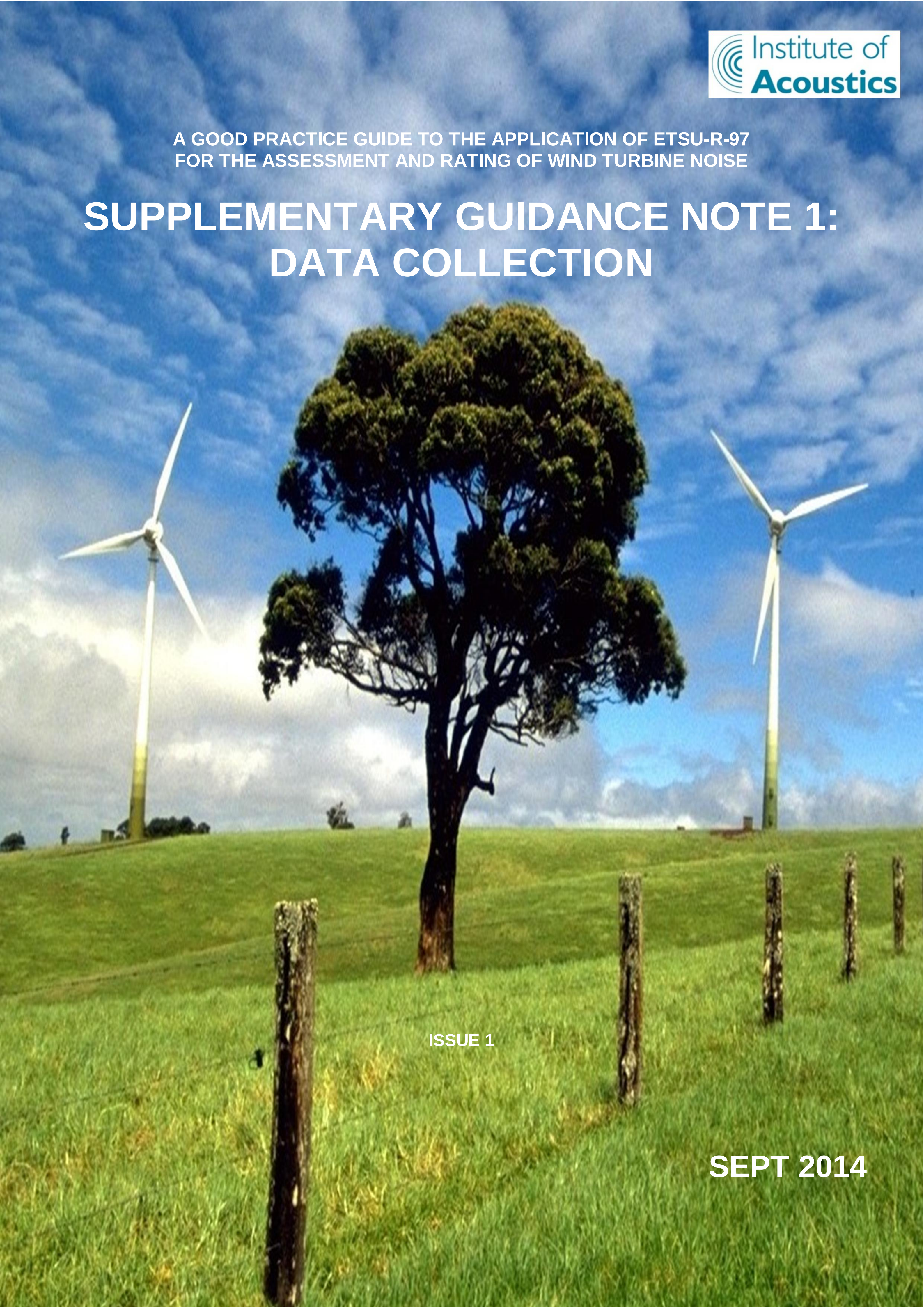
Institute of Acoustics

A GOOD PRACTICE GUIDE TO THE APPLICATION OF ETSU-R-97
FOR THE ASSESSMENT AND RATING OF WIND TURBINE NOISE

SUPPLEMENTARY GUIDANCE NOTE 1: DATA COLLECTION



ISSUE 1

SEPT 2014

PREFACE

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

Matthew Cand	Hoare Lea Acoustics
Robert Davis	RD Associates
Chris Jordan	Northern Group Systems (Environmental Health)
Malcolm Hayes	Hayes McKenzie Partnership Ltd.
Richard Perkins	Parsons Brinckerhoff Ltd.

