THE USE OF PROXY MEASUREMENTS TO DETERMINE WIND FARM NOISE COMPLIANCE, WHAT ARE THE OPTIONS, IS THERE A NEED FOR FURTHER GUIDANCE?

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1 INTRODUCTION

1.1 Background

As more wind farms are built in the UK the requirement for noise compliance monitoring is increasing. Compliance monitoring is usually undertaken for one of three reasons:

1) the wind farm operator undertakes the assessment voluntarily as part post commissioning works;
2) monitoring is required to satisfy a planning condition; or,
3) monitoring is required following receipt of a complaint relating to noise.

The method adopted for compliance monitoring can vary slightly depending on the site and the purpose of the monitoring, useful general guidance is provided in the Institute of Acoustics document *'A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise'*[1] (GPG) and particularly in the associated Supplementary Guidance Note 5 *'Post Completion Measurements'*[2] (SGN5).

Typically, compliance monitoring is undertaken at noise sensitive receptors, either at those located closest to the site for voluntary or conditioned monitoring or at the complainant's properties in the event of a complaint. For modern wind farms set back distances between the monitoring locations and the turbines are typically 400-1000m and the signal to noise ratio at these distances can be low making it difficult to accurately identify the specific noise contribution from the wind turbines.

Increasingly wind farms are being planned and built in clusters, meaning that compliance monitoring sometimes needs to consider cumulative noise impacts too. The GPG provides a number of solutions which can be adopted to ensure appropriate noise limits are set for individual developments (as discussed in Section 5 of that document). Many of the solutions suggested in the GPG result in developments being set very low noise limits which are sometimes below the background noise level.

Setting of limits which are below the background noise level is not a new practice in acoustics or indeed for wind farm noise. ETSU-R-97, which was published in 1996, detailed that a fixed 35dB L_{A90} limit might be appropriate from wind speeds up to 10m/s for *"single turbines or wind farms with very large separation distances between the turbines and the nearest properties"*. Adoption of this simplified limit often means that the limit is below the background noise level, particularly at higher wind speeds.

The challenges associated with undertaking compliance measurements against the simplified 35dB limit were recognised by Garnet and Sutherland when they presented a paper[3] at Acoustics 2015 on that very topic, additionally it is also referenced in SNG5, which notes in paragraph 2.4.8:

"It should be noted, however, that where the shut-down noise approaches the operational noise, the level of shut-down noise has an increasing effect on the calculated turbine noise such than when the difference between the two is 3 dB or less, it may no longer be appropriate to use this correction with any degree of accuracy and some other method of determining turbine noise in the presence of high levels of background noise may need to be agreed with the planning authority. ... In such cases where noise limits are less than ETSU-R-97 limits (e.g. apportionment of noise impacts due to cumulative impacts) compliance measurements may need to be undertaken in closer proximity to the wind farm to ensure background noise levels do not unduly influence the readings."

The concept of using of proxy measurement locations closer to the turbines to improve the signal to noise ratio has therefore been established for some time. In an industry which has provided such detailed guidance on many aspects of wind turbine noise assessment covering topics from wind shear to data analysis there appears to be a lack of guidance in relation to proxy measurements. This paper will explore some of the key variables that need to be considered when undertaking such measurements.

1.2 Previous Research

Bullmore *et al* presented a paper[4] in 2009 which considered wind farm noise predictions and how they compared with measurements. Data was collected at three wind farms and at a range of distances from each of the developments (between 100 and 1000m from the wind turbines) and the authors noted that predicted levels correlated relatively well at all distances and that:

"The margin between the prediction trend line and measurement trend line tends to progressively decrease with increasing distance from the turbines. The most obvious potential cause of this effect is the increasing influence of background noise at increasing distance."

The paper also concluded that:

"Our studies also illustrate the difficulties encountered in noise immission measurements, and in particular evaluating the measurement contribution directly attributable to turbine immissions alone and defining a relevant wind speed reference. Measurements made closer to the source can help in evaluating the different contributions within the measurements."

