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Template Planning Condition on Amplitude Modulation

Noise Guidance Notes

December 2013

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Introduction

This document contains guidance notes for the assessment and control of wind turbine amplitude modulation noise.

It is intended that the document is read in conjunction with the 'Example Planning Condition' contained in Annex B of the Institute of Acoustics 'A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise', Issue 1, published in May 2013, subject to the following modifications:

- the first paragraph and specific items of the 'Example Planning Condition' are replaced as shown below
- 'Guidance Notes for Noise Conditions' is replaced as shown below
- Item (a) of 'Guidance Note 1' is replaced as shown below
- the new 'Guidance Note 4' (below) is intended to follow Guidance Notes 1 – 3 in the 'Good Practice Guide'
- the original 'Guidance Note 4' is renumbered as 'Guidance Note 5' and replaced as shown below
- the new 'Guidance Note 6' (below) is intended to follow Guidance Notes 5.

Changes to the original text are highlighted in **bold**.

A complete version of the 'Example Planning Conditions', including the changes indicated above, is attached at the end of this document. Changes from the original text are highlighted in **bold**, as before.

Example Planning Condition

The first paragraph shall be amended to read as follows:

*The rating level of noise immissions from the combined effects of the wind turbines (including the application of any **penalties for tonal and/or amplitude modulation components**), when determined in accordance with the attached Guidance Notes (to this condition), shall not exceed the values for relevant integer wind speeds set out in, or derived from, the tables attached to these conditions at any dwelling which is lawfully existing or has planning permission at the date of this permission and:*

Item c) shall be amended to read as follows:

*Within 21 days from receipt of a written request from the Local Planning Authority following a complaint to it from an occupant of a dwelling alleging noise disturbance at that dwelling, the wind farm operator shall, at its expense, employ a consultant approved by the Local Planning Authority to assess the level of noise immissions from the wind farm at the complainants property in accordance with the procedures described in the attached Guidance Notes. The written request from the Local Planning Authority shall set out at least the date, time and location that the complaint relates to and any identified atmospheric conditions, including wind direction, and include a statement as to whether, in the opinion of the Local Planning Authority, the noise giving rise to the complaint contains, or is likely to contain, a tonal component **or an amplitude modulation component which may attract a penalty under these conditions**.*

Item d) shall be amended to read as follows:

The assessment of the rating level of noise immissions shall be undertaken in accordance with an assessment protocol that shall previously have been submitted to and approved in writing by the Local Planning Authority. The protocol shall include the proposed measurement location identified in accordance with the Guidance Notes where measurements for compliance checking purposes shall be undertaken, whether noise giving rise to the complaint contains or is likely to contain a tonal component ***or an amplitude modulation component, which may attract a penalty under these conditions****, and also the range of meteorological and operational conditions (which shall include the range of wind speeds, wind directions, power generation and times of day) to determine the assessment of rating level of noise immissions. The proposed range of conditions shall be those which prevailed during times when the complainant alleges there was disturbance due to noise, having regard to the written request of the Local Planning Authority under paragraph (c), and such others as the independent consultant considers likely to result in a breach of the noise limits.*

Item g) shall be amended to read as follows:

Where a further assessment of the rating level of noise immissions from the wind farm is required pursuant to Guidance Note ***5(a)****, the wind farm operator shall submit a copy of the further assessment within 21 days of submission of the independent consultant's assessment pursuant to paragraph (d) above unless the time limit has been extended in writing by the Local Planning Authority.*

Guidance Notes for Noise Conditions

The text of this section shall be amended to read as follows:

These notes are to be read with and form part of the noise condition. They further explain the condition and specify the methods to be employed in the assessment of complaints about noise immissions from the wind farm. The rating level at each integer wind speed is the arithmetic sum of the wind farm noise level as determined from the best-fit curve described in Guidance Note 2 of these Guidance Notes and any tonal penalty applied in accordance with Guidance Note 3 ***and any amplitude modulation penalty applied in accordance with Guidance Note 4****. Reference to ETSU-R-97 refers to the publication entitled "The Assessment and Rating of Noise from Wind Farms" (1997) published by the Energy Technology Support Unit (ETSU) for the Department of Trade and Industry (DTI).*

Guidance Note 1

Item (a) shall be amended to read as follows:

Values of the $L_{A90,10\ minute}$ *noise statistic should be measured at the complainant's property, using a sound level meter of EN 60651/BS EN 60804 Type 1, or BS EN 61672 Class 1 quality (or the equivalent UK adopted standard in force at the time of the measurements) set to measure using the fast time weighted response as specified in BS EN 60651/BS EN 60804 or BS EN 61672-1 (or the equivalent UK adopted standard in force at the time of the measurements). This should be calibrated in accordance with the procedure specified in BS 4142: 1997 (or the equivalent UK adopted standard in force at the time of the measurements). Measurements shall be undertaken in such a manner to enable* ***any required*** *tonal penalty to be* ***derived*** *in accordance with Guidance Note 3* ***and to enable any required amplitude modulation penalty to be derived in accordance with Guidance Note 4 (with both tonal and amplitude modulation penalties to be applied in accordance with Guidance Note 5)****.*