The working group gratefully acknowledges the assistance provided by Dani Fiumicelli from Temple Group in the drafting of this note.

This supplementary guidance note has been produced to supplement the IOA document 'A GOOD PRACTICE GUIDE TO THE APPLICATION OF ETSU-R-97 FOR THE ASSESSMENT AND RATING OF WIND TURBINE NOISE' which is available on the IOA website at the following link: http://www.ioa.org.uk/publications/good-practice-guide (checked 06.09.14).

Prior to publication of this note, a peer review was undertaken by a separate group.

Any comments on this document should be sent to ETSUCONSULT@IOA.ORG.UK. The IOA will keep the document under review, and consider updating when significant changes to current good practice have occurred.

Richard Perkins
Working Group Chairman & Editor.

Institute of Acoustics

3rd Floor St Peter's House
45-49 Victoria Street
St. Albans
Hertfordshire
AL1 3WZ
United Kingdom
www.ioa.org.uk

Supplementary Guidance Notes

Number	Title	Information
1	**Data Collection**	Equipment specifications; measurement surveys: Practical considerations and set-up guidance and examples.
2	**Data Processing & Derivation of ETSU-R-97 background curves**	Data filtering, processing and regression analysis for different types of noise environments.
3	**Sound Power Level Data**	Manufacturer's data and warranties analysis.
4	**Wind Shear**	Wind speed references and long-term data analysis.
5	**Post Completion measurements**	Examples, considerations and strategies.
6	**Noise Propagation over water for on-shore wind turbines**	Noise propagation for on – shore turbines, or those close to the shore over large bodies of water.

CONTENTS

1 Context

1.1 Background

1.1.1 The Institute of Acoustics (IOA) published 'A GOOD PRACTICE GUIDE TO THE APPLICATION OF ETSU-R-97 FOR THE ASSESSMENT AND RATING OF WIND TURBINE NOISE' (GPG) in May 2013 to provide technical assistance for the undertaking of wind turbine noise assessments using the ETSU-R-97 document. In order to keep the GPG to a reasonable length, but not to lose clarifications and case studies, it was decided to produce a number of supplementary guidance notes which would support the GPG.

1.1.2 This guidance note will be of relevance to:

i. Acoustics consultants;
ii. Local Planning Authority (LPA) Environmental Health and Planning departments;
iii. Developers;
iv. The Planning Inspectorate or equivalent regulating authority;
v. The general public.

1.2 Scope of the Document

1.2.1 A series of six Supplementary Guidance Notes have been produced. This Supplementary Guidance Note 1 supports Section 2 of the GPG. It provides additional information on the selection and use of noise and wind measuring instrumentation for the purpose of establishing background noise levels in accordance with the ETSU-R-97 procedure. Some of the content is also applicable to post-completion measurements of wind farm noise, which is the subject of Supplementary Guidance Note 5.

1.3 Statutory Context

1.3.1 This Supplementary Guidance Note has been approved by the IOA Council for use by IOA Members and others involved in the assessment and rating of wind turbine noise using ETSU-R-97. It covers technical matters of an acoustic nature which the IOA-NWG believes represent current good practice.

2 Background Data Collection

2.1 Specification of noise measuring equipment and periodic testing of accuracy (GPG 2.4.1)

2.1.1 Noise measurement equipment and field calibrators used in connection with ETSU-R-97 noise assessments should comply with the specifications for Class 1/Type 1 instruments set out in one or more of the following Standards.

2.1.2 Measurement systems (excluding microphone windscreens) should preferably comply with current Standards IEC 61672-1 and IEC 61672-2, although systems complying with older measurement standards BS EN 60651 and BS EN 60804 may be used**.** Field calibrators should preferably comply with BS EN 60942:2003. Calibrators complying with the previous version of IEC 60942 may be used: strictly, such calibrators may not comply with the 2003 version of the Standard in some environmental conditions. However, for practical purposes such distinctions can be ignored for this application.

2.1.3 In all cases, equipment used for noise surveys should be fully described in all relevant reports and this description should include a statement on the Standard(s) the equipment complies with.

