon Borough Council
John Shelton		AcSoft

This questionnaire has been produced specifically to promote discussion of the relevant issues during the consultation on a metric for amplitude modulation (AM) from wind turbines and should be read in conjunction with the "IOA AMWG Discussion Document". Respondents to the consultation are encouraged to provide their comments on the form provided. A word version has been provided to allow respondents to increase box sizes as required.
All comments on the consultation draft should be sent electronically to:

WTAMCONSULT@IOA.ORG.UK

Alternatively, written responses can be sent to:
IOA AMWG Consultation Feedback
Institute of Acoustics
3rd Floor St Peter's House,
45-49 Victoria Street,
St Albans,
Herts.
AL1 3BN.

The closing date for the receipt of comments is **30th June 2015**. Late comments may not be reflected in the deliberations on the choice of the AM metric.

CONTENTS

INTRODUCTION TO THE CONSULTATION

Background

The Institute of Acoustics Amplitude Modulation Working Group (IOA AMWG) has prepared a discussion document on methods for rating amplitude modulation in wind turbine noise, for the purpose of consultation to IOA Members and other interested parties.

The discussion document considers various methods and has proposed three methods for consultation. The intention of the IOA AMWG post-consultation is to recommend one method but at this consultation stage, three candidate methods are proposed. The AMWG will not be proposing a threshold or penalty mechanism for rating the subjective response.

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

Subsequent section numbers refer to the main discussion document.

Section 3 – AM Definition

Do you agree with the Definition of AM? Does it relate to your experience?

I would change “broadband” to “audible”. What matters is the audible fluctuations and you do have analysis methods that are frequency selective not broadband. “audible” defines the problem better.

You should omit “as observed outdoors at residential distances in free-field conditions”. That may be the way you will do the testing but the problem itself could be inside and not free field.

Whilst I think this defines what can be achieved at this stage, experience increasingly suggests to me that as large a problem may be non periodic characteristics of the noise.

Is the Definition of AM applicable to smaller turbines?

No. Not those under about 200kW anyway. Even if the problem here is periodic I don’t think you have any dose response data that would be applicable to them. In any case they all tend to be different.

Is it appropriate to measure AM Outside in free-field conditions? If not can you propose alternatives?

Yes. I can see the objections but the practicalities of indoor measurements where that is the problem are too great.

Section 4 – Literature Review

Are there any other rating methods or important references that the AMWG should consider?

Section 5 – Towards a preferred metric

In principle, which is the best domain for rating and describing amplitude modulation: the time domain; the frequency domain; or is a hybrid method preferred? Can you explain why?

The chosen metric MUST have a robust dedicated dose response relationship allied to it. If there are several metrics with dose response relationships then they should all give broadly the same answer. In that case the metric should be selected by speed and ease of assessment.

I think the answers to the questions that follow all come down to what best achieves this.

Do you agree with time intervals proposed, that is: 100 millisecond samples, 10 second blocks, 10 minute periods?

Do you agree with the band-limiting filtering approach for rating AM?

Is the default frequency range appropriate? What other frequency ranges could be considered, taking into account the desirability to characterize the frequency range in which AM occurs, the desirability to exclude spurious noise sources and the need for a consistent approach to avoid differences?

Section 6 – Time Series Method

Do you think the time series method proposed is suitable for rating AM? If not, can you explain why?

Section 7 – Frequency Domain Method

Do you think the frequency domain method proposed is suitable for rating AM? If not, can you explain why?

Should other parameters be used in the application of this method and why?

Section 8 – Hybrid Method

Do you think the hybrid method proposed is suitable for rating AM? If not, can you explain why?

Should other parameters be used in the application of this method and why?

Section 9 – Comparison of Methods

Of the three methods proposed, which is your preferred method?

Is there another alternative method not recommended by the AMWG which would be preferable? Explain why.

Section 10 – Instrumentation

Are the proposed requirements for instrumentation appropriate?

Would you like instrument manufacturers to make available an “AM rating” option for sound level meters?

Section 11 – Software

Should the IOA make available software for rating AM?

Do you have any comments on the software released?

Recommendations for Further Study and any other comments

Your details

Please provide your name and contact details in case the working group wishes to clarify any of the points raised in your feedback: Can you also indicate if you would like your response to be published anonymously or not published at all by the IOA?

Dick Bowdler. dick@dickbowdler.co.uk

No objection to response being public.

The IOA AMWG thanks you for your help in completing this document.

Gavin Irvine
AMWG Chair

INSTITUTE OF ACOUSTICS

Comments from the Independent Noise Working Group June 2015

Note: This is an edited collation of individual responses. Membership of the group does NOT necessarily imply that the person concerned holds the views expressed in this response.

IOA CONSULTATION QUESTIONNAIRE FOR

"METHODS FOR RATING AMPLITUDE MODULATION IN WIND TURBINE NOISE"

APRIL 2015

FOREWORD

** PLEASE READ BEFORE PROCEEDING TO THE MAIN DOCUMENT **

This discussion document has been produced by a working group on behalf of the Institute of Acoustics consisting of the following members:

Jeremy Bass		RES Ltd
Matthew Cand		Hoare Lea Acoustics
David Coles		24 Acoustics
Robert Davis		RD Associates
Gavin Irvine	(Chair)	Ion Acoustics
Geoff Leventhall		
Tom Levet		Hayes McKenzie
Sam Miller		
David Sexton		West Devon Borough Council
John Shelton		AcSoft

This questionnaire has been produced specifically to promote discussion of the relevant issues during the consultation on a metric for amplitude modulation (AM) from wind turbines and should be read in conjunction with the "IOA AMWG Discussion Document". Respondents to the consultation are encouraged to provide their comments on the form provided. A word version has been provided to allow respondents to increase box sizes as required.
All comments on the consultation draft should be sent electronically to:

WTAMCONSULT@IOA.ORG.UK

Alternatively, written responses can be sent to:
IOA AMWG Consultation Feedback
Institute of Acoustics
3rd Floor St Peter's House,
45-49 Victoria Street,
St Albans,
Herts.
AL1 3BN.

The closing date for the receipt of comments is **30th June 2015**. Late comments may not be reflected in the deliberations on the choice of the AM metric.

CONTENTS

INTRODUCTION TO THE CONSULTATION

Background

The Institute of Acoustics Amplitude Modulation Working Group (IOA AMWG) has prepared a discussion document on methods for rating amplitude modulation in wind turbine noise, for the purpose of consultation to IOA Members and other interested parties.

The discussion document considers various methods and has proposed three methods for consultation. The intention of the IOA AMWG post-consultation is to recommend one method but at this consultation stage, three candidate methods are proposed. The AMWG will not be proposing a threshold or penalty mechanism for rating the subjective response.

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

Subsequent section numbers refer to the main discussion document.

Section 3 – AM Definition

Do you agree with the Definition of AM? Does it relate to your experience?

AM is defined by the IoA AMWG as:

> *"periodic fluctuations in the level of broadband noise from a wind turbine (or wind turbines), the frequency of the fluctuations being the blade passing frequency of the turbine rotor, as observed outdoors at residential distances in free-field conditions."*

It is stated at 3.3 that there is no need for excessive specificity in definition, but this is not followed in the above that in essence is too narrow.

First, in 10.3 a relevant frequency band is defined or at least such a definition is implicit. It is claimed that noise measurement is not required at frequencies below 100 Hz. Yet IEC 61400-11, *"Wind turbine generator systems - Acoustic noise measurement techniques"*, endorsed by the IOAGPG for the purpose of wind turbine noise measurement, requires in 6.1.3 that *"The equipment shall fulfil the relevant requirements for IEC 60651 type 1 instrumentation in the 20 Hz to 11 200 Hz frequency range"*. The IOAGPG in 8.5.3 also sets the lower limit for tonal noise measurement at 20 Hz and endorses ISO 9613-2 for turbine immission noise prediction, which requires frequency coverage from 44 Hz to 11.3 kHz. It is therefore of concern that the IOA AMWG seeks to limit the frequency band of interest even further to frequencies above 100 Hz. This is conveniently consistent with the wind industry's own ReUK report, which set itself the same arbitrary and unnecessary lower limit. The 100Hz lower frequency limit is supported entirely by assertion, not by measurement or plausible theory. This is the more extraordinary as the Class 1 sound level meters used for the measurements in question are all specified down to 20Hz or lower; limitation to frequencies >100Hz therefore implies additional, not less, work.

Second, no measurements of the spectral distribution of EAM have been reported for any of the sites investigated by the Salford report commissioned by DEFRA or by the ReUK report. It is fundamental that the nuisance/sensation which many residents report may well include noise at frequencies lower than 20Hz.

Third, there are many aspects of noise character other than modulation depth that should be considered. Actual experience of EAM shows that the sensation can relate to detailed characteristics of the signal that may well be hidden in any frequency domain analysis. Finally, and by way of example, we note that although the modulation is at BPF there may also be modulation at other frequencies such as that of the rotation, that of any tower resonance, and the harmonics of both.

It should be noted that the purpose of all of the proposed noise levels and definitions of noise character is to protect receptors. At present, ALL these considerations are purely theoretical and must be confirmed with real-world studies.

Is the Definition of AM applicable to smaller turbines?

No explicit definition of 'smaller' is offered, although 3.3 suggests that this is <500kW nameplate capacity. In the last few years complaints from smaller wind turbines (rated power in the region of 50kW or less) have increased. Complaints typically focus on the *character* of the noise rather than the decibel level or volume. See, for example Large and Stigwood (2015) *Compliance isn't everything*, a paper presented at the 6th International Conference on Wind Turbine Noise, Glasgow. If blade stall is the mechanism that generates EAM there can be no reason to assume that it will not be generated by turbines of <=500kW capacity . What is clear is that ETSU simply does not protect close neighbours from noise from 'smaller' turbines.

DiNapoli (2011) showed that smaller, older WTG can produce significant EAM in the far field that did not decrease with distance 'as expected'. Many operational small turbines are downwind models, and some of those models are still manufactured today. Wind industry acousticians frequently acknowledge the low frequency noise problems of downwind turbines.

Is it appropriate to measure AM Outside in free-field conditions? If not can you propose alternatives?

Monitoring may not be as easy as it looks. It has to be very carefully defined and clear in its objectives. It is not entirely clear what the purpose of monitoring should be. Is it to check compliance after complaints, for example by an appropriately tasked EHO, or to facilitate mitigation by the turbine operators?

If for the guidance of the planning and compliance testing systems, this should be explicitly and clearly stated.

As a general principle if the purpose of measuring is to establish whether any noise complaints are justified then the monitoring should be conducted where that noise is experienced.. If this is close to a building then the measurement should be made there, if is inside a building then it should be measured there.

The reasons offered for measuring outdoors is that *"The measurements are made outdoors for consistency with other procedures for measuring wind turbine noise (such as ETSU-R-97)."* EAM is one of the areas where ETSU has failed to protect wind farm neighbours; consistency with that failure should not be the objective.

Outdoors only measurement has been justified elsewhere by the concern that residents may not grant access. This is most unlikely, since compliance measurements are usually the result of complaints, residents would surely wish to cooperate in the resolution of the noise problem giving rise to their complaint.

The ReUK report, co-authored by IOA AMWG member Cand (see 'Recommendations': this is but one objectively verifiable and clear example of a conflict of interest), states:

"Many of the reported complaints about AM were about sound heard indoors, which is not surprising as residents tend to be inside their dwellings at night when background levels are quieter and WTN (including AM if present) will tend to be more audible."

We concur with Cand on this: most complaints from residents relate to noise at night which deprives them of sleep. It is therefore essential to measure the turbine noise levels inside the home, which, due to room resonances, at low frequencies can be higher than those outside. This would also reduce rural wind induced noise from trees and vegetation, which is significant at low frequencies. There remains of course the vexed and frequently challenged and arguable ETSU night-time limit (43dB) with its implicit behavioral assumptions.

On the other hand:

if the main objective of the monitoring is to facilitate automatic operator mitigation this should also be explicitly and clearly stated

Monitoring outside might well be the only sensible approach, subject to the comments made elsewhere in

this response about the spatial distribution of the phenomenon. Unless this is the objective of the exercise, the imposition of an 'automation' criterion in the groups brief seems to be unnecessary. There are already many operating wind farms damaging the health of wind farm neighbours; protecting these residents must take urgent priority. Using residents as guinea pigs to develop the industry's still embryonic efforts to automate measurement of EAM is unacceptable and essentially immoral.

Section 4 – Literature Review

Are there any other rating methods or important references that the AMWG should consider?

Work Package 2.1 of the INWG provides an annotated chronological summary of the >150 reference documents we have consulted. We welcome the fact that, seemingly for the first time, the IoA AM NWG reference literature describes work from outside UK, notably from USA (WI, Shirley WF), Australia (Waterloo and Leonard's Hill WF), Japan and Sweden. It is clear that in studies that detect and monitor EAM authors in these countries have not been constrained by commercially convenient references to the so-called 'Salford Report' that, in a survey fatally flawed by its sampling, erroneously suggested that EAM is not a problem.

BS 4142 in its most recently revised form (BS4142: 2014) answers most if not all of the criticisms made by the team that drafted the original ETSU guidance in 1996/7, is well understood by those tasked to implement it, and should be the major alternative approach considered. Post June 16th 2015, a more simple if radical alternative that local authorities forced to implement complex acoustically-defined planning conditions may well prefer to use in their local plans is to impose a simple 'separation distance', so ending for good the recourse to acoustics..

Section 5 – Towards a preferred metric

In principle, which is the best domain for rating and describing amplitude modulation: the time domain; the frequency domain; or is a hybrid method preferred? Can you explain why?

Any answer to this question must also relate to the purpose of any monitoring (see Section 3 above).

Extensive measurements in the UK by Stigwood have shown that EAM is not rare as had been consistently claimed by the wind industry, but is widespread and frequently occurs for prolonged periods of time. That it has proved impossible to predict is not surprising as its likely causes are not yet well quantified. The INWG draws attention to three *desiderata* for *any* measurement system and metric: (1) It is vital that any adopted metric commands the confidence of all 'stakeholders' (to include local resident groups, planning authorities tasked to enforce relevant planning conditions, Government , and existing wind farm noise neighbours). It follows that any preferred metric should be (relatively) easily understood and relate to the 'EAM problem' as it is experienced. (2) This 'EAM problem' isn't an abstruse issue to do with how it is generated or even at what frequency (etc.). Rather it is a noise 'sensation' that from time to time wind turbine neighbours experience that impacts on their daily lives. This implies that it is the noise itself that is 'detected' and not some obfuscatory/erudite power spectrum derived from it after considerable selective filtering. (3) Finally, any metric must be capable of implementation by those responsible for protecting the public from noise nuisance such as EHO and the LPA. The wind industry might prefer some metric that can be automated by software (possibly even used as part of the WTG control) but this should not in itself be a major consideration.

All of the above argue that for compliance testing easy to understand time domain recording of the noise itself, with appropriate instrumentation and archiving, should be the preferred option. Time domain recording will allow (within some limits) any post-processing of the simultaneously acquired data. Critically it will also allow direct correlation with both the meteorological and SCADA data. Given what is known of the correlation between ambient weather and the reported incidence of EAM there is also a very clear research imperative that such correlations are explored. The experience at Cotton Farm is that 'auralization' is as effective a strategy when dealing with sound pressure as 'visualization'

is of graphic images.

Although monitoring based on assessment in the frequency domain might well be a preferred option where mitigation via control of the offending turbines is the objective, we already know from work on the so-called RES Den Brook condition (Swinbank, 2013) that analysis in the frequency domain of a signal that is not sinusoidal can significantly underestimate the EAM. FFT procedures have yet to be shown to provide efficient algorithms for this type of highly variable sound energy and can miss periods of impact, be falsely triggered by extraneous noise, or simply fail to reflect impact. Similarly, analysis in the frequency domain makes correlation with ambient weather or operational data problematical. FFT-derived procedures in a modified form to those currently presented by RES can be used as an extra evaluation tool to assist analysis of noise. Such procedures are unhelpful when dealing with sound data containing erratically varying AM and erratically varying extraneous noise sources. There are also problems identifying AM where there are other character features such as tonality or lower frequency noise and where there are multiple source turbines giving multiple blade passings.