Guidance Note 4 (New Section)

(a) Where, in accordance with the approved measurement protocol under paragraph (d) of the noise condition, noise immissions at the location or locations where compliance measurements are being

undertaken contain or are likely to contain an amplitude modulation component, the requirement for an amplitude modulation penalty is to be assessed and if necessary calculated using the following procedure.

(b) For each 10 minute interval for which $L_{A90,10minute}$ data have been determined as valid in accordance with Guidance Note 2, an amplitude modulation assessment shall be performed on noise immissions in consecutive, non-overlapping 10 sec periods within each 10 minute interval. Where a particular 10 sec period is corrupted, that period shall be discarded from further assessment.

(c) For each of the 10 sec samples within a particular 10 min interval, the level of amplitude modulation shall be determined using the following methodology, which is intended to determine the 'average' level of AM, at the blade passing frequency, within each sample:

(i). The 10 sec data shall be reduced to a time series of 100 values of $L_{Aeq,100msec}$.

(ii). The time series is to be de-trended using a 5^{th} order polynomial.

(iii). A single-sided, power spectral density function, using a Rectangular window, shall be calculated from the de-trended $L_{Aeq,100msec}$ data. A frequency resolution, Δf, of 5/128 Hz shall be used, and the spectrum shall comprise 128 lines, with a maximum frequency of 5 Hz.

(iv). For 10 sec periods where no amplitude modulation is observed, either in the time series of step (c)(i), or where there is no peak in the modulation spectrum, from step (c)(iii), then the objective measure of the level of amplitude modulation, for that 10 sec period, A_i, shall be set as zero.

(v). The energy in the band from $0.9f_c$ to $1.1\ f_c$ shall be calculated and denoted E_c, where f_c is the blade passing frequency in hertz.

(vi). The objective measure of the level of amplitude modulation, for each 10 sec period, i, is then derived as A_i, where:

$$A_i = 2 \cdot \sqrt{2 \cdot \Delta f \cdot E_c}$$

(d) The overall, objective measure of the level of amplitude modulation, A, for that 10 min interval shall be taken as the arithmetic mean of the 12 highest levels of amplitude modulation, A_i, from step (c)(vi), excluding any periods discarded as in (b) above. This is intended to determine an indicative level of AM, over each 10 min period, which is the average of the top 20 % of measured AM levels.

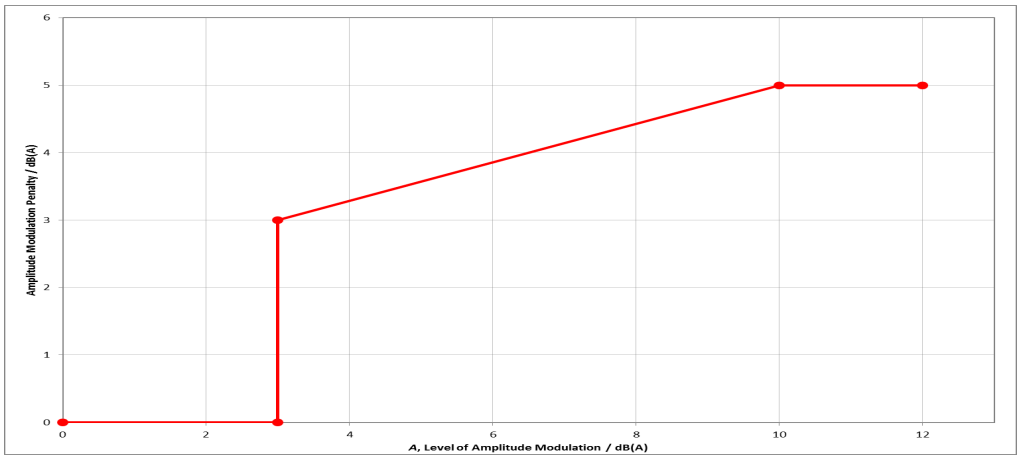
(e) If a value of A greater than 0 dB results from the above, the Independent Consultant shall investigate the SCADA data for that period and verify that the peak in the modulation spectrum, f_c, is consistent with the rotational frequencies of the turbines' rotors.

(f) Where there is doubt about the validity of a 10 min interval result, for example due to extraneous sources of noise, the Independent Consultant shall listen to the 10 minute of recorded noise data from which the amplitude modulation penalty was derived. If it is clear that the amplitude modulation is generated by such an extraneous source then the amplitude modulation penalty shall be discarded.