2.2 Equipment Calibration pre- and post-survey (GPG paras. 2.4.2 – 2.4.3)

2.2.1 Measurement systems should be check-calibrated on-site, using a field calibrator, immediately before the start and after the end of any measurement sequence. Any calibration drift should be reported.

2.2.2 It is not universal practice to 'match' sound measurement equipment with calibrators, such that the same calibrator is used exclusively with each system. However, the type of calibrator used to check-calibrate a measurement system should be either:

- a type specified by the system manufacturer for use with the specific microphone

or, if not:

- Users should satisfy themselves (e.g. by cross-checks with a 'matched' calibrator) that the specific model of calibrator can be reliably used with the measurement system (if necessary, with appropriate corrections to the reference level stated for the calibrator).

2.2.3 Some equipment is designed with internal calibration facilities. These provide a check on the electrical response of the system but not on the 'acoustical' sensitivity of the microphone. Internal calibration systems should only be used to record sensitivity changes (which may indicate a system defect), not to apply any calibration correction; they are no substitute for regular check-calibration using a calibrator on the microphone.

2.3 Periodic verification of equipment

2.3.1 Guidance on periodic testing of sound measurement systems and field calibrators is given in the UKAS document LAB 23 – '*Traceability for Equipment Used in Acoustical Testing*[i]*.* The general principle is that equipment should be calibrated, and certified to comply with the manufacturer's specification and the above Standards, at regular intervals. The calibration needs to be traceable to national standards. Calibration is generally carried out by a calibration laboratory who will issue the appropriate certificate. Certification of equipment by a laboratory which is UKAS-accredited for the relevant testing and certification is preferred, but certification by a non-UKAS test laboratory (including those appointed by equipment manufacturers) is acceptable. Users should satisfy themselves that verification procedures are sufficiently robust that the risk of data being questioned on the grounds of measurement precision are minimised.

2.3.2 The performance of measurement systems (such as sound level meters) should be verified and certificated at an interval not exceeding 2 years (1 year for calibrators). Intermediate verification should be carried out if field-calibration shows excessive calibration drift (GPG 2.4.3), or if equipment may have been subject to impact or other damage (such as might occur if a tripod is blown over in high winds), or if examination of a measurement time history reveals wide variations in measured levels that could only reasonably be explained by changes in the system sensitivity during the course of the survey (even if the 'final' check-calibration is within limits).

2.4 Microphone windscreens (GPG para. 2.4.1)

2.4.1 Noise measurements required for wind turbine noise assessments (both background noise surveys and compliance surveys) often require reliable measurements to be made in local wind speeds in excess of 4 - 5 m/s. It should be appreciated that the wind speed reference for noise measurements is a standardised or actual wind speed at 10 metres on the wind turbine site: the local wind speed at a survey location at 1.5 metres above ground level will be lower (and usually significantly lower) than the 10 metre (measured or standardised) 'on-site' wind speed, particularly if the measurement location is well-sheltered.

2.4.2 Pressure-fluctuations associated with air flow over the microphone will create wind-induced 'noise', and the measurement system will record levels that are higher than the true 'acoustical' noise levels. This can lead to unreliable results in low-noise environments at higher wind speeds, where measured noise levels can be higher than the 'true' levels. In extreme cases, an equipment overload may occur. Because the effects are specific to the site and to the wind-speed 'profiles' (i.e. the variations in instantaneous wind speed with time) during each 10 minute measurement period, it is not possible to make any generalised statement about the influence of microphone 'wind noise' on the reliability of baseline measurements. The effects can be minimised using an appropriate porous windscreen to contain the microphone. This also has the function of reducing the risk of water droplets reaching the microphone during or after rain or snow.

2.4.3 Most sound level measuring equipment manufacturers produce different types of wind and weather protection systems (windscreens) for their equipment. Not all systems are adequate to control wind-induced noise at wind speeds above 4-5 m/s in low noise environments. The GPG recommends that enhanced microphone windscreens should be used, because 'Standard' windshields of a diameter of less than 100 mm cannot be relied upon to provide sufficient reduction of wind noise in most circumstances.

2.4.4 The design of microphone windscreens has been the subject of considerable research. The ETSU report W/13/00386/REP (1996), referenced in the GPG, tested a number of windscreen configurations of different dimensions and porosity and concluded that the most practicable approach was to use a large secondary wind screen (of specified porosity) outside a typical manufacturer's standard spherical 90 - 100 mm diameter screen.