INWG has only completed a preliminary analysis of the so-called hybrid method. We have found that the hybrid method is still subject to the problems associated with using FFT procedures. These methods consistently underestimate the peak to trough of EAM and fail to identify EAM when it occurs erratically.

Do you agree with time intervals proposed, that is: 100 millisecond samples, 10 second blocks, 10 minute periods?

We suspect that 100ms sampling has been proposed because it is a standard SLM function but these are parameters that require testing against actual, not synthetic, EAM signals. It may well be that, given the shape of measured EAM waveforms, that <100ms sampling (i.e. higher frequency) is required to capture the full amplitude as observed.

Using 10 minute intervals seems to be an attempt to bring testing for EAM into line with ETSU, perhaps as a preliminary to suggesting some penalty approach perhaps with a wind speed-varying penalty. If this is the case the effect almost certainly would be cynically to 'hide' the problem under the much-criticised ETSU night-time limit, laying practitioners open to justified criticism and at the planning stage failing to protect the public from the potential nuisance.

What the consultation does not cover are issues related to the *spatial incidence* of the AM as perceived. Some theory and a great deal of observation show that the spatial distribution of where the EAM occurs is complex, varying greatly from place to place around any offending turbine(s). This implies that, whatever the sampling in time adopted, detected incidence at one place does not necessarily 'test' whether or not the EAM is experienced elsewhere. INWG notes that this issue has never been adequately referenced or addressed. This is a serious issue of which the Working Group seems unaware.

Do you agree with the band-limiting filtering approach for rating AM?

No.

Having a pre-defined band limit is difficult as the dominant frequencies vary between turbines / wind farms.

Any requirement to band pass filter raw noise data will eliminate harmonic noise from compliance assessment and has implications for not only the disputed Den Brook AM conditions but possibly any time series AM conditions. For example, the discussion document at 4.5.2 omits any mention of the scheme's requirement further to filter all raw data taken forward for analysis in accordance with the EAM parameters

established within Den Brook Condition 20.

Even if the filter specified,(i.e. 0.9 – 1.1), is appropriate and helps detect false positives, any such filter will exclude EAM harmonic noise from any compliance testing and so the requirement would materially prejudice against a full and proper test. INWG therefore suggests that an addendum should be published by the IoA AMWG in order to clarify and re balance this factual omission.

We conclude that more research is needed to support band limiting.

We also note that band limiting could obscure potential problem noise sensations in the deleted frequencies.

Is the default frequency range appropriate? What other frequency ranges could be considered, taking into account the desirability to characterize the frequency range in which AM occurs, the desirability to exclude spurious noise sources and the need for a consistent approach to avoid differences?

No, it will almost certainly miss significant EAM.

Suitable SLMs capable of measuring at frequencies down to once per revolution and the natural frequencies of blades and towers are needed to ensure the entire spectrum is captured.

The so-called 'problem' of 'false positives' is an unnecessary distraction and obfuscation related to the use of decibel scaling. Observation of actual EAM from extant turbines in simple time domain has shown that any such false positives are readily identified for what they are, even by individuals with no training in acoustics. Where routine monitoring is in place, it is reported that signals from, for example, early morning bird song, can readily be identified even to the exact species. The 'problem' only becomes such if the intent of the monitoring is to support some long term automated mitigation rather than to detect compliance. There may well be a problem with some metrics that generate undesirable 'false negatives'.

Section 6 – Time Series Method

Do you think the time series method proposed is suitable for rating AM? If not, can you explain why?

Yes, see above. The major objection seems to be that 'days, even weeks of data' would need to be archived and then analysed. INWG fails to see why this would be necessary in any compliance testing. It is also inconsistent to define the phenomenon as some subjectively perceived amplitude modulation depth and then demand some 'single number', 'objectively and repeatedly determined' as the outcome metric. However, should one be required there are several possible simple, 'objective' and repeatable metrics (as for example in the Den Brook condition) that can be used to characterize any time domain trace. In short, scanning time domain data might itself be subjective, but no more or less so than selection of filters in frequency domain and the characterization of the sought property of that trace need not be any more or less 'subjective' than any other approach.

Section 7 – Frequency Domain Method

Do you think the frequency domain method proposed is suitable for rating AM? If not, can you explain why?

As noted in the briefing document (4.2.2) the main approach used by researchers into the phenomenon is a transformation of the signals into the frequency domain. In principle INWG has no objection to the use of frequency domain approaches in *research* into wind turbine noise, but such use will not command the confidence of communities affected by EAM (or other aspects of the sound pressure from turbines).

Frequency domain analysis is a sharp tool best used where the periodicities in the signal are well understood (for example by day/night, sensor characteristics etc.) or relate to an hypothesis to be tested (e.g. 11 year sunspot cycles in climate data). Like the plain silly polynomial regression mandated by the IoA

in its *Good Practice Guide* to ETSU, it performs less well as a basic exploratory analytical approach. Any such use in monitoring and compliance testing will be seen by EHOs and any complainants as unnecessary obfuscation.

In our view the AMWG fails to understand the scientific meaning of the word 'objective', which is normally associated with **repeatability** over time, place and operator. In this sense time series methods such as Den Brook are fully 'objective', setting objective criteria such as. 28dB LAeq and 3dB peak to trough. Just because FFT approaches involve more processing does not make them any more or less 'objective' than this more direct and simpler approach. Because it implies essentially arbitrary selection of frequencies of interest it can be argued that frequency domain analysis is intrinsically more 'subjective' a process than the more direct engagement with the data implicit in time series approaches.

Should other parameters be used in the application of this method and why?

Such as?

Section 8 – Hybrid Method

Do you think the hybrid method proposed is suitable for rating AM? If not, can you explain why?

See comments above in Section 5. Hybrid approaches suffer from the same problems as those in frequency domain approaches.

Should other parameters be used in the application of this method and why?

Such as?

Section 9 – Comparison of Methods

Of the three methods proposed, which is your preferred method?

This is a matter for empirical testing using real recorded data with known EAM of a sufficient level to give rise to complaints.

Work Packages 5 and 7 of the INWG due to be completed shortly address this issue. INWG does not see how a preference can be obtained without at the same time specifying the relevant condition to be imposed and whether or not the proposed metric and condition is effective at detecting and enforcing adverse impact. In the absence of any condition there can be no criterion for pass/fail in compliance testing and hence no basis for a preference. If on the other hand the objective is to develop a metric that the industry can use in mitigation we should be told so and judge accordingly.

Is there another alternative method not recommended by the AMWG which would be preferable? Explain why.

See above. BS4142:2014 answers most of the deficiencies in the Standard that the original ETSU team identified. It may well be that the search for a metric that 'works' in all circumstances without reference to the context in which the assessment is being made is misguided and that what is need is a defined **process** appropriate to sets of circumstances and objectives (planning, operation, compliance)

Section 10 – Instrumentation

Are the proposed requirements for instrumentation appropriate?

No. Class 1 instrumentation has too high a noise floor fully to assess background noise that needs to be measured, typically around 18dB, and an inadequate frequency range when near audible lower frequencies need to be measured.

Would you like instrument manufacturers to make available an "AM rating" option for sound level meters?

Currently there is far too much uncertainty and lack of agreement to allow such a rating function to be developed.

Section 11 – Software

Should the IOA make available software for rating AM?

If the recommendation is to be for some approach based on analysis in the frequency domain then any agreed signal processing software has to be available FOC in the public domain as 'open source', with the code available for external inspection and testing. This is essential if the 'professional judgment' of acousticians contracted to developers is to be relied upon by EHO, the planning system, and the general public.

Moreover, as a basic check on the integrity of that employed, any analysis undertaken in such a system should be capable of being repeated using alternative software. There should also be no reliance on other external proprietary software (such as *MatLab*) and it should not be necessary for an LPA or EHO to have to employ an acoustician to understand the output.

Do you have any comments on the software released?

INWG will report on this later. The immediate release of the *MatLab* source code is requested.

Recommendations for Further Study and any other comments

INWG draws attention to several structural problems related to this project and this consultation:

a) Although TOR and 'success criteria' are listed there is no indication of the purpose of the exercise. As outlined in Section 3 (above) is it to develop a methodology for compliance testing or to assist the wind industry in handling what for it is rapidly becoming a difficult problem by development of an automated mitigation scheme? The result is that in the consultation we have a conflation of objectives;

b) In 'success criteria' there is no mention of 'practicality' or indeed of what 'success' might involve. It is difficult to see how any metric can be developed *independently* of any planning condition/critical threshold for complaints. Indeed it can be argued that attempting this generates a serious risk of there being a mis-match between the metric employed and any legislative or guidance framework into which it is injected. This risk is as great for the wind industry as it is for any LPA tasked with monitoring it;

c) Finally, INWG notes with concern the almost complete dominance in the IoA AM Noise Working Group of individuals either in the wind industry supply chain or known to be sympathetic to its narratives related to EAM. If the recommendations of the group are to be taken up by Government, there are some stark and obvious conflicts of interest that, if the IoA really does define itself as a truly independent professional institute, must be declared and resolved.

Your details

Please provide your name and contact details in case the working group wishes to clarify any of the points raised in your feedback: Can you also indicate if you would like your response to be published anonymously or not published at all by the IOA?

The above response was drafted on behalf of INWG by Professor D. J. Unwin to whom queries about it should be addressed (via wind-noise@tsp-uk.co.uk)

In the event of the response being published this should be attributed to 'INWG'. INWG has no objection to such publication. Indeed, it would be welcome and in contrast to the promise of publication that was not honoured for the IoA *Good Practice Guide* to ETSU. Your attention is also drawn to the disclaimer relating to the views of individuals in the group on the cover of this document.

The IOA AMWG thanks you for your help in completing this document.

Gavin Irvine
AMWG Chair

INSTITUTE OF ACOUSTICS

IOA CONSULTATION QUESTIONNAIRE FOR

"METHODS FOR RATING AMPLITUDE MODULATION IN WIND TURBINE NOISE"

APRIL 2015

FOREWORD

** PLEASE READ BEFORE PROCEEDING TO THE MAIN DOCUMENT **

This discussion document has been produced by a working group on behalf of the Institute of Acoustics consisting of the following members:

Jeremy Bass		RES Ltd
Matthew Cand		Hoare Lea Acoustics
David Coles		24 Acoustics
Robert Davis		RD Associates
Gavin Irvine	(Chair)	Ion Acoustics
Geoff Leventhall		
Tom Levet		Hayes McKenzie
Sam Miller		
David Sexton		West Devon Borough Council
John Shelton		AcSoft

This questionnaire has been produced specifically to promote discussion of the relevant issues during the consultation on a metric for amplitude modulation (AM) from wind turbines and should be read in conjunction with the "IOA AMWG Discussion Document". Respondents to the consultation are encouraged to provide their comments on the form provided. A word version has been provided to allow respondents to increase box sizes as required.
All comments on the consultation draft should be sent electronically to:

WTAMCONSULT@IOA.ORG.UK

Alternatively, written responses can be sent to:
IOA AMWG Consultation Feedback
Institute of Acoustics
3rd Floor St Peter's House,
45-49 Victoria Street,
St Albans,
Herts.
AL1 3BN.

The closing date for the receipt of comments is **30th June 2015**. Late comments may not be reflected in the deliberations on the choice of the AM metric.

CONTENTS

INTRODUCTION TO THE CONSULTATION

Background

The Institute of Acoustics Amplitude Modulation Working Group (IOA AMWG) has prepared a discussion document on methods for rating amplitude modulation in wind turbine noise, for the purpose of consultation to IOA Members and other interested parties.

The discussion document considers various methods and has proposed three methods for consultation. The intention of the IOA AMWG post-consultation is to recommend one method but at this consultation stage, three candidate methods are proposed. The AMWG will not be proposing a threshold or penalty mechanism for rating the subjective response.

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

Subsequent section numbers refer to the main discussion document.

Section 3 – AM Definition

Do you agree with the Definition of AM? Does it relate to your experience?

It is not *"generally accepted that there are two mechanisms causing amplitude modulation"*; "Blade swish" is a description, not a mechanism and "other" is an adjective, not a mechanism.

The cause (or mechanism) behind AM is understood, and indeed was successfully modelled in Oerlemans' paper in the ReUK research report of Dec 2013 (The ReUK report). However, no convincing cause of **excess** amplitude modulation has yet been proposed by the IOA AMWG/ReUK. Oerlemans found that stall at blade zenith accounts for only a fraction (3dB) of the measured increase in modulation depth that characterises EAM. This he inflated to 10 dB by the declared but rather unsubtle addition of 7 dB (page 17: *"7 dB is added to the spectral levels calculated using the BPM code, in order to obtain the desired 10 dB overall noise increase*").

Oerlemans' final conclusion (page 22) that "local stall is a plausible explanation for EAM" is therefore invalid if by EAM is meant by a modulation depth in excess of 3 dB. Stigwood and Huson have separately reported modulation depths of 25 dB, and Oerlemans himself cites (in ref. 21) the 2009 AIAA paper of Moreau et al. as measuring modulation depths of 30 dB.

The only possible conclusion to be drawn from this is EAM is not yet fully understood, and consequently should not be assumed to be exclusively due to modulation of the aerodynamic noise from 100 to 400 Hz, or indeed exclusively due to modulation and not at all due to direct emissions at frequencies below 100 Hz.

The IOA statement on wind farm noise assessment dated 19-12-2014 defines AM as *"A feature of the character of wind from noise caused by the cyclical nature of the blades".* There is no good reason to narrow this definition; indeed to do so, in the light of the above, would suggest at best a degree of scientific arrogance and at worst an intentional prejudgement.

The new definition of AM proposed in §0.1 is *"periodic fluctuations in the level of broadband noise from a wind turbine (or wind turbines), the frequency of the fluctuations being the blade passing frequency of the turbine rotor, as observed outdoors at residential distances in free-field conditions".*

Sound pressure levels at the blade pass frequency and its harmonics up to and beyond 20 Hz, when measured as dB(Z) rather than dB(A), are significantly higher than any broad band noise levels from the turbine, but are tonal rather than broadband in character, so could be considered not to be part of the "broadband noise from a turbine". Given that tonal noise is recognised as far more annoying than broadband noise such exclusion would be perverse. As the IOA AMWG should have as its main concern the welfare of wind farm neighbours I suggest that the IOA's 19-12-2014 definition of AM is retained, if only to avoid any accusation of concealment of the lower frequency contributions to EAM. This is particularly relevant as the ReUK AM "Research" report is determinedly silent about all frequencies below 100 Hz, even though ETSU, the IOAGPG and the International Standards referenced by the IOAGPG (IEC 61400-11 and ISO 9613-2) require consideration of lower frequencies, down to 20 Hz, and there is by now plenty of evidence suggesting that frequencies below 20 Hz may significantly contribute to EAM.

Is the Definition of AM applicable to smaller turbines?

In its proposed form it is not applicable to any turbines as it pre-judges the EAM noise spectrum. The IOA's 19-12-2014 definition however is applicable to all turbines.

Is it appropriate to measure AM Outside in free-field conditions? If not can you propose alternatives?

ETSU requires that background noise is measured in free-field conditions because otherwise reflections could artificially increase readings to the detriment of the WFN. However ETSU is concerned with both indoor and outdoor noise levels; the ETSU assumption of 10 dB attenuation through an open window has been observed not to be valid at very low frequencies, for which noise levels indoors can approach or even exceed those outdoors, due to room resonances, Helmholtz resonances, the transmission characteristics of windows, even double glazed, etc. Furthermore a higher signal to noise ratio is likely to prevail indoors. It is

true that free-field conditions are unlikely to prevail indoors, but the uncertainty this introduces is surely less than the uncertainty in using outdoor measurements as a proxy for indoor measurements. Whether the indoor régime is free-field or not it is the régime in which the wind farm neighbour must try to sleep, so the régime in which the noise should be measured.

The overriding reason for indoor measurements is that the majority of noise complaints are about sleep disturbance or sleep deprivation indoors; when resolving a noise complaint it is desirable to measure the noise complained about.

The "for consistency with ETSU and the IOAGPG" justification for free –field outdoor measurement is illogical. This consultation is about the EAM problem; there is simply no merit in consistency with documents that have failed to meaningfully address the EAM problem. Would any EHO in any other field seriously investigate a complaint about noise within a building by measuring the noise level outside the building?

Section 4 – Literature Review

Are there any other rating methods or important references that the AMWG should consider?