(g) The objective measure of the level of amplitude modulation shall be plotted against wind speed for each of the 10 minute periods. For periods in which no amplitude modulation is identified, a value of zero shall be used.

(h) A least squares "best fit" linear regression line shall then be performed to establish the average level of amplitude modulation for each integer wind speed derived from the value of the "best fit" line at each integer wind speed. If there is no apparent trend with wind speed then a simple arithmetic mean shall be used.

(i) The amplitude modulation penalty is derived from the average level of amplitude modulation for each integer wind speed according to the figure below.



Guidance Note 5 (originally Guidance Note 4)

Item (a) shall be amended to read as follows:

*If a tonal penalty **and/or an amplitude modulation penalty** is **required** in accordance with Guidance Note**s 3 & 4** the rating level of the turbine noise at each wind speed is the arithmetic sum of the measured noise level as determined from the best fit curve described in Guidance Note 2 and the **penalties for tonal and amplitude modulation noise as derived in accordance with Guidance Notes 3 & 4** at each integer wind speed within the range specified by the Local Planning Authority in its written protocol under paragraph (d) of the noise condition. **Where penalties are indicated for both tonal noise and amplitude modulation noise, then the total penalty to be added to the measured noise level shall be the arithmetic sum of the individual penalties.***

Item (b) shall be amended to read as follows:

*If no tonal **or amplitude modulation penalty** is to be applied then the rating level of the turbine noise at each wind speed is equal to the measured noise level as determined from the best fit curve described in Guidance Note 2.*

Item (d) shall be amended to read as follows:

The wind farm operator shall ensure that all the wind turbines in the development are turned off for such period as the independent consultant requires to undertake the further assessment provided in the previous paragraph. The further assessment shall be undertaken in accordance with the following steps:

Item (d)(ii) shall be amended to read as follows:

*The wind farm noise (L1) at this speed shall then be calculated as follows where L2 is the measured level with turbines running but without the addition of any tonal **or amplitude modulation penalties**:*

Item (d)(iii) shall be amended to read as follows:

*The rating level shall be re-calculated by adding arithmetically the tonal **and amplitude modulation penalties** (if any **are** applied in accordance with Note**s 3 & 4**) to the derived wind farm noise L1 at that integer wind speed.*

Item (h) shall be deleted.

Guidance Note 6 (New Section)

This section contains a glossary for Guidance Note 4, as follows:

Amplitude Modulation	means the modulation of the level of broadband noise emitted by a wind turbine at blade passing frequency, fc, as represented by the peak to trough level
Amplitude Modulation Penalty	the decibel penalty to be added to individual LA90,10min measurements as a result of amplitude modulation
Blade Passing Frequency	means the frequency, in hertz (Hz), at which the blades pass any fixed point, for example the tower
$L_{Aeq,n}$	means the equivalent continuous A-weighting sound pressure level over time period n
$L_{Aeq,100msec}$	means the equivalent continuous A-weighting sound pressure level over 100 milliseconds
De-trending	a function designed to remove an unwanted trend from a time series of data, resulting in a 'stationary' time series
Modulation Spectrum	a single-sided, power spectral density function: calculated using a Rectangular window; having a frequency resolution of 5/128 H; comprising 128 lines and having a maximum frequency of 5 Hz
Power Spectral Density	a function which describes how the variance (square of standard deviation) of a time series is distributed over the different frequencies
Rectangular Window	a windowing function used in the spectral analysis of time series data used to ensure an equal weighting to every value within the time window
Frequency Resolution	the size of the frequency bins used to define a frequency spectrum. The smaller the bins, the higher the resolution of the spectrum.

ANNEX B

Example Planning Condition

N.B. the following is an example condition, with attached guidance notes, the form of which has been the basis for the control of noise for several larger-scale UK wind farm developments, for example at recent planning appeals. More concise conditions may be acceptable, particularly for smaller-scale developments, and it is recommended that legal advice is sought.

The condition below assumes noise limits were referenced to standardised 10 metres height wind speed (derived from hub height). If considering noise limits referenced to measured 10 metres height, the condition should be modified appropriately: see in particular the Tables and Guidance Note 1 (d).