2.4.5 Other researchers[ii] have produced work that demonstrates the effects of various design parameters on windscreen effectiveness.

2.4.6 Instrumentation manufacturers provide information on microphone wind-induced noise, in the form of plots showing A-weighted levels and associated frequency spectra for a range of wind speeds, for bare microphones and for microphones fitted with the manufacturer's windscreens. These results are usually obtained from measurements in wind tunnels or using a rotating-boom rig. Such data can be used to 'rank-order' the effectiveness of windscreens; although the results are dependent on the test procedure. Comparisons between test results and may be unreliable unless the same procedures were followed. It has been suggested that such data could be used to correct on-site measurements made in wind by subtracting the wind induced 'component' from the overall measured level at any wind speed. However, there is no practicable means of devising and applying such corrections, for the following reasons:

- Wind-induced noise levels are dependent on the characteristics of turbulence in the air flow as well as the local mean velocity. Manufacturer's data on wind-induced noise and the effectiveness of microphone windscreens is derived from tests carried out in a nominally uniform, steady airflow, with the degree of turbulence of known intensity and scale that is specific to the test environment. On an outdoor site, the microphone/windscreen combination will be subject to variable wind speeds in any 10 minute interval (as adopted for background noise measurements) and inflow turbulence that may be very different from manufacturer's test conditions.
- Background noise measurements (and post-completion measurements) for wind turbine assessments are measured as L_{A90} (the 10^{th} percentile) levels, using the rms 'fast' weighting, over 10-minute intervals. During any 10 minute period the wind speed at the microphone will vary, possibly over a wide range in gusty conditions. Consequently, the extent to which the measured L_{A90} level is affected by wind-induced noise will depend on the distribution of wind speed during any 10 minute interval. This variability means there can be no fixed relationship between a 10 minute average wind speed (even if measured at the same location) and an L_{A90} noise level measured over the same period.

2.4.7 The recommendation is therefore to minimise wind-induced noise using an enhanced windscreen of a design known to provide significant reductions in wind-induced noise compared with a 'standard' (typically 90–100 mm diameter spherical) windscreen. Until more specific design advice becomes available, the recommendations in the ETSU Report W/13/00386/REP (1996) should be followed where possible.

2.4.8 Some 'oversized' or double-layer proprietary windscreens are suitable. Some practitioners design and build their own windscreens to the 1996 ETSU report specification. The NWG recognises that further work is required to assist users to select windscreens for this application, particularly since there is no widely-available proprietary windscreen suitable for long term use in the field which complies fully with the build specification in the 1996 ETSU Report (although some proprietary windscreens are accepted as having equivalent performance). The absence of a standard test procedure for measuring windscreen performance (in terms of reduction of wind-generated noise compared with an exposed microphone) presents an additional problem. The NWG intends to promote further research to resolve issues associated with windscreen selection and welcomes suggestions on how such research might be conducted. In the meantime, the recommended approach is:

- The use of 'standard' windscreens with a diameter of (typically) less than 100mm should be avoided because there is a serious risk that measurements using this type of windscreen will be corrupted by wind-induced noise at the microphone. Measurements using standard windscreens can only be considered reliable where the measurement location is sheltered and there is evidence that local wind speeds at microphone height did not exceed 5 m/s during the survey period.
- The windscreen should be of a type that can be demonstrated to provide a significantly greater reduction in wind-generated noise than a standard windscreen. The caution concerning the use of <100 mm windscreens does not imply that a single – layer foam windscreen of (say) 110 mm diameter is acceptable. An assessment report should state the type of windscreen used. If non-proprietary, the construction of the windscreen in terms of compliance with the 1996 ETSU Report should be described.

2.4.9 Evidence should be available to demonstrate that the acoustic insertion loss of any windscreen does not exceed the value stated in GPG 2.4.1. This evidence may be manufacturer's data for proprietary windscreens or results of tests carried out on purpose-made wind screens. This evidence need not be provided routinely but should be available in the event that the insertion loss of the windscreen is questioned. The use of a windscreen with excessive acoustic insertion loss will lead to measured noise levels being lower than 'true' noise levels which results in a conservative outcome for background noise surveys, but for compliance measurements could result in wind farm noise levels being incorrectly assessed as being compliant with noise limits.