The IOA has made it clear that determining noise ratings for AM was to be left to DECC as acousticians are not appropriately qualified to address matters of health. With this I concur, although it raises two questions: whether DECC as opposed to DoH was any better qualified, and were the original authors of ETSU any better qualified than the IOA AMWG when they set the ETSU noise limits?

So the IOA AMWG is to produce a relative scale of harm from AM. Government will decide where on that scale the level of harm becomes unacceptable. There seems to be something of an obsession with opaque processing the measurement data to create that scale. Yet by visual examination of the measured data as a time series it is entirely evident what the modulation depth is to within a dB. The skill level required of the examiner is not high and several weeks' data can be visually processed in one working day. The IOAGPG refers in several instances to the use of "professional judgement" in decision making rather than offering detailed guidance; determination of the modulation depth by examination of the time series scarcely requires professional judgement, just minimal numeracy and professional integrity; the latter could be encouraged by requiring the publication of the time charts in the assessments based upon them.

If many weeks of data are accrued in a post compliance test its examination would indeed be time consuming to the point of impracticality. There is however an urgent need to respond effectively to noise complaints arising from operational wind farms. For this purpose the complainant could be provided with a time stamp button to press whenever the noise became intolerable. This would take the examiner straight to the relevant data. MAS environmental appear to be the leaders in the gathering of EAM noise data, both in quality and quantity, and their advice on the practicality of such complainant-driven analysis should be sought.

Section 5 – Towards a preferred metric

In principle, which is the best domain for rating and describing amplitude modulation: the time domain; the frequency domain; or is a hybrid method preferred? Can you explain why?

The time domain has the following attributes, which I consider to be advantages over the frequency domain:

(a) Transparency
(b) Economy
(c) It works.

Testing of the IOA AMWG software on real data from several wind farms/turbines with EAM, without EAM and borderline, shows that method 1 works, but underestimates the modulation depth by a dB or so. On data without EAM method 1 gives very few false positives. Methods 2 and 3 simply do not work; I do not understand why they have been included in this document.

As I understand it the IOA AMWG is charged with defining an AM measurement procedure for post-completion compliance testing. What is less clear is the relative importance being given to:

(a) the protection of existing wind farms neighbours by the precise definition of a procedure for measuring AM

(b) the confection of a planning condition on AM to allow new applications to be consented, presumably with 100% compliance testing by acousticians.

With the recent change of Government policy wind farm acousticians will no doubt become available for compliance testing, as business opportunities in noise impact assessments for new planning applications dwindle. But as, in truth, the IOA AMWG have not yet correctly identified the cause or causes of EAM the only mitigation available is to stop offending turbines. This would greatly reduce the financial allure of onshore wind energy development.

Do you agree with time intervals proposed, that is: 100 millisecond samples, 10 second blocks, 10 minute periods?

The 100 ms sample time may be too long for smaller turbines; as many smaller turbines are downwind models AM is a serious issue in spite of their smaller scale. Even for current large turbines with a BPF around 1 s 100 ms corresponds to 12º rotation, which may overlap the blade stall event and therefore underestimate the peak noise level. These are all very round figures, so seemingly somewhat plucked out of the air; they may well suffice, but I am not aware of any work that has examined the sensitivity of the derived “metrics” to each of them.

Do you agree with the band-limiting filtering approach for rating AM?

If by “band-limiting” is meant the removal of any emissions below 100 Hz I do not agree. There is measurement evidence from several countries that wind farms with serious noise problems emit significant noise power at frequencies well below 100 Hz. Wind turbine manufacturers devote considerable research effort to matters of blade and tower resonance with good reason. The 100 Hz HPF approach of the IOA AMWG and of course of the ReUK report pre-judges the cause of EAM by assuming that it is indeed due entirely to BPF modulation of higher frequencies and not at all due to emissions at the BPF and harmonics thereof, nor to any tower or blade resonances excited by the BPF. Finally the IOA AMWG proclaim that stall at blade zenith is responsible for EAM which has a measured modulation depth of 10 dB. I refer to this above in my response to the first question.

Is the default frequency range appropriate? What other frequency ranges could be considered, taking into account the desirability to characterize the frequency range in which AM occurs, the desirability to exclude spurious noise sources and the need for a consistent approach to avoid differences?

Almost certainly not appropriate, as explained above.

Section 6 – Time Series Method

Do you think the time series method proposed is suitable for rating AM? If not, can you explain why?

A time series is clearly suitable, but the proposed software solution is lacking in both transparency and necessity.

Section 7 – Frequency Domain Method

Do you think the frequency domain method proposed is suitable for rating AM? If not, can you explain why?

No, because in its present form it is opaque and unnecessary and appears not to work as implemented in the IOA AMWG software.

Should other parameters be used in the application of this method and why?

No comment.

Section 8 – Hybrid Method

Do you think the hybrid method proposed is suitable for rating AM? If not, can you explain why?

No further comment

Should other parameters be used in the application of this method and why?

No further comment

Section 9 – Comparison of Methods

Of the three methods proposed, which is your preferred method?

1, as it is the only one that works.

Is there another alternative method not recommended by the AMWG which would be preferable? Explain why.

Yes; the complainant driven method of visual examination as described above. I would add here that in any event the ruling document in any legal dispute should be the unprocessed time series data and not any complex and opaque derivative thereof and the ruling threshold should be set (by the medical specialists of DECC?) in dB of modulation depth.

Section 10 – Instrumentation

Are the proposed requirements for instrumentation appropriate?

Not 20 Hz or 63 Hz? From which I must assume that: The IOA AMWG has established by measurement (but not published) that frequencies below 100Hz have no influence at all on EAM modulation depths.

Would you like instrument manufacturers to make available an “AM rating” option for sound level meters?

No

Section 11 – Software

Should the IOA make available software for rating AM?

The IOA should make available the MATLAB source code used to generate the .exe file distributed by the IOA AMWG.

Do you have any comments on the software released?

Method 1 works a bit – it understates however. Methods 2 and 3 do not work.

Recommendations for Further Study and any other comments

Collaborative investigation with INWG to investigate by measurement at several wind farms/turbines known to have high levels of EAM to determine the extents to which they are due (a) to modulation of aerodynamic noise in the 100Hz to 800 Hz band and (b) to fundamental emissions at the BPF and harmonics in the 0.5 Hz to 100 Hz band.

I note that there is no mention of health in the consultation document, but 24 mentions of annoyance. With the former I agree, as acousticians are not qualified in medical matters. With the latter I cannot agree as acousticians are not psychologists either. I trust that the health and annoyance aspects of wind farm noise are being appropriately assessed elsewhere by Government, but I am not aware of any such assessment.

Your details

Please provide your name and contact details in case the working group wishes to clarify any of the points raised in your feedback: Can you also indicate if you would like your response to be published anonymously or not published at all by the IOA?

John V Yelland MA DPhil (Oxon) MInstP FIET MIOA
Yelland.john@live.fr
01983 533655
07999 539000

Very happy to have my response published and attributed to me.

The IOA AMWG thanks you for your help in completing this document.

Gavin Irvine
AMWG Chair

Turncole and Rotsea Wind Farms

§4.5.2 of the discussion document refers to a high rate of false positives in the Den Brook time series methodology for detection of EAM, and to Dr Bass's report of the measurement of a large number of "false positives" at two typical wind farm sites – typical except that were in fact rural locations devoid of wind turbines. This, he considers, is evidence of a failure of the Den Brook methodology. A simple argument; if you have all those false positives indicating excessive AM even without any turbines present then how can one possibly rely on the data with turbines present? But this argument has a fundamental, and frankly rather elementary, flaw.

It is easier to explain the flaw by starting at the beginning rather than working backwards from Dr Bass's wrong conclusion. I intend this note to be understood by non-specialists, to whom the rest of this page is addressed.

For the present purpose decibels only serve to confuse. The decibel is not a unit of sound as is the metre a unit of length; it is just a multiplication factor. It is one tenth of a bel, and the bel is a multiplication factor of 10. Normal counting just requires the repeated **addition** of 1. Counting in bels requires repeated **multiplication** by 10, and counting in decibels requires repeated multiplication by $^{10}\sqrt{10}$, which is very close to 1.259. Note that $1.259^3 = 1.996$, which is very close to 2, so adding 3 dBs (i.e. multiplying three times by 1.259) is equivalent to multiplying by two. As examples, £1 is 20 dB more than one penny, and 3 bananas are 3 dB fewer than 6 bananas.

Counting by addition is absolute, whereas counting by multiplication is relative, so when counting in dBs a starting point must be defined, and it must be positive, not negative or zero. To state a sound level without a reference value, just as a number of dBs, is meaningless.

The usual reference point for sound levels is an average air pressure variation of 20 micropascals (μPa), which is the nominal threshold of human hearing. (Actual thresholds vary of course, particularly in respect of health, gender and age.) Strictly even to state a sound level as dB(A) is ambiguous; a fuller statement for example might be LA_{eq} = 25 dB re 20 μPa, where L indicates sound pressure level, A indicates A-weighting and eq indicates an equivalent mean value over the measurement period. There is no need to understand A-weighting for the purpose of this note.

The decibel is remarkable in that it can represent the vast range of sound levels experienced by the human ear, a ratio of 10,000,000,000 from the threshold of hearing to the threshold of pain, (20 dB(A) to 120 dB(A)) without even having recourse to unit multipliers or dividers such as kilo or micro. Unfortunately the decibel is also rather effective as a means of obfuscating simple science.

Those whose school days preceded the IT era will remember logarithms as a part of the O-level maths syllabus, and slide rules as part of the sixth form scientist's tool kit. We used logarithms as a faster means of multiplying; one looked up the log of the numbers that need multiplying in log tables, added the logs together then looked up their sum in the antilog tables, which gave the multiplicand. Even better, the tables could transform a long division into a simple subtraction. Those who knew what they were doing as well as why they were doing it realised that their slide rules were just logarithmic scales which converted multiplication and division to addition (sliding right) and subtraction (sliding left).

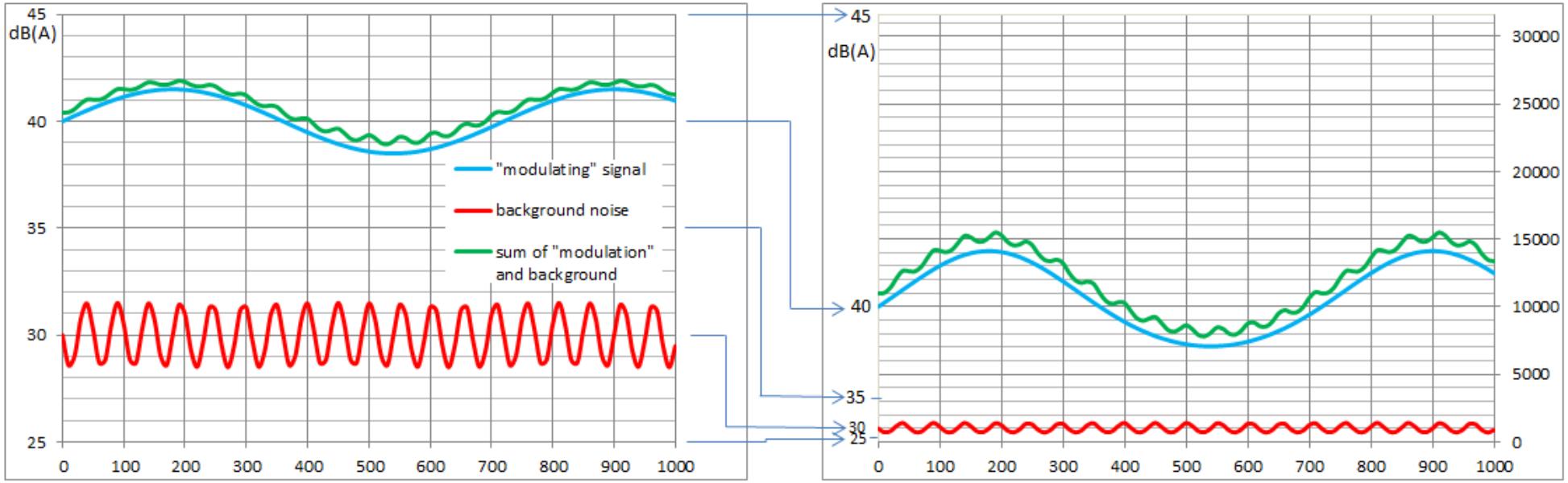


Figure 1 (a) shows the amplitude modulated turbine immission noise T (blue), the background noise B (red), and their sum S (green). Both T and B vary by ± 1.5 dB. The turbine immission noise is obviously idealised, and the single tone background noise is obviously unrealistic, but they serve well to illustrate the flaw. Notice that the variation in the total S is far less (in dBs) than the variation in the background noise. Figure 1 (b) is the same as figure 1 (a) except that it is plotted with the sound pressure on a linear scale instead of the logarithmic decibel scale. Both charts cover the same range of sound pressure levels, but figure 1 (a) has the sound pressure levels towards the bottom vertically expanded and those towards the top vertically compressed. The blue arrows between the charts indicate how the log and linear scales differ. Because dB scales are logarithmic the sum S is not given by S = B + T, but is instead by $S = 10 \log (10^{B/10} + 10^{T/10})$. The equivalent equation for the linear chart is much easier: S = B + T.

The human ear is logarithmic, because it automatically turns down its volume control when noises are louder, just as the eye contracts its iris when the light is brighter. The ability of the ear to progressively reduce its sensitivity as the noise level increases enables it to cope with a huge range of sound pressure levels from 20 uPa to 200,000,000,000 µPa. The only difference between the two graphs is that the left hand one is logarithmic because it is plotted with dBs on a linear scale whereas the right hand one is linear because it is plotted with the sound pressure level on a linear scale. If the turbine noise is loud enough to mask the background noise then, as the right had graph shows, adding the 3 dB variation in background noise to the turbine noise makes very little difference.

At the turbine-free wind farms measured by Dr Bass there is no wind turbine noise to mask the background noise, so of course a change in background noise will be detected if it is measured in dB rather than in µPa. Doubling the background noise from 28.5 dB(A) to 31.5 dB(A) (i.e. 3 dB) would trigger a "false positive", but would in fact increase the total noise only by around 0.5 dB, but because this raises the S trace further up the log scale there is in fact precisely no change in the total amplitude modulation as measured in dB. By its very variable nature background noise will always produce "false positives" in the absence of turbine noise – only they are real positives; it is Dr Bass's use of them to criticise the Den Brook methodology that is false.

INSTITUTE OF ACOUSTICS

IOA CONSULTATION QUESTIONNAIRE FOR

"METHODS FOR RATING AMPLITUDE MODULATION IN WIND TURBINE NOISE"

APRIL 2015

FOREWORD

** PLEASE READ BEFORE PROCEEDING TO THE MAIN DOCUMENT **

This discussion document has been produced by a working group on behalf of the Institute of Acoustics consisting of the following members:

Jeremy Bass		RES Ltd
Matthew Cand		Hoare Lea Acoustics
David Coles		24 Acoustics
Robert Davis		RD Associates
Gavin Irvine	(Chair)	Ion Acoustics
Geoff Leventhall		
Tom Levet		Hayes McKenzie
Sam Miller		
David Sexton		West Devon Borough Council
John Shelton		AcSoft

This questionnaire has been produced specifically to promote discussion of the relevant issues during the consultation on a metric for amplitude modulation (AM) from wind turbines and should be read in conjunction with the "IOA AMWG Discussion Document". Respondents to the consultation are encouraged to provide their comments on the form provided. A word version has been provided to allow respondents to increase box sizes as required.
All comments on the consultation draft should be sent electronically to:

WTAMCONSULT@IOA.ORG.UK

Alternatively, written responses can be sent to:
IOA AMWG Consultation Feedback
Institute of Acoustics
3rd Floor St Peter's House,
45-49 Victoria Street,
St Albans,
Herts.
AL1 3BN.

The closing date for the receipt of comments is **30th June 2015**. Late comments may not be reflected in the deliberations on the choice of the AM metric.

CONTENTS

INTRODUCTION TO THE CONSULTATION

Background

The Institute of Acoustics Amplitude Modulation Working Group (IOA AMWG) has prepared a discussion document on methods for rating amplitude modulation in wind turbine noise, for the purpose of consultation to IOA Members and other interested parties.