In 2011 Hessler[5] presented a paper which discussed the challenges associated with determining the specific noise of a development, particularly where it is impractical to undertake turbine shut downs to obtain background noise data. Hessler suggested that simultaneous background noise measurements could be taken at a location thought to experience a similar background noise environment whilst being outside the area acoustically influenced by the wind turbine noise. The paper noted that in areas of the USA background noise levels are often similar over quite large areas although experience in the UK suggests that this may not be true in many areas, meaning that such an approach could not be widely adopted.

More recently Garnett and Sutherland (2015) considered the use of proxy locations as part of their paper *'Measuring compliance with the ETSU-R-97 simplified limit'* and concluded:

"A potential solution to this problem (high uncertainty levels when turbine noise level is low compared to background levels) *is to increase the use and acceptability of intermediate proxy locations for noise monitoring. However, as mentioned, ensuring a robust proxy measurement can still provide problematic and may not eliminate the need to monitor at the property itself."*

2 KEY CONSIDERATIONS

2.1 Where to measure

The existing guidance in the SGN5 does not specify what distance proxy measurements should be made at, simply noting that measurements could be undertaken *"in closer proximity to the wind farm"*.

The benefit of measuring close to the noise sensitive receptors is of course that measurements should be representative of the noise level being received at those locations. The disadvantage is the lack of signal to noise ratio and the potential for relatively quiet events to distort the results. Conversely measuring very close to the turbines will usually reduce the level of masking from background noise but such measurements may not be representative of noise levels at the receptors and there is no agreed method to extrapolate measurements from a proxy location back out to a noise sensitive receptor further away. The effects of wind shear can also lead to refraction effects meaning that turbine noise may not attenuate uniformly as distance from the development increases and the impacts of topography can also influence propagation as noted in section 4.3 of the GPG.

The requirement to evaluate the character of the noise will also be an important consideration when choosing a measurement location. Most modern wind farm noise planning conditions include provision for a tonal penalty which, if required, is determined using data collected at the receptor as set out in ETSU-R-97. In addition, emerging guidance from the IOA and DECC is expected to provide a framework for the calculation of a penalty to account for amplitude modulation too. Whilst the propagation of noise with distance is relatively well understood the presence (or absence) of amplitude modulation or tonal noise at a proxy location cannot be easily used to determine the requirement for a penalty at another location further away.

The measurement location may also determine the need for a background noise correction and this can be an important consideration for turbine operators who may be keen to avoid unnecessary wind turbine shut downs associated. Bullmore *et al* showed that at some measurement locations close to the wind turbines measurements will be dominated by turbine noise as background noise (or noise measured upwind of the turbines) may be 10dB the levels measured during turbine operation (as shown by the measurements presented for Site B). In such circumstances it could cautiously be assumed that all noise measured during a compliance assessment is attributable to the wind farm. If extrapolation of that data set to the required assessment location shows that noise is less than the limit then a background noise correction may not be required.

Whilst there are many potential permutations of noise monitoring locations which could be considered, five are explored here as illustrated in Figures 1-5. Table 1 below summarises the advantages and disadvantages of each option.

Figure 1 – Option 1 - measurements at receptor (the traditional approach)