2.5 Siting Noise Measuring Equipment (GPG Section 2.5)

2.5.1 The selection of suitable noise monitoring locations for background noise surveys is not straightforward and only general guidance can be given as it is not possible to be prescriptive. The general principles are summarised in the GPG at box SB8. Often there are practical constraints on where equipment can be placed, and a considerable degree of experience-based judgement is required when selecting these positions. Therefore the selection of monitoring locations should only be undertaken by a person suitably experienced in carrying out outdoor noise measurements and making the necessary informed decisions. The Local Authority EHO should be invited to comment on measurement locations (GPG 1.5) and to be present when equipment is installed although it is recognised that some local authorities may not wish to be involved in this aspect of the noise assessment.

Distances from reflective surfaces

2.5.2 The specification of a minimum distance from a dwelling (or any other acoustically reflective surface other than the ground) is to ensure standardised measurements approximating to free-field conditions, where the potential effects of acoustic reflections from surfaces such as building façades, walls, fences and other surfaces are minimised. In gardens it is sometimes difficult to identify a measurement location that is substantially flat and unobstructed more than 3.5 metres from an acoustically reflective surface other than the ground (because of low retaining walls, raised rockeries, cold frames etc.) and judgment often has to be applied in deciding whether relatively small reflective surfaces would influence the measurements and to select the ‘best’ location when all the constraints are taken into consideration.

2.5.3 In some cases, where a regularly used amenity area is within a semi-enclosed area such as a courtyard, it may be appropriate to waive the ‘3.5 metre’ guideline and measure in that area, especially if the area is screened from background noise sources such that the noise levels are lower than at other ‘free field’ locations. In such cases, the reason for selecting that location should be explained. Measurements in such locations are obviously specific to that dwelling and should not be used as proxies for others.

Local noise sources

2.5.4 Background noise levels measured at each survey position can only strictly apply to that specific position: however, a position may serve as a proxy for other positions in the immediate vicinity e.g. at other positions around the dwelling, when the position is in a garden, and also, in many cases, for other dwellings in the local area. The choice of survey positions is often an area of dispute between those proposing a wind turbine development and those opposing it: with claims made that background noise levels at the selected locations are higher than at other positions for which the actual measurement position is a proxy, which leads to higher noise limits and therefore disadvantages local residents. In some cases such claims have been valid: with measurements at other ‘representative’ positions have been shown to be consistently lower, by significant margins, than levels at the selected positions. Therefore it is important to carefully select ‘representative’ survey locations and equally important to be able to justify the selection decision.

2.5.5 In the absence of any significant noise source such as a main road, the main factors causing place-to-place variations in background noise levels in rural areas will be the presence and proximity of local noise sources: trees, shrubs and other vegetation disturbed by wind, water courses, ‘domestic’ sources such as boiler flues and water features, and equipment and activities on farms or industrial premises. Generally, equipment should not be sited where noise levels are influenced by local noise sources specific to the measurement location. Noise created by wind in trees and vegetation is likely to be a common element in most rural and semi-rural environments, the level of noise being dependent on the proximity and type of vegetation. Although equipment should generally not be located close to hedges, shrubs or noise-generating vegetation, except in those situations where such locations might be ‘typical’ of the amenity area around the dwelling and around other dwellings for which the measurement location is a proxy. Wind-generated noise from low-level vegetation, particularly in sheltered gardens, is generally less likely to affect measurement than noise from trees. Where measurement positions are necessarily placed outside the curtilage of a dwelling (perhaps because access to the premises cannot be obtained) particular care should be taken to select a position that can reasonably be judged as being representative of the dwelling and other dwellings, perhaps on the basis that the positions are similar in terms of the nature and density of and distances from local trees and vegetation and experience the noise of the same sound sources with similar separation distances and screening.

2.5.6 Noise from water courses is a particular issue, especially in hilly districts where higher noise levels due to increased flows may occur for long periods after rainfall (which may not itself significantly affect the measurement). Where continuous noise from a watercourse is a feature of that location then it is not necessary to minimise its influence, although such a location would not serve as a proxy for other dwellings that are less-affected. Where noise from a watercourse is likely to be variable (seasonal variation is common) then steps should be taken to minimize its influence and to measure typical 'low flow' background noise levels. Selection of measurement location, using a position screened from the source, may assist. Data corresponding with high water flows can often be identified from time histories and the dataset edited accordingly (GPG para. 3.1.13) as the background, ambient and maximum noise levels often tend to converge where the sound of running water dominates.