The discussion document considers various methods and has proposed three methods for consultation. The intention of the IOA AMWG post-consultation is to recommend one method but at this consultation stage, three candidate methods are proposed. The AMWG will not be proposing a threshold or penalty mechanism for rating the subjective response.

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

Subsequent section numbers refer to the main discussion document.

Section 3 – AM Definition

Do you agree with the Definition of AM? Does it relate to your experience?

Yes, but this is based only on my reading of other information sources, not experience.

Is the Definition of AM applicable to smaller turbines?

I think that the discussion of this in the document is reasonable – one would expect turbines with higher rotational rates to exhibit AM which was different in character to larger, slower turbines

Is it appropriate to measure AM Outside in free-field conditions? If not can you propose alternatives?

I think that this is a pragmatic approach that recognises the difficulties associated with indoor measurement and the need to provide consistency with the other methods of wind farm noise assessment current in the UK. There may be a need however, for an additional or alternative methodology for indoor measurements for circumstances where outdoor measurements to do sufficiently address the complaint.

Section 4 – Literature Review

Are there any other rating methods or important references that the AMWG should consider?

Not aware of any.

Section 5 – Towards a preferred metric

In principle, which is the best domain for rating and describing amplitude modulation: the time domain; the frequency domain; or is a hybrid method preferred? Can you explain why?

I think that it is important to characterise AM in relation to the blade passing frequency. Therefore frequency domain or hybrid methods are preferable. The most important factor is that the method is practicable, reliable, repeatable and objective. It appears that methods based on the time-domain only may introduce an undesirable element of subjectivity or may be affected by extraneous (i.e. non-wind turbine) noise.

Do you agree with time intervals proposed, that is: 100 millisecond samples, 10 second blocks, 10 minute periods?

Yes, these seem appropriate: 100ms should be readily available from typical SLMs, 10 seconds should be enough to characterise AM for a sufficient number of cycles, whilst balancing the need to consider the variation in modulation with time. 10 minutes is essential to relate to current WTN assessment methods.

Do you agree with the band-limiting filtering approach for rating AM?

It appears to be sensible to me, based on my reading of other information, but I have no first-hand practical experience to base this on.

Is the default frequency range appropriate? What other frequency ranges could be considered, taking into account the desirability to characterize the frequency range in which AM occurs, the desirability to exclude spurious noise sources and the need for a consistent approach to avoid differences?

It appears to be sensible to me, based on my reading of other information, but I have no first-hand practical experience to base this on.

Section 6 – Time Series Method

Do you think the time series method proposed is suitable for rating AM? If not, can you explain why?

I do not think that the proposed method would be able to automatically differentiate WTN with AM from other time-varying noise sources and for that reason do not consider it to be suitable.

Section 7 – Frequency Domain Method

Do you think the frequency domain method proposed is suitable for rating AM? If not, can you explain why?

I think that this method shows a lot of promise and that the refinements on the RUK methods proposed are sensible. I recognise the concerns of some commentators that the resulting method does not well represent modulation depth, but I think this is a minor issue provided that it is accounted for in the establishment of any assessment method that should be used.

I was surprised that the inclusion of higher harmonics of BPF was not part of the method as this seems to provide better correspondence with overall modulation depth. The relative strength of these harmonics may also provide an indication of the character of the AM.

Should other parameters be used in the application of this method and why?

Perhaps more consideration should be given to the inclusion of higher harmonics of BPF.

Section 8 – Hybrid Method

Do you think the hybrid method proposed is suitable for rating AM? If not, can you explain why?

It has a certain elegance, though is quite complex. It seems to combine the best aspects of both the time-domain and frequency-domain methods. The description of methodology at 8.2 is a little hard to understand, and I don't think it is helpful to refer to formulae from standards which the user would likely have to purchase to implement the method. The description of the method described should be complete enough in itself to allow a user to carry it out.

Should other parameters be used in the application of this method and why?

Section 9 – Comparison of Methods

Of the three methods proposed, which is your preferred method?

I like the relative simplicity of the time-series method, but the hybrid method seems to offer some advantages over this.

Is there another alternative method not recommended by the AMWG which would be preferable? Explain why.

Section 10 – Instrumentation

Are the proposed requirements for instrumentation appropriate?

Yes

Would you like instrument manufacturers to make available an “AM rating” option for sound level meters?

It could be useful, though I would be very wary about this being the only readily available means of implementing the method as this could give certain manufacturers a competitive advantage.

Section 11 – Software

Should the IOA make available software for rating AM?

Yes, I consider this to be absolutely essential. This will ensure that results are standardised and repeatable. It would be best if the software could work with both audio files or time-histories of LAeq,100ms measurements

Do you have any comments on the software released?

I have tested the draft software provided, and found it quite useful. It would however be helpful if it could accept audio files as an input rather than just time-series data, as this would provide greater flexibility. Batch processing would also be useful. Additional inputs like those from the RUK software (graphs and charts) might also be helpful.

Recommendations for Further Study and any other comments

P31 talks about removing any periods contaminated by extraneous noise then goes on (in 5.3) to talk about only logging 1/3-octave LAeqs rather than using audio. How can extraneous noise be identified without audio recordings?

Section 5.3.1 refers to band-passing the signal, it would be simpler to discuss in terms of the relevant 1/3-octaves to be included in the assessment.

Please include all definitions and formulae necessary to implement the method (e.g. 'Butterworth filters', not making reference to formulae in external standards)

Your details

Please provide your name and contact details in case the working group wishes to clarify any of the points raised in your feedback: Can you also indicate if you would like your response to be published anonymously or not published at all by the IOA?

The IOA AMWG thanks you for your help in completing this document.

Gavin Irvine
AMWG Chair

INSTITUTE OF ACOUSTICS

IOA CONSULTATION QUESTIONNAIRE FOR

"METHODS FOR RATING AMPLITUDE MODULATION IN WIND TURBINE NOISE"

APRIL 2015

FOREWORD

** PLEASE READ BEFORE PROCEEDING TO THE MAIN DOCUMENT **

This discussion document has been produced by a working group on behalf of the Institute of Acoustics consisting of the following members:

Jeremy Bass		RES Ltd
Matthew Cand		Hoare Lea Acoustics
David Coles		24 Acoustics
Robert Davis		RD Associates
Gavin Irvine	(Chair)	Ion Acoustics
Geoff Leventhall		
Tom Levet		Hayes McKenzie
Sam Miller		
David Sexton		West Devon Borough Council
John Shelton		AcSoft

This questionnaire has been produced specifically to promote discussion of the relevant issues during the consultation on a metric for amplitude modulation (AM) from wind turbines and should be read in conjunction with the "IOA AMWG Discussion Document". Respondents to the consultation are encouraged to provide their comments on the form provided. A word version has been provided to allow respondents to increase box sizes as required.
All comments on the consultation draft should be sent electronically to:

WTAMCONSULT@IOA.ORG.UK

Alternatively, written responses can be sent to:
IOA AMWG Consultation Feedback
Institute of Acoustics
3rd Floor St Peter's House,
45-49 Victoria Street,
St Albans,
Herts.
AL1 3BN.

The closing date for the receipt of comments is **30th June 2015**. Late comments may not be reflected in the deliberations on the choice of the AM metric.

CONTENTS

INTRODUCTION TO THE CONSULTATION

Background

The Institute of Acoustics Amplitude Modulation Working Group (IOA AMWG) has prepared a discussion document on methods for rating amplitude modulation in wind turbine noise, for the purpose of consultation to IOA Members and other interested parties.

The discussion document considers various methods and has proposed three methods for consultation. The intention of the IOA AMWG post-consultation is to recommend one method but at this consultation stage, three candidate methods are proposed. The AMWG will not be proposing a threshold or penalty mechanism for rating the subjective response.

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

Subsequent section numbers refer to the main discussion document.

Section 3 – AM Definition

Do you agree with the Definition of AM? Does it relate to your experience?

Yes.

Is the Definition of AM applicable to smaller turbines?

Yes, though the higher BPF may call for different measurement and analysis parameters.

Is it appropriate to measure AM Outside in free-field conditions? If not can you propose alternatives?

Yes, that must be the primary measurement. However, there may be a case for measuring indoors as well. It is plausible that, for turbine noise at normal incidence to a wall, in isotropic background noise, the wall might act as a directional filter, leading to higher levels of AM indoors.

Section 4 – Literature Review

Are there any other rating methods or important references that the AMWG should consider?

While I agree there is evidence for transient stall as a possible source of unusually high levels of AM at source, I would be wary of assuming it is the only possible mechanism for producing unusually high levels in the far field. AM is always present in the near field, and it is conceivable that some combination of temperature profile and wind shear could lead to propagation conditions analogous to the convergence zones in underwater sound propagation, where the noise is focussed at specific distances from the source. Papers by David Ecotière and Stuart Bradley at the recent Glasgow conference had some interesting comments on this theme.

Section 5 – Towards a preferred metric

In principle, which is the best domain for rating and describing amplitude modulation: the time domain; the frequency domain; or is a hybrid method preferred? Can you explain why?

There must be a frequency domain component to it. Otherwise, it is not possible to discriminate between BPF modulated noise and random variations, hence the Den Brook method's 83% false alarm rate.

Do you agree with time intervals proposed, that is: 100 millisecond samples, 10 second blocks, 10 minute periods?

The samples should be statistically independent. If samples are to be gathered every 100 ms, then fast rms values, which have 125 ms integration, would overlap, which will always underestimate the variation.

The samples need to give a Nyquist frequency higher than the blade passing frequency. For large turbines, 100 ms seems about right. For small turbines, a shorter sample may be necessary.
I think a 10 s block is about the minimum to give an acceptable resolution of modulation frequency.
And 10 minute periods are consistent with ETSU-R-97, which seems reasonable.

Do you agree with the band-limiting filtering approach for rating AM?

In my experience with Dick Bowdler's "swish to thump" example, the noise being modulated shifted from the 1 kHz octave down to 250 Hz over the space of about 20 seconds. Not filtering can lead to underestimating the modulation.

Is the default frequency range appropriate? What other frequency ranges could be considered, taking into account the desirability to characterize the frequency range in which AM occurs, the desirability to exclude spurious noise sources and the need for a consistent approach to avoid differences?

In my experience, with a *very limited* data set, the 500 Hz octave, 354 to 707 Hz produced consistently high values, but I could believe lower frequencies are better if based on others' greater experience. As I said above, I believe different AM can appear in different octaves. Perhaps consider 125 to 500 Hz octaves, or even 1 kHz?

Section 6 – Time Series Method

Do you think the time series method proposed is suitable for rating AM? If not, can you explain why?

No. It might be effective at assessing the level of AM once AM has been identified by other means. But as it does not discriminate by frequency, it cannot detect AM in the first place. And if the AM is not the only, or dominant, source of variation, it will overestimate the level of AM.

Section 7 – Frequency Domain Method

Do you think the frequency domain method proposed is suitable for rating AM? If not, can you explain why?

Yes, though I have long been concerned as to how to deal with prominent harmonics.

Should other parameters be used in the application of this method and why?

As stated above, I think the parameters used seem about right for a large turbine, but if it were ever considered necessary to deal with AM from small turbines, the 100 ms samples and 10 s blocks might be too long.

Section 8 – Hybrid Method

Do you think the hybrid method proposed is suitable for rating AM? If not, can you explain why?

I am very pleased to see this being considered. I have often thought I would like to try something very much like this approach.

Should other parameters be used in the application of this method and why?

My gut feeling was that two to three harmonics would be sufficient, so I'm not surprised you have settled for three.

Section 9 – Comparison of Methods

Of the three methods proposed, which is your preferred method?

For synthesised data, where the variation is entirely at BPF, Method 2 is clearly the best. I am slightly disappointed in Method 3, given that significant levels of harmonics are obviously present in the signals.

As expected, the Tachibana method shows a very high false alarm rate, when not manually corrected, with real data including other sources of variation. But looking at the plot, the outliers are fairly obvious, so they can be removed; but then it appears to significantly underestimate high levels of AM.

On the evidence, Method 2 appears best.

Is there another alternative method not recommended by the AMWG which would be preferable? Explain why.

Section 10 – Instrumentation

Are the proposed requirements for instrumentation appropriate?

Yes.

Would you like instrument manufacturers to make available an "AM rating" option for sound level meters?

In principle yes, but I suspect the perceived need is not sufficiently widespread outside the UK to make it economically viable.

Section 11 – Software

Should the IOA make available software for rating AM?

Somebody certainly should, and I think the IOA is better resourced to maintain it than, say, RenewableUK. But if we are all to use the same software, it should be open source. That way, we all share the responsibility for finding bugs.

Do you have any comments on the software released?

Recommendations for Further Study and any other comments

Your details

Please provide your name and contact details in case the working group wishes to clarify any of the points raised in your feedback: Can you also indicate if you would like your response to be published anonymously or not published at all by the IOA?

Dave McLaughlin
SgurrEnergy
david.mclaughlin@sgurrenergy.com
0141 227 1733
Happy for you to publish my comments.

The IOA AMWG thanks you for your help in completing this document.

Gavin Irvine
AMWG Chair

INSTITUTE OF ACOUSTICS

IOA CONSULTATION QUESTIONNAIRE FOR

"METHODS FOR RATING AMPLITUDE MODULATION IN WIND TURBINE NOISE"

APRIL 2015

FOREWORD

** PLEASE READ BEFORE PROCEEDING TO THE MAIN DOCUMENT **

This discussion document has been produced by a working group on behalf of the Institute of Acoustics consisting of the following members:

Jeremy Bass		RES Ltd
Matthew Cand		Hoare Lea Acoustics
David Coles		24 Acoustics
Robert Davis		RD Associates
Gavin Irvine	(Chair)	Ion Acoustics
Geoff Leventhall		
Tom Levet		Hayes McKenzie
Sam Miller		
David Sexton		West Devon Borough Council
John Shelton		AcSoft

This questionnaire has been produced specifically to promote discussion of the relevant issues during the consultation on a metric for amplitude modulation (AM) from wind turbines and should be read in conjunction with the "IOA AMWG Discussion Document". Respondents to the consultation are encouraged to provide their comments on the form provided. A word version has been provided to allow respondents to increase box sizes as required.
All comments on the consultation draft should be sent electronically to:

WTAMCONSULT@IOA.ORG.UK

Alternatively, written responses can be sent to:
IOA AMWG Consultation Feedback
Institute of Acoustics
3rd Floor St Peter's House,
45-49 Victoria Street,
St Albans,
Herts.
AL1 3BN.

The closing date for the receipt of comments is **30th June 2015**. Late comments may not be reflected in the deliberations on the choice of the AM metric.

CONTENTS

INTRODUCTION TO THE CONSULTATION

Background

The Institute of Acoustics Amplitude Modulation Working Group (IOA AMWG) has prepared a discussion document on methods for rating amplitude modulation in wind turbine noise, for the purpose of consultation to IOA Members and other interested parties.

The discussion document considers various methods and has proposed three methods for consultation. The intention of the IOA AMWG post-consultation is to recommend one method but at this consultation stage, three candidate methods are proposed. The AMWG will not be proposing a threshold or penalty mechanism for rating the subjective response.

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

Subsequent section numbers refer to the main discussion document.

Section 3 – AM Definition

Do you agree with the Definition of AM? Does it relate to your experience?

For a definition of AM, we would suggest that it focuses on periodic fluctuation and the amplitude of the fluctuation. There should not be referencing to footnotes within the definition, perhaps a separate definition for blade passing frequency. Examples of suggested alternative wording:

Wind Turbine AM: *"Periodic fluctuations in the level of broadband wind turbine noise from a wind turbine (or wind turbines), the frequency of the fluctuations being the blade passing frequency (Frequency in Hertz (Hz) calculated as follows: bpf = rotor rpm x No. of Blades / 60). The amplitude of the fluctuations will be one of the key factors which will influence how AM is perceived.*

It may also be useful to provide some comment on the fact that AM is a commonly expected feature of wind turbine noise and some turbines exhibit levels greater than expected.

Stating "observed outside in free field" should not be in the actual definition of AM, it can be stated though that this is within the scope of the AM metric or in the measurement recommendations.

Is the Definition of AM applicable to smaller turbines?

The generic definition (see above) should be applicable to any wind turbines. It is appropriate to state that the AM metric was designed based on observations on large turbines and that it may apply or not to smaller turbines.