Figure 2 – Option 2 – measure very close to the development

Figure 3 – Option 3 – measure at two locations near the development

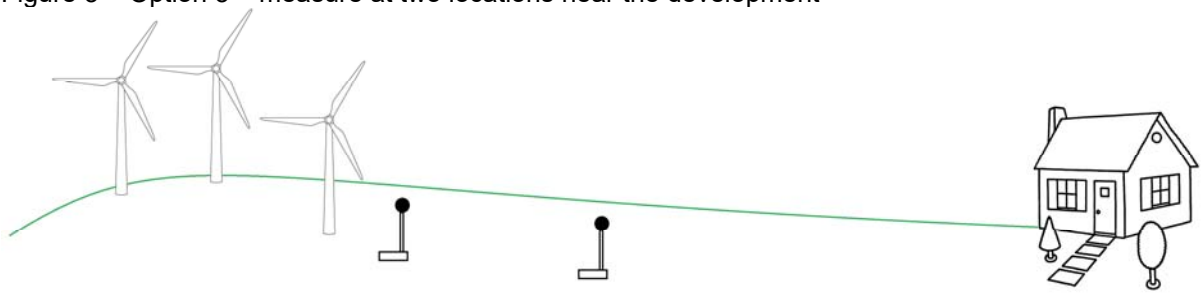

Figure 4 – Option 4 - measure near development and at receptor

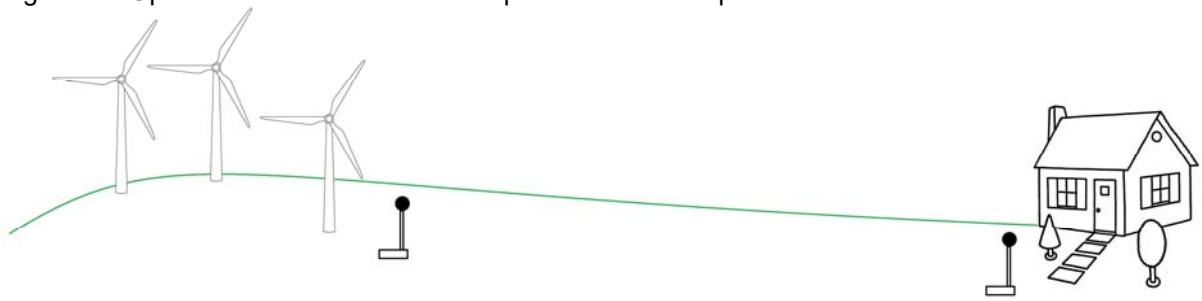

Figure 5 – Option 5 - measure in all three locations

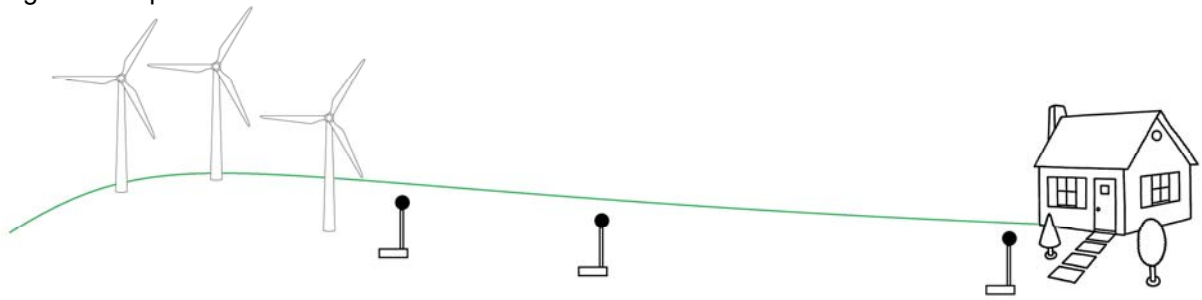

Table 1 – Advantages and disadvantages of the five measurement location options

Advantages	Measurement Option 1	2	3	4	5
Low cost	X	X			
Representative of levels at the property	X			X	X
Data can be used to consider character corrections	X			X	X
Likely to be good signal to noise ratio		X	X	X	X
May reduce requirement for wind turbine shut down and background noise corrections		X	X	X	X
Can potentially validate attenuation with distance			X	X	X
Could compare data to see if noise levels at receptor reflects variations close to the source				X	X
Long term surveys can be made without disturbing residents		X	X		
Disadvantages	**Measurement Option 1**	**2**	**3**	**4**	**5**
Signal to noise ratio can be poor which could lead to inaccurate results	X				
Propagation effects not fully understood which could lead to inaccurate results		X	X		
Character corrections not possible		X	X		
Increased costs due to increased equipment and analysis time			X	X	X
Uncertainties associated with extrapolation could lead to inaccurate results		X	X		

2.2 How can data collected at a proxy location be extrapolated

Many modern wind farms are being designed such that expected noise levels are very close to the noise limit, particularly when limits have been apportioned between schemes. In some cases compliance or exceedance of the noise limits will be achieved by a margin of a decibel or less, and so any method chosen to extrapolate measurements will need to be accurate. A number of potential methods are outlined below.