2.5.7 Measurements sometimes have to be made in gardens where there are water features such as fountains, cascades or ornamental ponds, and associated noise sources such as water and air pumps. Whilst such sources might be considered to be a feature of that location, they are unlikely to be a feature of other locations for which this measurement could be a proxy, and they are unlikely to be permanent. If an alternative location cannot be identified, it may be possible to arrange for the equipment to be stopped during amenity and night time hours or at least for parts of these periods: affected data can then be identified (by the raised noise levels) and discarded.

2.5.8 Positions affected by noise from boiler flues should be avoided where possible, since the pattern of boiler operation is seasonal and depends on the lifestyle of the occupier, the source may not be permanent (boilers are changed) and such a position is unlikely to provide a 'proxy' for other dwellings if this is intended. Where the influence of noise from a boiler flue cannot be effectively eliminated by selection of measurement position, it is generally possible to identify affected data and to discard it from the dataset (GPG 3.1.5). In all cases, it is good practice when presenting background survey results to describe the environment local to each survey position and to explain why it is considered to be representative of other positions for which it serves as a proxy.

2.5.9 Illustrations of measurement positions are shown in the following photographs, with comments on some of the factors that should be considered in selecting the most appropriate positions. In all cases it should be assumed (unless stated) that the photographs are taken from the direction of the proposed wind farm site. These are examples only – each location is unique and all relevant factors need to be assessed. The overriding test for the suitability of a measurement position, as set out in the GPG (2.2.5) is that "*it can reasonably be claimed, from inspection and observation, that there are no other locations, in the vicinity of any selected location and close to a dwelling, where background noise levels would be expected to be consistently lower than the levels at the selected location*".

Figure 1 **Figure 2**

Equipment in fields outside immediate dwelling curtilages (sometimes necessary e.g. because access is not available).

Factors to consider (Figures 1 &2):

2.5.10 Trees and vegetation around the measurement position should be similar (in terms of potential for generating noise in wind, taking into account distance, density and type) to those in the vicinity of amenity areas around the dwelling itself, or any other dwellings for which this position is a proxy.

2.5.11 The position is not more (or less) screened from a local noise source, including trees, a main road, or watercourse, than the dwelling amenity area(s) and is not significantly closer to (or more distant from) such local noise sources than the dwelling. A simple calculation can generally confirm whether or not a difference in distance might be 'significant'.

Figure 3 **Figure 4**

Location with partly-enclosed patios located to side of house facing wind farm site.

Factors to consider (Figures 3 & 4):

2.5.12 Identify existing local noise sources (in Figure 3, trees to the rear of the house). The patio may be better-screened from these than an 'open' position and background noise levels may be lower despite the effect of local reflections (2.5.3 above). If semi-enclosed measurement positions are adopted then the justification for selecting them should be explained.

Figure 5 **Figure 6**

***Typical installations in small semi-rural gardens*.**

Factors to consider (Figures 5 & 6):

2.5.13 Since each of these locations would serve as a proxy for other dwellings in the vicinity, the position of equipment relative to noise-generating vegetation should be assessed. Is this reasonably representative of other locations for which this measurement is a proxy? Locations of amenity areas at other dwellings, and the types and numbers of trees etc. in other gardens, can often be assessed from website aerial photographs if the gardens cannot be viewed directly.

2.5.14 Clothing on washing lines, lawn-mowing and other domestic activities (children at play etc.) can create extraneous noise, although these would not generally take place at night. Residents might be asked to record any periods of relatively continuous noise (lawn-mowing, hedge trimming etc.) since these might be expected to result in elevated $L_{A90,10m}$ levels. However, these events and sources can usually be detected from examination of time histories of both L_{Aeq} and L_{A90} levels.

Figure 7

Proxy position outside gardens to reduce influence of noise from trees.

Factors to consider (Figure 7):

2.5.15 Trees (because of their height) will generally generate more noise in wind than low–growing vegetation, especially in situations where the latter is sheltered. In this example, access could be gained to the garden of the right-hand house, but this would not be a representative position to serve as a proxy for other houses in the vicinity because of the presence of the trees. The chosen location is relatively distant from these trees and the lower vegetation surrounding it will be less of a source of noise in windy conditions.