Is it appropriate to measure AM Outside in free-field conditions? If not can you propose alternatives?

Yes outside recordings are reasonable for the scope of providing an AM metric as inside noise measurements are subject to technical challenges.
Stating "observed outside in free field" should not be in the actual definition of AM, it can be stated though that this is within the scope of the AM metric or in the measurement recommendations.

Section 4 – Literature Review

Are there any other rating methods or important references that the AMWG should consider?

The hum which is sometimes behind the thumping (OAM) has been shown to be an annoying tonal feature with a periodic feature. Perhaps a review of the papers on the Doppler effect (WTN Glasgow 2015) ?

Section 5 – Towards a preferred metric

In principle, which is the best domain for rating and describing amplitude modulation: the time domain; the frequency domain; or is a hybrid method preferred? Can you explain why?

Frequency domain = It offers possibility of cross correlation with wind turbine rotor rpm data, hence the analysis can focus on noise levels at the blade passing frequency.

The most important is to ensure that the chosen metric is based on the method which results in the least false positives as all methods broadly show similar results for periods of clear AM and stimulus.

Do you agree with time intervals proposed, that is: 100 millisecond samples, 10 second blocks, 10 minute periods?

Yes for 100ms,10 second, it offers a possibility of qualifying every single 10s period with an AM rating.

In term of how a 10 minute rating should be determined we don't have enough data to comment on which statistic approach should be used. Perhaps this work could stop at rating every 10 second period. We do however agree that ultimately a 10 minute rating must be obtained from statistics using the 10 seconds AM ratings. Without sufficient data, we can not comment on the specific choice of 90th percentile or an average of the 10 highest or 20 highest.

If a 10minute rating is included in the final metric, a comment can be added stating that it would be appropriate to calculate a 10 minute AM rating based on 2 minute of 10s AM rating. The primary reason is that it that noise survey at residential receptors near operational wind turbines (past/present/future) often includes recording of 2minute of audio every 10 minute to allow for tonal analysis and this data could be retrospectively used for past survey to re-analyse AM. Using audio recordings to establish AM ratings for every 10 second with a 2 minute period is possible, and such data should therefore be allowed to be used to statistically calculate a 2 minute rating which can by generic assumption be assumed to be a valid rating for the full 10 minute period in question (ie. same assumption as when undertaking a tonal analysis).

Do you agree with the band-limiting filtering approach for rating AM?

Yes, this in principle seems to provide more focused results compared than using broadband levels. A comments could perhaps inform that "the 100ms Leq levels for 100-400Hz may be obtained from averaging the energy in the seven 1/3 octave bands from 100Hz to 400Hz. Alternatively, narrow band analysis of audio signal may also provide the required data for input in the AM metric."

Is the default frequency range appropriate? What other frequency ranges could be considered, taking into account the desirability to characterize the frequency range in which AM occurs, the desirability to exclude spurious noise sources and the need for a consistent approach to avoid differences?

Not in a position to comment, not tested.

Section 6 – Time Series Method

Do you think the time series method proposed is suitable for rating AM? If not, can you explain why?

Time Series Method may be suitable but seems to require a higher requirement for manual scrutiny to test for false positives.

The selected metric should be selected based on a known method which provides, to date, the least false positives. Long surveys are expected and a rating for each 10minute is needed and manual inspection would provide too much interpretation and inconsistency of use. The Frequency Domain method seems the most suitable for such purpose.

Section 7 – Frequency Domain Method

Do you think the frequency domain method proposed is suitable for rating AM? If not, can you explain why?

Yes it is the most suitable compared to Time Series in our opinion.

Should other parameters be used in the application of this method and why?

The methods relies on Leq numbers and therefore dispense for the needs to record audio signals. It is our opinion that recommendations should be made that audio signals are also recorded as an optional extra in addition to the Leq 100ms 1/3 octave levels, even if it is only 1 minute every 10 minute or 2 minute every 10 minute and at a low sampling rate. This would allow for listening of selected worst case 10 minute AM samples selected following the rating of an entire survey(by the main AM metric methodology).

Section 8 – Hybrid Method

Do you think the hybrid method proposed is suitable for rating AM? If not, can you explain why?

Hybrid Method would be suitable but its principles are quite complex and it is difficult to see what are the advantages in comparison to rely solely on the Frequency Domain Method which seems to provide similar outputs.

Should other parameters be used in the application of this method and why?

Section 9 – Comparison of Methods

Of the three methods proposed, which is your preferred method?

Method 2 or Method 3. Method 2 is less complex though and provides similar results so it may be preferred.

Is there another alternative method not recommended by the AMWG which would be preferable? Explain why.

The Japanese fast / slow method seemed to present some interesting results whilst also being simple to use and we understand that undertaking a band filter of the data before undertaking the analysis might significantly reduce the false positives so this might warrant further investigation.

See above comment, add comments to allow 10 minute AM rating based on statistics on 2 minute of 10s AM rating. . Add strong recommendations for optional Audio recording (1 or 2 min every 10minute and low rates), which would allow for validating some samples by subjective listening. Or if needed, it would allow for further detailed narrow band analysis.

Once an AM rating is provided for every 10minute, recommendation could be provided to plot a scatter of AM versus wind speed or produce a time series where AM, LAeq levels, Wind speeds are all plotted.

Section 10 – Instrumentation

Are the proposed requirements for instrumentation appropriate?

Why proposing a correction on wind shield frequency response if it is only for those who have the relevant information available and also if it is to state that this will not be a significant correction due to the expected frequencies of AM. In this context, the comment on correction on wind shield frequency response is not necessary.

Should make a clearer distinction between requirements of 10.3 "SLM" and 10.4 "Audio recording equipment only". For example 10.3 could read:
" The sound level meter should be set-up to measure at least the following:
- 1/3 Octave band Leq 100ms recorded continuously during the survey.
And Optionally...
- Uncompressed Audio (Wav, FLAC, ALAC .. files) with at least 16bits depth and 12KHz sampling. The audio in this case would allow for samples to be listened to following the main analysis based on the processing of the 100ms Leq data."
- ....all other options here"
And 10.4 could read:
"The audio recording equipment should be set-up to measure at least the following:
- Uncompressed Audio (Wav, FLAC, ALAC .. files) with at least 16bits depth and 12KHz sampling recorded as a minimum 2 minute every 10 minute or if possible continuously. The audio files in this case are used for two purposes, a)to extract the 100ms Leq and undertake the main OAM analysis b)to allow for listening of samples following main analysis"
No optional in this case has recording the all signal means any analysis can be undertaken.
"

Would you like instrument manufacturers to make available an “AM rating” option for sound level meters?

Yes as long as software processing is consistent with the recognised metric and allows for re-programming or updates in case good practice changes.

Section 11 – Software

Should the IOA make available software for rating AM?

Yes if possible as it would provide a baseline of the "expected result" (for the selected methodology) when compared to other custom software (ie. potential manufacturer or consultants own implementations). A simple version like the trial released, analysing only a 10minute period may be sufficient and easy enough to supply and maintain for the IOA. The most important is that it provides the "expected result" for at least a given 10 minute and then it could be down to others to implement their own batch processing.

Do you have any comments on the software released?

Excellent simple interface, clear inputs and outputs, easy to use.
Is there a need for user input of Minimum and Maximum,modulation frequency, the AM metric could define that it will find the maximum modulation peak in the range 0Hz to 1.25Hz (hence it deals with any turbines up to 25RPM) without user input.
Could write a timestamp rather than block count, but would require user to add the start timestamp perhaps as first line in the header of the input txt file.
Could output the frequency at the maximum peak (ie. or even estimated turbine RPM)

Being limited to one 10 minute period at a time does not allow for processing of long surveys which makes the software in its current form of limited use in practice.

Recommendations for Further Study and any other comments

Once metric is agreed, study statistics on overall frequency of AM occurrence, wind conditions of occurrence, occurrence per wind speed bin per wind directions at various sites were sufficient quality data is available. Correlate the estimated RPM from the AM analysis to actual SCADA data RPM (for every 10sec).

It would be useful to see some research relating to how people react to a 10 minute period of low level steady AM versus a short period of very high amplitude AM.

The work undertaken by the NWG is very good but ultimately there is a requirement for the metric, once agreed, to be related back to a dose response relationship so that an absolute limit or a progressive AM penalty can be determined. Until this key next step is completed the good work undertaken to date may be of limited value, arguments over planning conditions will continue and it will be hard for residents, developers, EHO's and consultant to conclude whether AM at a site is acceptable.

In the event that the Government do not commission the previously proposed work on dose response / an absolute limit / a penalty system we would like to see this work taken on by another body / bodies. We would hope that the IOA would lead or at the very least be involved with this next stage of work.

Your details

Please provide your name and contact details in case the working group wishes to clarify any of the points raised in your feedback: Can you also indicate if you would like your response to be published anonymously or not published at all by the IOA?

The IOA AMWG thanks you for your help in completing this document.

Gavin Irvine
AMWG Chair

INSTITUTE OF ACOUSTICS

IOA CONSULTATION QUESTIONNAIRE FOR

"METHODS FOR RATING AMPLITUDE MODULATION IN WIND TURBINE NOISE"

APRIL 2015

FOREWORD

** PLEASE READ BEFORE PROCEEDING TO THE MAIN DOCUMENT **

This discussion document has been produced by a working group on behalf of the Institute of Acoustics consisting of the following members:

Jeremy Bass	RES Ltd
Matthew Cand	Hoare Lea Acoustics
David Coles	24 Acoustics
Robert Davis	RD Associates
Gavin Irvine (Chair)	Ion Acoustics
Geoff Leventhall	
Tom Levet	Hayes McKenzie
Sam Miller	
David Sexton	West Devon Borough Council
John Shelton	AcSoft

This questionnaire has been produced specifically to promote discussion of the relevant issues during the consultation on a metric for amplitude modulation (AM) from wind turbines and should be read in conjunction with the "IOA AMWG Discussion Document". Respondents to the consultation are encouraged to provide their comments on the form provided. A word version has been provided to allow respondents to increase box sizes as required.
All comments on the consultation draft should be sent electronically to:

WTAMCONSULT@IOA.ORG.UK

Alternatively, written responses can be sent to:
IOA AMWG Consultation Feedback
Institute of Acoustics
3rd Floor St Peter's House,
45-49 Victoria Street,
St Albans,
Herts.
AL1 3BN.

The closing date for the receipt of comments is **30th June 2015**. Late comments may not be reflected in the deliberations on the choice of the AM metric.

CONTENTS

INTRODUCTION TO THE CONSULTATION

Background

The Institute of Acoustics Amplitude Modulation Working Group (IOA AMWG) has prepared a discussion document on methods for rating amplitude modulation in wind turbine noise, for the purpose of consultation to IOA Members and other interested parties.

The discussion document considers various methods and has proposed three methods for consultation. The intention of the IOA AMWG post-consultation is to recommend one method but at this consultation stage, three candidate methods are proposed. The AMWG will not be proposing a threshold or penalty mechanism for rating the subjective response.

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

Subsequent section numbers refer to the main discussion document.

Section 3 – AM Definition

Do you agree with the Definition of AM? Does it relate to your experience?

Yes, the definition of AM is adequate, although some may object to the *'as observed outdoors at residential distance in free-field conditions'* part, because this is not necessary for the definition. It is recommended these words are removed, and make clear later that the focus of the work has been in such conditions for pragmatic reasons.

Is the Definition of AM applicable to smaller turbines?

Possibly, although if OAM is caused by asymmetric flow into the rotor disc, then the smaller the size of the rotor disc the lower the likelihood of OAM occurring. For example, the stable atmospheric conditions/high wind shear/veer conditions known to drive shear across large rotors would not be as significant for small rotors, because the difference in wind speed from top to bottom of the rotor's arc would be much smaller.

It is also agreed that the applicability of the defined metric is classified to a specific turbine size, and this may only be established following analysis of AM data from smaller turbines.

Is it appropriate to measure AM Outside in free-field conditions? If not can you propose alternatives?

Yes, it is the only pragmatic choice, and essential for consistency with all other noise control standards, e.g. BS 4142 (2014), ETSU-R-97 etc. Whilst AM might be a problem for some indoors, if it can be measured and controlled outdoors then this should resolve the indoor problem.

Section 4 – Literature Review

Are there any other rating methods or important references that the AMWG should consider?

No.

Section 5 – Towards a preferred metric

In principle, which is the best domain for rating and describing amplitude modulation: the time domain; the frequency domain; or is a hybrid method preferred? Can you explain why?

The frequency domain (Method 2) because it is a good compromise between complexity and clarity, and as long as both time series and modulation spectra are looked at carefully, can return high quality results.

It is not believed that there are any credible, stand-alone time domain methods, for example Tachibana's approach (Method 1) requires verification in the frequency domain, because it has no frequency specificity.

It is tempting to believe that the hybrid reconstruction (Method 3) may provide a cleaned-up time series which is 'noise free', however, unless there is a clear peak in the modulation spectrum then there is no AM present and the concern is that this critical step will get overlooked in all the complexity, and a bad time series will get generated that will be used without question.

Do you agree with time intervals proposed, that is: 100 millisecond samples, 10 second blocks, 10 minute periods?

Yes, this seems a pragmatic choice. Note justification for the decision to use the 90th percentile value for 10 minute period isn't provided (paragraph 5.2.3). Shouldn't this be informed by subjective response? Is this typically more or less conservative than average of top 20 values of AM as in RUK method?

Do you agree with the band-limiting filtering approach for rating AM?

Yes, RES' experience of extensive analysis clearly shows that sometimes OAM is not apparent in A-weighted level data, whereas it is readily apparent in 100-400 Hz data.

It is also identified that band pass filtering (100-400Hz) gives greater modulation depths/AM ratings, does this completely over-come previous criticism of RUK method under-estimating level of AM?

Is the default frequency range appropriate? What other frequency ranges could be considered, taking into account the desirability to characterize the frequency range in which AM occurs, the desirability to exclude spurious noise sources and the need for a consistent approach to avoid differences?

The choice of 100-400 Hz as a default/standard is a good first choice and, for the vast majority of the AM data analysis that we've looked at it's the ideal choice. It should be recognised that this may need to vary depending on what a spectrogram of the audio data shows, and for this reason it is recommended as a 'first step' to data analysis. After all, we have explicitly said that our AM metric is source mechanism agnostic and so we can hardly restrict users to a range which is far more relevant to OAM than it is to NAM.

The following is therefore proposed:

- 100-400 Hz is the default
- If there is overwhelming evidence, perhaps from a spectrogram, that modulation is happening at other frequencies, then the range is moved to centre on the frequency that gives the maximum level
- This is done on an 'entire analysis' basis, i.e. hours or days, not on a 10 min by 10 min basis, and the range should remain at seven 1/3 octave bands but can be moved up or down as necessary.

Section 6 – Time Series Method

Do you think the time series method proposed is suitable for rating AM? If not, can you explain why?

This method is only suitable for rating AM for small amounts of data, because the number returned is only meaningful if you can verify, using some other method (frequency domain?), that AM is definitely present. Used on its own, Method 1 is not a reliable indicator of AM.

It also fails to meet one of the criteria the working group set for identifying viable methods, i.e. 'Specificity', which states that '*as AM is currently defined as 'the modulation of the broadband noise emission of a wind turbine at the blade passing frequency', it is essential that the methodology is specific to nature of the signal and not sensitive general fluctuations.'*

Clearly Method 1 is frequency insensitive, and as likely to return high values due to 'general fluctuations' as it is due to AM. If it has no ability to distinguish between these two then it is not useful. The same criticism has been made by RES of the Den Brook Condition (section 4.3.2).

Section 7 – Frequency Domain Method

Do you think the frequency domain method proposed is suitable for rating AM? If not, can you explain why?

Method 2, the frequency domain method, is the preferred approach, as experience/testing has proved it to be a very robust & reliable indicator of AM, often over periods of months. Fourier showed that any periodic motion, however complex, can be made up of a series of simple harmonic motions, hence the AM caused by the rotation of the turbine blades can be clearly identified by the frequency domain method.

One area where the text is weak is in discriminating between genuine OAM and false positives, which the document glosses over. Section 0.2.2 mentions that there must be 'a clear peak' in the modulation spectrum at BPF for AM to be considered as present, although there are not any objective methods included for verifying that a peak is 'clear' in the text.