Use data collected close to the development to estimate a sound power level for the wind turbines then use that data to predict levels at the location of interest. Such a calculation could be undertaken using the method described in IEC-61400-11[6]. There are a number of challenges with this approach, particularly with the first stage as consideration may need to be given to the relative contribution of a number of turbines in a wind farm. Predictions will also need to assume a frequency spectrum and this can have a big influence on predicted levels. One advantage to this

approach is that predictions can be undertaken in accordance with established principles to take account of factors known to affect propagation such as topography.

A relatively simple extrapolation could be made using the inverse square law and where measurements have been undertaken in accordance with measurement location Option 3 the second measurement location can be used to validate this approach. Care will need to be taken that attenuation with distance is not underestimated when taking this approach as measurements at the second location may include a greater contribution from background noise which might make it look like turbine noise is not attenuating as quickly as would be expected.

It may also be possible to undertake a period of calibration with data collected at a proxy location and at the receptor location simultaneously to inform the relationship between the two locations with longer term measurements only taking place at the proxy location.

3 DISCUSSION

Where the signal to noise ratio at the receptor is strong then good practice, most modern planning conditions and common sense suggests that measurements at that location are preferable. Where a combination of low noise limits and high background noise make determination of the specific noise difficult then the use of proxy locations may be advantageous.

In the absence of guidance explaining how proxy measurement data should be collected and analysed it seems likely that practioners may well take very different approaches and may therefore get different answers even if supplied with the same raw datasets. Whilst it would be preferable to agree a method which could be universally adopted site specific considerations (such as whether a character correction is required or the dominance of other local noise sources) is likely to mean each site, and perhaps each individual location will need to be considered individually.

If it is assumed that, in the short term, a set of good practice principles are unlikely to be agreed the question then perhaps becomes, ‘Are the uncertainties associated with the use of proxy measurements more or less than the uncertainties involved with using datasets with a poor signal to noise ratio?’, or perhaps ‘Can proxy measurements be used to reduce the uncertainty associated with assessments as opposed to sole reliance on measurement with a poor signal to noise ratio?’

Consideration of Table 1 above perhaps unsurprisingly suggests that collecting data at several locations simultaneously may be the most flexible and robust approach. The additional cost of adopting such an approach may however be prohibitive whilst such an approach may also be disproportionate and unnecessary.

4 FURTHER WORK

As more data is collected using proxy locations further analysis may inform agreement on the preferred monitoring locations and even development of a standard approach to extrapolation. The authors of this paper are currently collecting data at two wind farm developments using measurement location Option 5 as outlined above and these data will be used to compare and contrast the results obtained using the various method outlined above.

If a strong correlation between measurements at proxy locations and measured levels at receptors can be shown it may be possible to use proxy data to fine tune the operation of a wind farm to ensure compliance is constantly evaluated and it potentially be used to constantly monitor wind farm noise characteristics like tonal emissions or amplitude modulation.

Modern noise monitoring solutions which are being developed and used for wind farm noise monitoring are capable of collecting large, high resolution datasets which can be sent over the mobile phone network for almost instant analysis which could in turn be used to provide an early indication of potential noise problems. Collection of such data at proxy locations can help identify

the source of a characteristic (if for example there are two- or more) wind farms in an area and it is not apparent which one(s) are the source of a particular characteristic.

5 REFERENCES

[1] *'A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise'*, Institute of Acoustics, 2013.
[2] *'Supplementary Guidance Note 5: Post Completion Measurements'* Institute of Acoustics, 2014.
[3] *'Measuring Compliance with the ETSU-R-97 simplified limit'* Merlin Garnett, Cameron Sutherland, Acoustics 2015, Harrogate, 2015.
[4] *'Wind Farm Noise Predictions and Comparison with Measurements'* Andrew Bullmore, Justin Adcock, Mark Jiggins, Matthew Cand, Third International Meeting on Wind Turbine Noise, Aalborg Denmark, 2009.
[5] *'Accounting for background noise when measuring operational sound levels from wind turbine projects'* David Hessler, Fourth International Meeting on Wind Turbine Noise, Rome, Italy 2011.
[6] IEC61400-11:2012 *'Wind turbine generator systems — Part 11: Acoustic noise measurement techniques'*