2.5.16 Judgement is needed to assess the significance of these 'natural' noise sources, taking their proximity into account, when selecting the most appropriate measurement position. The nature of the vegetation is also a factor - for example, measurements in fields of growing crops should generally be avoided.

Figure 8
Unsuitable position for equipment

Figure 9
Inadequate windscreen

Factors to consider (Figures 8 & 9):

2.5.17 Figure 8 shows that microphone is positioned within 2 metres of a wall and within a flower border. Both factors are likely to result in background noise levels being elevated above 'typical' levels on the adjacent lawn, the main amenity area. In this case it is believed that the homeowner objected to equipment being placed in a more appropriate position on the lawn: it is important that the need to obtain reliable data is fully explained to residents and that this may mean installing equipment in a position they might find inconvenient. Small–diameter windscreens should not be used in a location which is clearly unsheltered.

2.5.18 Figure 9 shows a small–diameter windscreen used in a location which is clearly unsheltered.

Information to be provided - photographs

2.5.19 Reports on noise assessments which rely on background noise measurements should include photographs on the measurement positions (GPG 6.1). These photographs should illustrate the position relative to the dwelling(s) and the locations of local trees and other vegetation. This generally requires photographs from at least 2 viewpoints.

2.6 Use of SODAR and LIDAR equipment (GPG para. 2.8.12)

2.6.1 The GPG recognises that recently there has been increasing use of ground–based equipment (SoDAR and LiDAR) for wind speed measurements at proposed wind turbine sites, as an alternative to conventional anemometers mounted on a tall mast.

- SoDAR stands for - **So**nic **D**etection and **R**anging)
- LiDAR stands for **LI**ght **D**etection and **R**anging).

2.6.2 The use of such remote-sensing devices for wind speed measurement is a developing field. Users and potential users should be aware of current guidelines such as those published by the International Energy Agency (IEA). Detailed advice on the application of these devices is outside the scope of this document and only the following general comments and recommendations are made.

2.6.3 The limitations of both SoDAR and LiDAR should be appreciated. For example, some LiDAR systems cannot accurately resolve low-velocity wind speeds (2-4 m/s). The presence of local ground cover and complex terrain can significantly reduce the reliability of data generated by both SoDAR and LiDAR. LiDAR measurements are affected by the presence of water droplets in the air, although most devices incorporate sensors to identify periods when data may be so-affected.

2.6.4 It is therefore essential that the maintenance and installation of SoDAR and LiDAR devices is carried out by personnel trained in its use. The data generated required filtering to check its validity and to remove anomalous measurements: this process requires the appropriate experience. Where SoDAR or LiDAR measurements are used in connection with wind turbine noise assessments, the resulting report should include:

- A brief report of the installation procedure to demonstrate that the location and set-up is in accordance with the manufacturers' recommendations.
- A statement of how, and by whom, the data has been analysed and anomalous data removed.

[i] See http://www.ukas.com/library/Technical-Information/Pubs-Technical-Articles/Pubs-List/LAB23.pdf (Last Viewed 15th August 2013)

[ii] **a)** Strasberg, M. 1988, 'Dimensional analysis of windscreen noise', J. Acoust. Soc. Am. 83 (2), pp 544-548.
b) Van den Berg, G.P. 2006, 'Wind induced noise in a screened microphone', J. Acoust. Soc. Am. 119 (2), pp 824-833; and, G.P. van den Berg "The sound of high winds: the effect of atmospheric stability on wind turbine sound and microphone noise", PhD Thesis, RIJKSUNIVERSITEIT GRONINGEN, 2006.
c) Hessler G. F., Hessler D. M., Brandstätt P. and Bay K. 2008, 'Experimental study to determine wind-induced noise and windscreen attenuation effects on microphone response for environmental wind turbine and other applications', Noise Control Eng. J., 56 (4), pp. 300-309.
d) Leclercq D., Cooper J. and Stead M., 2008, 'The use of microphone windshields for outdoors noise measurements', Acoustics 2008, Geelong, Australia.
e) Jonathan Cooper, Damien Leclercq , and Matthew Stead, Wind induced aerodynamic noise on microphones from atmospheric measurements, Proceedings of 20th International Congress on Acoustics, ICA 2010 23-27, August 2010, Sydney, Australia.

Institute of
Acoustics