It is essential to rectify this, ideally with a clear procedure, but failing that then at least some spectra showing valid and invalid AM spectra, to help the user interpret their own data. These can be provided if no-one else has any examples.

Should other parameters be used in the application of this method and why?

The 100-400 Hz band pass filtering range could be altered where there is incontrovertible evidence that another range would capture the OAM better - see previous comment.

It is not believed the L90 approach to determining the level of AM in a 10 min period works, as experience suggests it is biased upwards by a few atypical values of 10 sec AM. Unless the 10 sec data are very efficiently filtered, which is very difficult to do in practice for more than a day or so of data, the L90 value ends up reflecting only extreme values and doesn't relate to the vast body of data within the 10 min period. As mentioned before, examples can be provided.

We should either:

- Set a higher standard for data filtering, with an explicit procedure, if we want to keep the L90
- Replace the L90 with a L75 or lower.

Section 8 – Hybrid Method

Do you think the hybrid method proposed is suitable for rating AM? If not, can you explain why?

Possibly, but it is not the preferred method and therefore do not believe it should be pursued, despite its apparent skill.

It may be viewed that Method 3 is best, because it provides a cleaned-up time series which is 'noise free', however, unless there is a clear peak in the modulation spectrum then it may be viewed that there is no AM present, and the concern is that this critical step will get overlooked in all the complexity. Bad time series will get generated, as a result, that will be used without question. Method 3 should be removed to prevent this happening.

Should other parameters be used in the application of this method and why?

Why use 1/3 octave band filtering at the BPF and 2^{nd} & 3^{rd} harmonics? Why not a narrower filter, e.g. 1/12 octave band, or perhaps ± 0.1 Hz. Is the choice of 1/3 octave band supported by evidence, or does it just 'feel right'?

Also similar comments on forming a 10 min value as above.

Section 9 – Comparison of Methods

Of the three methods proposed, which is your preferred method?

Method 2, the Fourier analysis method is preferred. This is because the frequency domain method is relatively simple and directly provides modulation spectra which can be used to determine whether AM is genuinely present or not.

Method 1 (Time-domain) under-estimates modulation depth (as shown in figures 9.1 & 9.4), is most susceptible to corruption (figure 9.9), fails to meet the criteria of specificity, and is not a reliable indicator of OAM.

Method 3 (Hybrid) can over-estimate modulation depth as shown in figure 9.3 and the additional complexity in comparison to Method 2 is unnecessary. It is also a method newly developed by the AMWG team and therefore has no track record of prior use within the acoustics community – this is in contrast to Method 2.

Whether the three methods result in a larger or smaller AM rating for a given sample does not matter as long as any penalty that may be applied as a result is appropriate to the metric that is being used i.e. based on a dose-response relationship to modulation depths determined by the metric in question.

Is there another alternative method not recommended by the AMWG which would be preferable? Explain why.

No. Some people may suggest the Den Brook Condition, which has been mentioned in the literature review (section 4.3.2), but this has exactly the same problems as Method 1 and doesn't even return a number/metric for AM, it merely says 'pass' or 'fail', so would not be recommended as an alternative method.

Section 10 – Instrumentation

Are the proposed requirements for instrumentation appropriate?

Yes, it is believed there needs to be a defined standard, and as a minimum the Institute of Acoustics Good Practice Guide should be referenced so that there is a suitable classification of instrument, adequate calibration, and appropriate wind shield.

It is suggested that reference to specific suppliers is removed, as an example has been included in section 10.4 to 01dB's "dBFA".

Would you like instrument manufacturers to make available an "AM rating" option for sound level meters?

No. At present all methods suggested need human intervention to verify that there is a clear peak in the modulation spectrum, and therefore OAM is present. Until there is an algorithm that can actually do this filtering it would be senseless to encourage an OEM to include one of the proposed AM methods. If they do, users will end up believing the values returned, even if they don't necessarily result from genuine OAM.

Section 11 – Software

Should the IOA make available software for rating AM?

Not necessarily, although if they chose to it would be helpful. If they did the software would need suitably checked before it could be released.

Do you have any comments on the software released?

It looks slick and runs quickly, seems very good. The outputs from the software could however be improved, with charts showing the level of AM over the sampled times series.

Recommendations for Further Study and any other comments

The fundamental problem we face is that aperiodic, and even periodic (crows, dogs etc.) amplitude modulation is a universal feature of most outdoor noise environments, whether just background noise or in the vicinity of a wind farm. Detecting periods of AM in that environment is very challenging and the result is a high, but completely unacknowledged level of false positives.

The greatest concern about this document is that we don't really discuss how to do this time consuming subjective filtering objectively – we simply provide much guidance on how to do this other than by reference to waterfall plots, which are only a feature of Method 2 and even then:

- We don't define how you can generate them
- We don't show enough examples of them to help users discriminate between real and false AM.

The final document must clearly explain how you efficiently and reliably filter a large dataset, i.e. months long, to isolate genuine AM from other sources that look like AM, e.g. dogs, crows, pigeons, reversing lorries etc. We need to address this deficiency in the final recommendation document.

Note that the last 4 paragraphs of the Executive Summary should be new section, perhaps 'Commonalities Between Methods', rather than sitting in a discussion of Method 3.

The other concern is how you verify that there is a genuine peak (and at harmonics) in your modulation spectrum before you determine the level of AM. A spike in the time domain can create a white-noise like spectrum which may display a high value at the BPF but which is nothing to do with AM, there won't be a clear peak, just bumps. Unless you have checks in place, Methods 2 and particularly 3, will give you a completely nonsense result which will greatly overestimate the true levels of AM.

Also, although we have ignored the psycho-acoustics of AM because we understood that DECC would be addressing these, in the current climate it is entirely possible that they won't. A metric without a dose-response relationship is of no use to anyone. If DECC do not pursue this it is recommended the AMWG should do it, otherwise all the work has been pointless. The AMWG could review the information and, without providing any specific guidance, at least delineate all the options. Tom Levet's results presented at Newcastle for both the RUK & Tachibana results get us almost half-way there already.

The only penalty scheme that is available at the moment is the one published as part of the RUK work. It should be made clear that the results provided by the three metrics presented in this consultation document should not be used in conjunction with the RUK AM penalty scheme as they produce different modulation depths than the metric proposed in the RUK work.

Your details

Please provide your name and contact details in case the working group wishes to clarify any of the points raised in your feedback: Can you also indicate if you would like your response to be published anonymously or not published at all by the IOA?

Matthew Cassidy
Renewable Energy Systems Ltd
Third Floor, STV
Pacific Quay
GLASGOW
G51 1PQ

+44 (0)141 404 5532
Matthew.Cassidy@res-ltd.com

*Feedback can be published, no anonymity required

The IOA AMWG thanks you for your help in completing this document.

Gavin Irvine
AMWG Chair

INSTITUTE OF ACOUSTICS

IOA CONSULTATION QUESTIONNAIRE FOR

"METHODS FOR RATING AMPLITUDE MODULATION IN WIND TURBINE NOISE"

APRIL 2015

FOREWORD

** PLEASE READ BEFORE PROCEEDING TO THE MAIN DOCUMENT **

This discussion document has been produced by a working group on behalf of the Institute of Acoustics consisting of the following members:

Jeremy Bass	RES Ltd
Matthew Cand	Hoare Lea Acoustics
David Coles	24 Acoustics
Robert Davis	RD Associates
Gavin Irvine (Chair)	Ion Acoustics
Geoff Leventhall	
Tom Levet	Hayes McKenzie
Sam Miller	
David Sexton	West Devon Borough Council
John Shelton	AcSoft

This questionnaire has been produced specifically to promote discussion of the relevant issues during the consultation on a metric for amplitude modulation (AM) from wind turbines and should be read in conjunction with the "IOA AMWG Discussion Document". Respondents to the consultation are encouraged to provide their comments on the form provided. A word version has been provided to allow respondents to increase box sizes as required.
All comments on the consultation draft should be sent electronically to:

WTAMCONSULT@IOA.ORG.UK

Alternatively, written responses can be sent to:
IOA AMWG Consultation Feedback
Institute of Acoustics
3rd Floor St Peter's House,
45-49 Victoria Street,
St Albans,
Herts.
AL1 3BN.

The closing date for the receipt of comments is **30th June 2015**. Late comments may not be reflected in the deliberations on the choice of the AM metric.

CONTENTS

INTRODUCTION TO THE CONSULTATION

Background

The Institute of Acoustics Amplitude Modulation Working Group (IOA AMWG) has prepared a discussion document on methods for rating amplitude modulation in wind turbine noise, for the purpose of consultation to IOA Members and other interested parties.

The discussion document considers various methods and has proposed three methods for consultation. The intention of the IOA AMWG post-consultation is to recommend one method but at this consultation stage, three candidate methods are proposed. The AMWG will not be proposing a threshold or penalty mechanism for rating the subjective response.

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

Subsequent section numbers refer to the main discussion document.

Section 3 – AM Definition

Do you agree with the Definition of AM? Does it relate to your experience?

SSE agrees with the definition of AM in principle however believes that the definition of the AM should reflect the cause / source of the noise. For this reason the difference between normal AM and Other AM should continue to be acknowledged.

Is the Definition of AM applicable to smaller turbines?

No comment.

Is it appropriate to measure AM Outside in free-field conditions? If not can you propose alternatives?

Yes, measurements should be taken in a manner which is re-producible, unobtrusive and in line with the methodology for standard operational noise surveys.

Section 4 – Literature Review

Are there any other rating methods or important references that the AMWG should consider?

No comment.

Section 5 – Towards a preferred metric

In principle, which is the best domain for rating and describing amplitude modulation: the time domain; the frequency domain; or is a hybrid method preferred? Can you explain why?

SSE's preferred method for identification of AM is the frequency domain method, as it seems to give conclusive results and allows the measured data to be automatically post processed on a large scale. SSE would like to see further information on the methodology to be used in determining a rating and subsequent penalty from the measurements.

There is little evidence in the Discussion Document of consultation with instrument suppliers in the design of the proposed measurement campaigns. The practicalities of any methodology defined need to be considered, including the requirement to leave instrumentation unattended in remote locations for prolonged periods of time. It is essential that issues such as data storage and power requirements, as well as the likelihood and impact of equipment failure are considered.

Monitoring of wind conditions on site is believed to be an important part of the measurement campaign, and should be extended to include wind shear and turbulence measurements. This would allow for correlation between the site conditions and any occurrence of AM to be assessed. This may also facilitate the definition of a defined measurement period, in a similar manner to the required wind speed and direction bins to be filled during a standard Operational Noise Survey.

Ultimately the method proposed will be used to define a penalty scheme. If the occurrence of AM is relatively rare, site conditions information may be required to ensure the wind farm is not overly penalised during times when AM does not occur. Any penalty scheme should consider the frequency of occurrence as well as the modulation depth of any AM identified. As per other noise impacts, there should be an level an allowed level of AM prior to a penalty being applied.

Another point to note is that RPM is likely to be available at 10 minute averaging period, rather than the 10 second minor interval. SSE would like to understand the sensitivity of the method to RPM as on a given site different WTGs may have different RPM values at the same times, particularly during the ramp up of the WTG power curve.

SSE would like to understand of the likelihood of another noise source leading to modulation that would be seen in the 100-400Hz band.

Do you agree with time intervals proposed, that is: 100 millisecond samples, 10 second blocks, 10 minute periods?

SSE agree with the major interval being the same as that for a standard Operational Noise Survey, and that the minor interval and sampling rate would be in line with that facilitated on standard SLMs.

SSE do have concerns over the equipment powering and data storage requirements for the proposed measurement campaigns, particularly given the duration of measurement campaign that may be required to identify a relatively rare phenomenon. Possible solutions to this may be to measure intermittently, restricting the measurement to times of the day when AM is likely to occur, if the equipment allows for this. The correlation of the occurrence of AM with the wind conditions at site may allow the extension of any penalty to periods when noise data is not available.

Measurement at 100 millisecond intervals will lead to a significant amount of data to be post-processed. This will have an impact on the analysis time and cost for any AM noise survey, and SSE would like this to be a consideration in the definition of the approved methodology.

Do you agree with the band-limiting filtering approach for rating AM?

SSE have concerns over the band-limiting filtering approach for rating AM as the noise which is filtered out may be noise which reduces the impact of the AM in practise.

SSE agree in principle with the band-limiting filtering approach for automated identification of AM, however further information is required on how this will be then used to define a rating level of AM, and any subsequent penalty. It is considered important that the rating level represents the actual noise impact, including any masking noise from other frequency bands.

Is the default frequency range appropriate? What other frequency ranges could be considered, taking into account the desirability to characterize the frequency range in which AM occurs, the desirability to exclude spurious noise sources and the need for a consistent approach to avoid differences?

No comment

Section 6 – Time Series Method

Do you think the time series method proposed is suitable for rating AM? If not, can you explain why?

SSE does not consider the time series method suitable for rating AM.

SSE considers that there are merits to the time-series method, due to the relative-simplicity of the method and the required data inputs are easier to obtain. SSE consider that this method may be suitable in conjunction with a complaints log and audio sampling, where the periods analysed are those when complaints were noted in the log.

However, SSE has concerns over the time-series method due to the subjectivity of the analysis and the likelihood of false positive results when analysis is carried out on a full data-set, which seems to be relatively labour intensive. Contamination from other background noise is a concern; again this may lead to subjectivity in the analysis method which may lead to dispute over results and protracted measurement campaigns.

It is noted in Section 4.2.1 that 'time-series methods have the advantage of relative simplicity'; while it would be favourable to have a simple method, this should not be at the expense of confidence in the results, as the measurements and analysis should be undertaken by competent acoustic professionals.

Section 7 – Frequency Domain Method

Do you think the frequency domain method proposed is suitable for rating AM? If not, can you explain why?

SSE do consider the frequency domain method suitable for identifying AM, however further information is required in order to confirm if it is suitable for use directly as a rating method.

SSE considers the method suitable for identification of AM due to the standardised data processing method, the reproducibility of results and the ability to apply an automated method to process large quantities of data. Section 4.2.2 notes that 'this type of analysis does have the ability to discriminate between wind turbine AM and other modulated noise sources' which is a key feature for the chosen analysis method.

It should be noted that RPM / wind speed data is unlikely to be available on 10s intervals and SSE would like to understand the impact of this on the analysis methodology.

As mentioned above, use of the frequency domain method directly for the rating of AM may underestimate the masking effect of other frequency bands. Similarly harmonics are not accounted properly in this methodology.

Should other parameters be used in the application of this method and why?

Yes, SSE consider that additional wind condition monitoring should be included in the methodology, to determine the periods when AM occurs. Without this it will be difficult to impose a penalty on wind turbines that is not overly onerous, given that AM is only expected to occur under specific site conditions. Also, this may allow a quota of required measurement data to be defined (similar to the wind speed and direction bins required to be filled in a standard noise measurement campaign), to allow a measurement campaign to have a defined duration rather than continue indefinitely.

Section 8 – Hybrid Method

Do you think the hybrid method proposed is suitable for rating AM? If not, can you explain why?

SSE do consider the hybrid method suitable for the identification of AM, however further information is required in order to confirm if it is suitable for use directly as a rating method.

SSE consider the hybrid method suitable, however this method appears to be more labour intensive and open to interpretation / subjectivity than the frequency domain method. It is understood that a concern with the frequency domain method is that some instances of AM may be missed. The hybrid method does not seem to address this concern, as the frequency domain method identifies the periods for detailed analysis. While it may give a more accurate understanding of the depth of modulation due to the analysis of the harmonics, this seems to introduce an additional element of uncertainty into the results. Also, the masking effect of other noise is not accounted for in this method, similar to the Frequency Domain Method.

The hybrid method is described as requiring complex filtering and data processing (Section 8.1). While a complex methodology is not necessarily to be avoided, a methodology that requires significant subjectivity in the analysis should be.

Should other parameters be used in the application of this method and why?

As noted for frequency domain method re. site conditions data.

Section 9 – Comparison of Methods

Of the three methods proposed, which is your preferred method?

SSE's preferred method is the Frequency Domain Method, for the reasons outlined above. However, SSE have residual concerns with this method relating to the practicality of the survey on site, the quantity of the data to be post-processed and the removal of masking effects in the rating methodology.

Is there another alternative method not recommended by the AMWG which would be preferable? Explain why.

No comment.

Section 10 – Instrumentation

Are the proposed requirements for instrumentation appropriate?

Use of instrumentation that is readily available is preferable.

SSE has a concern that the equipment proposed will have large data storage and power requirements for long periods of time. The practicalities of the methodology, with cognisance of the length of measurement campaign likely to be required, should be a key consideration and this should be discussed with equipment suppliers prior to confirmation of the methodology to be adopted.

Would you like instrument manufacturers to make available an "AM rating" option for sound level meters?

As above, the practicalities of the proposed survey methodology should be discussed with equipment manufacturers, and if an 'AM rating' option is deemed appropriate then this should be made available.

Section 11 – Software

Should the IOA make available software for rating AM?

Yes the IOA should make software available, with the underlying calculations being carried out by the software clearly defined. The software provided should be designed to process the large amounts of data that will be measured during the noise survey.

The software proposed has not been tested by SSE.

Do you have any comments on the software released?

No comment.

Recommendations for Further Study and any other comments

As mentioned previously, further study is required to confirm the conditions under which AM occurs and to ensure that any penalty / mitigation is only applied during the appropriate times. Disturbance due to AM is an issue that needs to be dealt with, however it is also important that the power output from new or installed renewable generation is not curtailed without reason, and under conditions which AM is unlikely to occur.

SSE would like to see further information on the way in which a penalty would be applied if appropriate, e.g. at all wind speeds or only those at which AM occurs. Is the penalty system going to apply differently to different wind speeds therefore different BPF? And will the penalty take frequency of occurrence into account?

SSE would like to see guidance on the time of year when an AM study should be carried out, or, as mentioned above, a requirement for specific wind shear and turbulence bins to be filled. It is noted that 'On sites where it has been reported, occurrences appear to be occasional, although they can persist for several hours under some conditions, dependent on atmospheric factors, including wind speed and direction.' It is important that this is considered in the definition of the methodology, to ensure that a measurement campaign addresses the conditions under which a resident has concerns, and equally that the wind farm operator can carry out a defined measurement campaign drawing to a clear conclusion. As per a standard noise complaint, there should be a requirement for the Planning Authority to determine if a noise complaint is genuine and likely to be AM prior to the Developer being required to undertake an AM Noise Survey.

Although it is outside of the scope of this document, SSE believe that the AMWG can and should provide valuable guidance on the practicalities of a noise measurement campaign, to ensure the results of any survey can be implemented on site. The practicalities of a noise survey should also be given due consideration in the definition of an AM Noise Survey.

Your details

Please provide your name and contact details in case the working group wishes to clarify any of the points raised in your feedback: Can you also indicate if you would like your response to be published anonymously or not published at all by the IOA?

Claire McKeown
SSE Renewables

Email: Claire.McKeown@sserenewables.com
Ph. 0141 224 7228

The IOA AMWG thanks you for your help in completing this document.

Gavin Irvine
AMWG Chair

INSTITUTE OF ACOUSTICS

IOA CONSULTATION QUESTIONNAIRE FOR

"METHODS FOR RATING AMPLITUDE MODULATION IN WIND TURBINE NOISE"

APRIL 2015

FOREWORD

** PLEASE READ BEFORE PROCEEDING TO THE MAIN DOCUMENT **

This discussion document has been produced by a working group on behalf of the Institute of Acoustics consisting of the following members:

Jeremy Bass	RES Ltd
Matthew Cand	Hoare Lea Acoustics
David Coles	24 Acoustics
Robert Davis	RD Associates
Gavin Irvine (Chair)	Ion Acoustics
Geoff Leventhall	
Tom Levet	Hayes McKenzie
Sam Miller	
David Sexton	West Devon Borough Council
John Shelton	AcSoft

This questionnaire has been produced specifically to promote discussion of the relevant issues during the consultation on a metric for amplitude modulation (AM) from wind turbines and should be read in conjunction with the "IOA AMWG Discussion Document". Respondents to the consultation are encouraged to provide their comments on the form provided. A word version has been provided to allow respondents to increase box sizes as required.
All comments on the consultation draft should be sent electronically to:

WTAMCONSULT@IOA.ORG.UK

Alternatively, written responses can be sent to:
IOA AMWG Consultation Feedback
Institute of Acoustics
3rd Floor St Peter's House,
45-49 Victoria Street,
St Albans,
Herts.
AL1 3BN.

The closing date for the receipt of comments is **30th June 2015**. Late comments may not be reflected in the deliberations on the choice of the AM metric.

CONTENTS

INTRODUCTION TO THE CONSULTATION

Background

The Institute of Acoustics Amplitude Modulation Working Group (IOA AMWG) has prepared a discussion document on methods for rating amplitude modulation in wind turbine noise, for the purpose of consultation to IOA Members and other interested parties.

The discussion document considers various methods and has proposed three methods for consultation. The intention of the IOA AMWG post-consultation is to recommend one method but at this consultation stage, three candidate methods are proposed. The AMWG will not be proposing a threshold or penalty mechanism for rating the subjective response.

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

Subsequent section numbers refer to the main discussion document.

Section 3 – AM Definition

Do you agree with the Definition of AM? Does it relate to your experience?

Is the Definition of AM applicable to smaller turbines?

Is it appropriate to measure AM Outside in free-field conditions? If not can you propose alternatives?

Section 4 – Literature Review

Are there any other rating methods or important references that the AMWG should consider?

Section 5 – Towards a preferred metric

In principle, which is the best domain for rating and describing amplitude modulation: the time domain; the frequency domain; or is a hybrid method preferred? Can you explain why?

Do you agree with time intervals proposed, that is: 100 millisecond samples, 10 second blocks, 10 minute periods?

1. Regarding 10s blocks:
    a. With real data, variation is seen within 10s period, and averaging that variation, and then taking statistical measures of those average values, likely averages out the extreme albeit short-lived values (both on the low and high end of the scale). You also get bursts of AM that may fall across the edge of two 10s blocks.
    b. Shorter windows? E.g. 5s, with an overlapping window may be more appropriate?
    c. That will likely provide a truer description of the variation in modulation over a longer period.
    d. The ideal approach is to divide up the dataset into small enough sub-periods, such that those sub-periods have constant modulation. With real data, 10s isn't short enough for that to happen. But the sub-division should be long enough, so that the sub-period is perceived as modulation character (having just 1-2 cycles is probably not long enough for it to be of periodic character)
    e. To link up the results of real data with a subjective dose-response relationship (that is based on constant modulation), then the real data needs to be sub-divided into periods of constant modulation.
    f. In some circumstances, taking the 90th percentile of 10s averages may not be that dissimilar to results from shorter time windows. Nevertheless that may not be borne out for all scenarios.

Do you agree with the band-limiting filtering approach for rating AM?

Is the default frequency range appropriate? What other frequency ranges could be considered, taking into account the desirability to characterize the frequency range in which AM occurs, the desirability to exclude spurious noise sources and the need for a consistent approach to avoid differences?

2. Frequency Range
    a. Needs a tighter procedure for picking correct range.
    b. What do you do if you have intermittent stall vs TE swishing? I.e. mostly TE swishing (where 200-800Hz would be appropriate), but stall effects happening intermittently (where 100-400Hz would be more appropriate).
        i. Such a scenario would probably require different frequency ranges for each 10s block. Hence a procedure is probably required to determine how the frequency range is chosen.
    c. If there is the option to analyse a lower frequency range, the procedure should have some consideration of the hearing threshold, or direction for the user to make such a consideration. It is possible that apparently high modulation values may be measured in some low frequencies. That doesn't necessarily mean such frequencies are an issue, or should be assessed as such, if the levels aren't high enough to be audible in the first place.

Section 6 – Time Series Method

Do you think the time series method proposed is suitable for rating AM? If not, can you explain why?

3. Method 1
    a. DAM will be triggered by times of variance, which is not necessarily of modulating character. Some would argue that that is a type of character that removes the noise from being benign, and hence should be penalised. But such character would likely fall outside the scope of the current objective.
    b. Instances of abrupt changes in level (that aren't related to a regular periodic character) are not something that the authors of the DAM approach had accounted for in their dose-response relationships. I.e. the artificial stimuli used in those listening tests do not contain abrupt changes in level, that are not associated with regular pulsing. Listeners were reacting purely to the difference in modulation depth.
    c. So if an assessment method were based upon DAM method, and those results were then related to the Japanese dose-response relationships for the purposes of an evidence based penalty scheme, it could be argued that the assessment would have to remove all the instances when the DAM method was triggered by character not present in the artificial stimuli.
    d. The same probably applies to the Salford listening tests.
        i. E.g. can one measure some real data and assess them with Method X, look up where

Method X results sat on Salford's dose response relationships (when the artificial stimuli is analysed using Method X), and then expect that subjective response to be the same as that encountered from the real data (dis-regarding any variances due to intermittency or pre-conceptions etc)? Such an approach is most applicable if the real data in question exhibits the same relative character that the artificial stimuli listening tests were quantifying.

1. Therefore a sensible link with the Salford measured subjective response may require the real data to exhibit modulation character in a similar frequency range, with similar harmonic content. Or corrections to be made where the similarities are not present.

Section 7 – Frequency Domain Method

Do you think the frequency domain method proposed is suitable for rating AM? If not, can you explain why?

Should other parameters be used in the application of this method and why?

4. Method 2
    a. Should probably have some consideration for the harmonic content.
    b. Otherwise a sine wave with 5dB PtT will get assessed in the same way as a saw tooth wave with 7dB PtT. Yet people probably hear the difference in those examples.
    c. Also including harmonic content would allow for the capture of periods when you have several turbines running at the same speed, but out of phase. And what is measured/heard is individual blade passages from different machines.
    d. Is 7 third octave bands really an appropriate bandwidth?
        i. Or do people hear modulation in individual critical bands?
        ii. So if the modulation was concentrated in 1 or 2 third octave bands, maybe that is what they hear.
        iii. They may not hear the masking provided by the other third octave bands surrounding those 1 or 2 bands. Hence combining the 7 third octave bands, may fill in the troughs, and smooth out the peaks, to some extent.
    e. Regarding the 1.3 correction factor, it may not always be appropriate to have such an arbitrary correction, for the scenario where no third octave data is available. The applicability of such a

correction will depend upon which frequency range is dominating the modulation, and the frequency range that drives the overall A-weighted level. Hence 1.3 is only appropriate for a limited number of scenarios.

Section 8 – Hybrid Method

Do you think the hybrid method proposed is suitable for rating AM? If not, can you explain why?

Should other parameters be used in the application of this method and why?

5. Method 3
    a. Conditions for including harmonics
    b. Maybe don't have these –
        i. At times the 2nd and 3rd harmonics will be higher than fundamental
        ii. Is it appropriate to just consider the fundamental in those instances?
        iii. It remains to be seen whether this only happens for times of extraneous sources.
    c. What do we do if the fundamental is reasonably high in frequency?
        i. E.g. For some turbines the RPM may give rise to BPF of up to 2Hz.
        ii. That requires a frequency range of up to say 8Hz to consider the third harmonic
        iii. Having 100ms sampled data (i.e. 10Hz fs), only allows for frequencies up to 5Hz to be picked up. Would there be merit in considering other sampling frequencies?
    d. When identifying peaks and troughs in reconstructed signal
        i. Sometimes a window of 0.5 x period may not be large enough.
        ii. That's fine for a sine wave.
        iii. But when you have more saw tooth type shapes, the trough might come immediately before the peak. Hence the trough might fall just after the conventional half a cycle. Something like 0.75 may work better?

Section 9 – Comparison of Methods

Of the three methods proposed, which is your preferred method?

Is there another alternative method not recommended by the AMWG which would be preferable? Explain why.

Section 10 – Instrumentation

Are the proposed requirements for instrumentation appropriate?

Would you like instrument manufacturers to make available an “AM rating” option for sound level meters?

Section 11 – Software

Should the IOA make available software for rating AM?

Do you have any comments on the software released?

Recommendations for Further Study and any other comments

6. Downwind machines
    a. The methods preclude themselves from being able to suitably analyse the thumping of downwind machines. By basing things on overall A-weighted levels or band-limited 100-400 Hz range, the more lower frequency dominated thumping will be under-estimated by the three methods.
    b. Seems like there should at least be some guidance for this scenario.

Your details

Please provide your name and contact details in case the working group wishes to clarify any of the points raised in your feedback: Can you also indicate if you would like your response to be published anonymously or not published at all by the IOA?

Tom Levet
tom@hayesmckenzie.co.uk
Hayes McKenzie Partnership Ltd

The IOA AMWG thanks you for your help in completing this document.

Gavin Irvine
AMWG Chair

INSTITUTE OF ACOUSTICS

IOA CONSULTATION QUESTIONNAIRE FOR

"METHODS FOR RATING AMPLITUDE MODULATION IN WIND TURBINE NOISE"

APRIL 2015

FOREWORD

** PLEASE READ BEFORE PROCEEDING TO THE MAIN DOCUMENT **

This discussion document has been produced by a working group on behalf of the Institute of Acoustics consisting of the following members:

Jeremy Bass	RES Ltd
Matthew Cand	Hoare Lea Acoustics
David Coles	24 Acoustics
Robert Davis	RD Associates
Gavin Irvine (Chair)	Ion Acoustics
Geoff Leventhall	
Tom Levet	Hayes McKenzie
Sam Miller	
David Sexton	West Devon Borough Council
John Shelton	AcSoft

This questionnaire has been produced specifically to promote discussion of the relevant issues during the consultation on a metric for amplitude modulation (AM) from wind turbines and should be read in conjunction with the "IOA AMWG Discussion Document". Respondents to the consultation are encouraged to provide their comments on the form provided. A word version has been provided to allow respondents to increase box sizes as required.
All comments on the consultation draft should be sent electronically to:

WTAMCONSULT@IOA.ORG.UK

Alternatively, written responses can be sent to:
IOA AMWG Consultation Feedback
Institute of Acoustics
3rd Floor St Peter's House,
45-49 Victoria Street,
St Albans,
Herts.
AL1 3BN.

The closing date for the receipt of comments is **30th June 2015**. Late comments may not be reflected in the deliberations on the choice of the AM metric.

CONTENTS

INTRODUCTION TO THE CONSULTATION

Background

The Institute of Acoustics Amplitude Modulation Working Group (IOA AMWG) has prepared a discussion document on methods for rating amplitude modulation in wind turbine noise, for the purpose of consultation to IOA Members and other interested parties.

The discussion document considers various methods and has proposed three methods for consultation. The intention of the IOA AMWG post-consultation is to recommend one method but at this consultation stage, three candidate methods are proposed. The AMWG will not be proposing a threshold or penalty mechanism for rating the subjective response.

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

Subsequent section numbers refer to the main discussion document.

General Comments on Consultation

IoA Consultation Process Flawed

1. This is the third consultation on wind turbine noise carried out by the IoA in recent years. The first two were a) that for the Good Practice Guidance (GPG) and b) the Supplementary Guidance Notes (SGN).
2. The process adopted by the IoA for these earlier consultations was flawed. It is a normal requirement following a consultation that a consultation response document is produced in which the specific points raised by consultees are addressed. Where a consultee has made a recommendation or criticism of the original document, the IoA, as a professional body, must explain either what adjustment to the guidance was made to accommodate the point, or, on what evidential basis the point was rejected. The IoA has not done this.
3. Instead, the IoA has argued that reports made by planning inspectors following planning inquiries provides sufficient detail to explain why the IoA does not need to respond to technical criticism of acoustic issues contained within IoA Guidance. (See http://www.ioa.org.uk/sites/default/files/IOA%20statement%20on%20wind%20farm%20noise%20assessment%2019-12-2014.pdf). This position is absurd and untenable; no other professional, let alone scientific body would delegate the responsibility of technical rebuttal to a planning inspector whose own expertise is in Town Planning.
4. We urge the IoA to respond to the current consultation with a professional consultation response document that explains what regard has been paid to the consultation responses and why.
5. We further note that the consultation responses to both the GPG and SGN reports are not apparently available on the IoA website in spite of an earlier statement that they were to be published. This should be rectified, and the responses to this AM consultation also published.
6. In spite of our organisation, the Renewable Energy Foundation, having responded to both the GPG and SGN consultations, and having produced original work on AM that is cited (inaccurately) in the IoA AM Discussion Document, REF was not notified of this consultation by the IoA. This suggests that other individuals and organisations who have responded to the earlier consultations might similarly have been ignored in this consultation process. This undermines confidence in the IoA's ability to carry out a proper consultation exercise.
7. In summary, the process for earlier IoA consultations has been seriously and significantly inadequate; there are worrying signs that the current consultation will be no better. The pattern that is emerging does no credit to the IoA and must be rectified if reputational harm is to be avoided.

Selection of NWG Members

8. In any exercise involving recommendations of how to define a potential noise nuisance, it is important that the participants involved in formulating the recommendations are seen to have no vested interest in the outcome, or that the recommendations are framed in such a properly scientific manner that they are seen to be reasonable and not to unfairly serve any interest.
9. There is a long history related to AM noise nuisance. Following the 2006 DTI report by Hayes McKenzie Partnership (HMP) which highlighted the fact that UK wind farms were producing AM noise at levels that exceeded what is accounted for in the ETSU-R-97 guidance, a NWG was set up by the then Department of Trade and Industry (DTI). Many of the same members and or organisations in the IoA NWG and AM subgroup were represented in the 2006 DTI NWG.
10. The draft minutes and emails relating to the meetings of the 2006 NWG were released under a Freedom of Information request.[1]

[1] http://www.ref.org.uk/publications/328-foi-dti-noise-working-group

11. It is clear from these released documents that there was wholesale resistance to the idea of limiting AM noise even though it was recognised that AM levels of 15dB had been measured as long ago as 1997. It is also plain that the concerns of neighbours and objectors were treated by some members with disdain. It is also plain that considerations other than purely acoustic issues coloured the judgement of some members of the group.
12. No empirical AM data was collected nor were any attempts to limit AM problems made as a result of the efforts of 2006 NWG. In fact, the situation nine years later is unchanged from when the last NWG group was convened.
13. The fact that the same people and/or organisations have been chosen to form the 2015 NWG is profoundly alarming and unlikely to generate confidence or improve the prevailing public opinion of the IoA as an appropriate organisation to formulate robust and fair wind farm noise guidance.

Lack of real world evidence

14. The 2006 DTI report by the Hayes McKenzie Partnership (HMP) gathered AM data at three sites. One of the sites, Far Old Wind Farm at Askam in Cumbria could be considered a benchmark site for AM noise problems. It is the wind farm site in the UK with the most neighbour complaints about AM noise and has been causing these complaints for 14 years since April 2001.[2] We find it surprising that no effort has been made to test the suggested methodologies by quantifying the AM measured by HMP that actually triggered the AM debate.
15. We need to understand how the different methodologies proposed by the IoA would quantify AM at the wind farm sites with incontrovertible AM problems, such as Askam and Deeping St Nicholas for example. REF has carried out the exercise on the Askam data for both the original Den Brook AM condition and the RUK AM condition and shown that the former condition would be breached and the latter not breached at Askam.[3]
16. This is definitely the sort of exercise that the IoA NWG should be carrying out.
17. There is a clear bias in the document towards a penalty mechanism which we could not possibly endorse for the reasons spelled out below in the answer to the time interval question in Section 5. However, if the reader was provided with the quantified AM level under each of the proposed methodologies for Askam and other sites with outstanding long-term AM complaints, it would be possible to see if a penalty scheme would result in a breach or no breach.
18. Without provision of real world data of this sort, the document seems likely to result in another decade where wind farm developers can build too close to neighbours and generate AM noise with impunity. This would suit wind farm developers, but would amount to a professional betrayal of lay members of the public to whom the IoA has a professional duty of care.

Section 3 – AM Definition

Do you agree with the Definition of AM? Does it relate to your experience?

19. We disagree with the definition. Although superficially it appears reasonable, this definition can be exploited by the wind industry to the unacceptable disadvantage of wind farm neighbours. Evidence for this can be seen in the developers' revision to the AM condition at Den Brook. In that case, a scheme was put in place that includes a step which states:

[2] http://www.ref.org.uk/Files/D.pdf
[3] http://www.ref.org.uk/publications/310-the-efficacy-of-the-ruk-am-condition
http://www.ref.org.uk/publications/242-the-den-brook-amplitude-modulation-noise-condition

"4 c) if this assessment indicates that GTE-AM is present, then the $L_{Aeq,125msec}$ data required by Condition 20 shall be band pass filtered, from $0.9f_c$ to $1.1f_c$, 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, f_c.**" (emphasis added)

20. This demonstrates how the definition recommended by the IoA AM NWG can be misused. By filtering out the harmonics using FFT techniques as required in the amended Den Brook scheme, the level of AM at blade passing frequency will significantly understate the AM depth experienced by neighbours.

21. Given that three of the members of the IoA AM NWG were involved with drafting and validating the Den Brook amended AM condition, we are surprised and concerned that this loophole in the definition of AM has been allowed to persist in the IoA document.

Is the Definition of AM applicable to smaller turbines?

Is it appropriate to measure AM Outside in free-field conditions? If not can you propose alternatives?

22. No. The 2006 DTI report by Hayes McKenzie explicitly noted that greater AM had been measured indoors than outside in free-field conditions. We are surprised that this evidence and its significance is not discussed in the IoA report.

Section 4 – Literature Review

Are there any other rating methods or important references that the AMWG should consider?

23. There are inaccuracies in Section 4 that need to be corrected.

24. The REF work on AM is described at page 20 as a criticism of the RenewableUK AM research produced in 2013. The REF work cited is a 2011 paper on the Den Brook AM condition and clearly cannot be a criticism of the RUK work produced 2 years later. The correct reference is http://www.ref.org.uk/attachments/article/310/ref.info.note.ruk.am.condition.20140319.pdf

25. The brief comment on REF's work included in the IoA document does not accurately represent the conclusions we reached. To summarise, these were that the methodology always understated the actual AM, it is too complex and computationally intensive to provide a reasonably accessible and transparent methodology for assessing excessive AM noise and that, crucially, it would not be

breached at Askam wind farm. Askam is a benchmark site for AM noise problems. It is the wind farm site in the UK with the most neighbour complaints about AM noise and has been triggering these complaints for 14 years since April 2001.[4]

26. Bizarrely, given that three of the members of the AM NWG were closely involved with devising and approving the Den Brook condition 21 scheme (that modifies the original Den Brook AM condition), it is incorrectly described at page 22. What is omitted is the crucial part of Condition 21 that states if the AM levels breach the original 3dB limit set by a planning inspector, the noise data is filtered via a Fourier transform to restrict the assessed noise data to blade passing frequency +/- 10%. A breach is only recorded if this band pass filtered data also exceeds 3dB. The corollary of this is that although the Inspector limited AM to 3dB, the developer and local authority have subsequently raised that limit to as much as 4 to 5 dB.

27. It is important that the Den Brook condition 21 scheme is correctly characterised in the IoA document because the increase in permitted AM depth was justified on the basis of the definition of AM which is the same as the IoA are proposing in this consultation. See the response to Section 3 AM definition above.

Section 5 – Towards a preferred metric

In principle, which is the best domain for rating and describing amplitude modulation: the time domain; the frequency domain; or is a hybrid method preferred? Can you explain why?

28. The time domain is unquestionably the best domain. As the RUK document, this IoA document and others, including REF's review of the RUK AM condition[5] have all demonstrated, any methodology involving Fourier transforms is absurdly esoteric. If the aim was to exclude the neighbours affected by AM noise from understanding whether a wind farm complies with an AM noise condition or not, a better methodology could not have been chosen. This is unacceptable and must be corrected.
29. The only acceptable methodology for a noise condition needs to be one that can be implemented readily and understandably with ordinary equipment such that no suspicion or controversy regarding compliance arises. We have previously demonstrated that the original Den Brook condition (prior to its recent amendment) is straightforward to implement and understand.[6]

Do you agree with time intervals proposed, that is: 100 millisecond samples, 10 second blocks, 10 minute periods?

30. We don't understand the rationale for 10 minute periods unless the IoA NWG is already committed to recommending a penalty for AM. This would be wholly unacceptable. It is unreasonable to treat the annoyance arising from the beating noise character of wind farm AM noise as an adjunct to the

[4] http://www.ref.org.uk/Files/D.pdf
[5] http://www.ref.org.uk/publications/310-the-efficacy-of-the-ruk-am-condition
[6] http://www.ref.org.uk/publications/242-the-den-brook-amplitude-modulation-noise-condition

total sound levels rather than as a distinct problem in its own right. Applying a correction to the measured sound levels will not address the issue of noise complaints arising from excess AM noise; it should be treated as a standalone problem. This is because annoyance is not linked to overall noise level, but to its modulation even at low noise levels. It is AM that has to be removed not just compensated for in a way which is inevitably ineffective.

31. The fact that a penalty will be ineffective arises because of the IoA GPG and SGN recommending use of the so-called 'standardised' wind speeds as distinct from actual wind speeds. The corollary of this is that more headroom is available for wind farms to make noise at times of high wind shear and at night time; exactly the times when AM is likely to become a nuisance to neighbours. Evidence demonstrating this extra headroom for wind farm noise provided by the IoA guidance was covered in our SGN consultation response.[7]
32. Furthermore, by limiting quantification of AM to specific blocks of time in this way and electing to use the FFT methodology, it also dictates the start and end times of the measured samples. As anyone who has worked on real-world AM data will appreciate, varying the starting point changes the outcome value of AM depth.

Do you agree with the band-limiting filtering approach for rating AM?

33. No because it can be misused in an opaque way to remove wind farm noise – see response to the first question of Section 3.

Is the default frequency range appropriate? What other frequency ranges could be considered, taking into account the desirability to characterize the frequency range in which AM occurs, the desirability to exclude spurious noise sources and the need for a consistent approach to avoid differences?

34. This question presupposes that frequency space analysis is acceptable which it is not.

Section 6 – Time Series Method

Do you think the time series method proposed is suitable for rating AM? If not, can you explain why?

35. Yes

[7] Page 14ff of http://www.ref.org.uk/attachments/article/305/REFIoAConsultation2014.02.07v2.pdf

Section 7 – Frequency Domain Method

Do you think the frequency domain method proposed is suitable for rating AM? If not, can you explain why?

36. Not suitable
37. REF provided a detailed, evidence-based critique of frequency domain methodology in the report at http://www.ref.org.uk/publications/310-the-efficacy-of-the-ruk-am-condition
38. In addition to these criticisms, Section 7 of the IoA document has a number of problems. Firstly, the data represented in Figure 7.1 looks implausible. The frequency domain spectrum shows a significant harmonic contribution in addition to the fundamental peak of 5.2 dB. It seems unlikely that a reverse FT of that frequency spectrum would generate the time series which appears to show AM of around 5dB. i.e. the clear presence of a harmonic means the fundamental peak would not be expected to be as great as 5.2dB. Whether an error has arisen in the scaling because the time series is 20s not 10s as labelled is not clear, but it does appear that there is an error in the figure. This could mislead readers into believing that the fundamental in a Fourier transform of a typically asymmetric wind turbine AM signal would give a reasonably accurate measure of the actual modulation in the time domain.
39. The method as described requires the blade passing frequency and the SCADA data is suggested as a source of this data. It is claimed that the rotational speed is unlikely to vary significantly but there is no evidence to back up this assertion – even though members of the IoA AM NWG would certainly have access to this sort of information. In fact for multiple turbines in a wind farm, the rotational speed will vary significantly – not only from one turbine to the next but also over a ten minute period. There will be considerable difficulty in deciding which BPF to use with the resultant debate and suspicion that any results are unrepresentative of the true impacts.
40. We cannot endorse any methodology where key bits of data are in the hands of the wind farm owners and obtaining that data is at their discretion. This is not likely to be perceived as fair or reasonable by wind farm neighbours.

Should other parameters be used in the application of this method and why?

41. As stated, frequency domain analysis is not suitable for a wind farm noise condition administered by hard pressed local authorities and requiring the confidence of wind farm neighbours that the condition is fair.

Section 8 – Hybrid Method

Do you think the hybrid method proposed is suitable for rating AM? If not, can you explain why?

42. No – because it implies frequency domain analysis is acceptable.

Should other parameters be used in the application of this method and why?

Section 9 – Comparison of Methods

Of the three methods proposed, which is your preferred method?

43. A time domain method

Is there another alternative method not recommended by the AMWG which would be preferable? Explain why.

44. A straightforward implementation of the Condition 20 Den Brook AM condition as demonstrated in the REF report at http://www.ref.org.uk/publications/242-the-den-brook-amplitude-modulation-noise-condition

Section 10 – Instrumentation

Are the proposed requirements for instrumentation appropriate?

Would you like instrument manufacturers to make available an “AM rating” option for sound level meters?

Section 11 – Software

Should the IOA make available software for rating AM?

45. Absolutely not. Any noise condition that requires black-box software is inevitably going to be mistrusted by the neighbours of any wind farm site. In view of the EIA requirements, we would anticipate that the raw code underpinning any software would be required to be in the public domain which indicates proprietary software could not be used. It is surprising to us that the IoA is confident they could write and support what is clearly quite complex software from first principles.
46. Furthermore provision of software is subject to all the well-known problems and risks associated with all IT products including bugs, support, obsolescence, and licensing. The IoA presumably has no track record as a successful software supplier and would be extremely ill-advised to diversify into such an expensive and risk-prone area.

Do you have any comments on the software released?

Recommendations for Further Study and any other comments

Your details

Please provide your name and contact details in case the working group wishes to clarify any of the points raised in your feedback: Can you also indicate if you would like your response to be published anonymously or not published at all by the IOA?

Dr Lee Moroney, Renewable Energy Foundation, lee.moroney@ref.org.uk
De Morgan House
57-58 Russell Square
London
WC1B 4HS
Telephone: 0207 637 4847

I am happy for this response to be published by the IOA and do not seek anonymity

The IOA AMWG thanks you for your help in completing this document.

Gavin Irvine
AMWG Chair

Jeremy Bass

From: Richard Tyler <richard@avi.f2s.com>
Sent: 08 June 2015 13:21
To: WTAMCONSULT@ioa.org.uk
Subject: Instrumentation for the AM consultation document

Hi,

I'm not really in a position to comment on the proposed methods of defining AM for wind turbines, but I read the document out of general interest, and would like to make the following comments about instrumentation and instrument standards.

Firstly, on page 59 your reference to EN 61672-1 is out of date. A fully revised edition was published in 2013, all 3 parts, so an update to EN 61672-1:2013 should be made here.

Secondly, the references to windshields on page 58 leave it wide open for all sorts of different measurements to be made by different people with different approaches. If you are to get any consistency in the measurement process, so that different people measuring the same source get reasonably similar date, then the type of windshield, type of microphone fitted to the measuring instrument, and the angle of incidence for "normal" sound should all be specified. Some windshields are designed for sound normal to the microphone diaphragm, some for grazing incidence, and some microphones, especially from GRAS, have altered frequency responses that are only correct when the exact type and model of windshield is fitted. You are definitely talking dB's worth of difference, even at the frequencies sub 1kHz that you state are the required measuring range. For the final document, I would strongly recommend that you decide what your requirements for the microphone, enclosure and mounting angle for the microphone system, and any permissible corrections that can be applied are, and add these to the instrumentation section of the report, otherwise to me the variation in measurements from the different selections of microphone, windshield and angle of incidence makes the actual measurement less than repeatable and somewhat meaningless.

Best regards,

Richard

Richard Tyler, Chairman, IOA Measurement & Instrumentation Group
AVI Ltd., 27 Sand Lane, Northill, Biggleswade, Beds. SG18 9AD
Tel: 01767 627004 Mob: 07812 588298
www.avinstruments.co.uk

Jeremy Bass

From: Susan Dowson <susan.dowson@npl.co.uk>
Sent: 18 May 2015 13:24
To: WTAMCONSULT@ioa.org.uk
Subject: Amplitude Modulation Discussion Document

Hi

I have looked at this document just with respect to instrumentation, and have a couple of comments on this aspect.

Clause 10.3 this should also refer to the current sound level meter standard BS EN 61672-1:2013 (which is Edition 2 of BS EN 61672-1: 2003)

Clause 10.4 should read BS EN 60651 and not BS EN 651.

Thanks.

Susan

Susan Dowson
Group Leader Acoustics
National Physical Laboratory
Teddington
Middlesex TW11 0LW
UNITED KINGDOM
Tel: 020 8943 6703
Email: susan.dowson@npl.co.uk
www.npl.co.uk