Example Planning Condition

*The rating level of noise immissions from the combined effects of the wind turbines (including the application of any **penalties for tonal and/or amplitude modulation components**), when determined in accordance with the attached Guidance Notes (to this condition), shall not exceed the values for the relevant integer wind speeds set out in, or derived from, the tables attached to these conditions at any dwelling which is lawfully existing or has planning permission at the date of this permission and:*

a) The wind farm operator shall continuously log power production, wind speed and wind direction, all in accordance with Guidance Note 1(d). These data shall be retained for a period of not less than 24 months. The wind farm operator shall provide this information in the format set out in Guidance Note 1(e) to the Local Planning Authority on its request, within 14 days of receipt in writing of such a request.

b) No electricity shall be exported until the wind farm operator has submitted to the Local Planning Authority for written approval a list of proposed independent consultants who may undertake compliance measurements in accordance with this condition. Amendments to the list of approved consultants shall be made only with the prior written approval of the Local Planning Authority.

*c) Within 21 days from receipt of a written request from the Local Planning Authority following a complaint to it from an occupant of a dwelling alleging noise disturbance at that dwelling, the wind farm operator shall, at its expense, employ a consultant approved by the Local Planning Authority to assess the level of noise immissions from the wind farm at the complainant's property in accordance with the procedures described in the attached Guidance Notes. The written request from the Local Planning Authority shall set out at least the date, time and location that the complaint relates to and any identified atmospheric conditions, including wind direction, and include a statement as to whether, in the opinion of the Local Planning Authority, the noise giving rise to the complaint contains or is likely to contain a tonal component **or an amplitude modulation component which may attract a penalty under these conditions**.*

*d) The assessment of the rating level of noise immissions shall be undertaken in accordance with an assessment protocol that shall previously have been submitted to and approved in writing by the Local Planning Authority. The protocol shall include the proposed measurement location identified in accordance with the Guidance Notes where measurements for compliance checking purposes shall be undertaken, whether noise giving rise to the complaint contains or is likely to contain a tonal component **or an amplitude modulation component, which may attract a penalty under these conditions**, and also the range of meteorological and operational conditions (which shall include the range of wind speeds, wind directions, power generation and times of day) to determine the assessment of rating level of noise immissions. The proposed range of conditions shall be those which prevailed during times when the complainant alleges there was disturbance due to noise, having regard to the written request of the Local Planning Authority under paragraph (c), and such others as the independent consultant considers likely to result in a breach of the noise limits.*

e) Where a dwelling to which a complaint is related is not listed in the tables attached to these conditions, the wind farm operator shall submit to the Local Planning Authority for written approval proposed noise limits selected from those listed in the Tables to be adopted at the complainant's dwelling for compliance checking purposes. The proposed noise limits are to be those limits selected from the Tables specified for a listed location which the independent consultant considers as being likely to experience the most similar background noise environment to that experienced at the complainant's dwelling. The rating level of noise immissions resulting from the combined effects of the wind turbines when determined in accordance with the attached Guidance Notes shall not exceed the noise limits approved in writing by the Local Planning Authority for the complainant's dwelling.

f) The wind farm operator shall provide to the Local Planning Authority the independent consultant's assessment of the rating level of noise immissions undertaken in accordance with the Guidance Notes within 2 months of the date of the written request of the Local Planning Authority for compliance measurements to be made under paragraph (c), unless the time limit is extended in writing by the Local Planning Authority. The assessment shall include all data collected for the purposes of undertaking the compliance measurements, such data to be provided in the format set out in Guidance Note 1(e) of the

Guidance Notes. The instrumentation used to undertake the measurements shall be calibrated in accordance with Guidance Note 1(a) and certificates of calibration shall be submitted to the Local Planning Authority with the independent consultant's assessment of the rating level of noise immissions.

g) *Where a further assessment of the rating level of noise immissions from the wind farm is required pursuant to Guidance Note **5(a)**, the wind farm operator shall submit a copy of the further assessment within 21 days of submission of the independent consultant's assessment pursuant to paragraph (d) above unless the time limit has been extended in writing by the Local Planning Authority.*

TABLE 1 – BETWEEN 07:00 AND 23:00 – NOISE LIMITS EXPRESSED IN DB LA90,10 MINUTE AS A FUNCTION OF THE STANDARDISED WIND SPEED (M/S) AT 10 METRE HEIGHT AS DETERMINED WITHIN THE SITE AVERAGED OVER 10 MINUTE PERIODS.

Location	*Standardised wind speed at 10 metre height (m/s) within the site averaged over 10-minute periods*											
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*

TABLE 2 – BETWEEN 23:00 AND 07:00 – NOISE LIMITS EXPRESSED IN DB LA90,10-MINUTE AS A FUNCTION OF THE STANDARDISED WIND SPEED (M/S) AT 10 METRE HEIGHT AS DETERMINED WITHIN THE SITE AVERAGED OVER 10 MINUTE PERIODS.

Location	*Standardised wind speed at 10 metre height (m/s) within the site averaged over 10-minute periods*											
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*

TABLE 3: COORDINATE LOCATIONS OF THE PROPERTIES LISTED IN TABLES 1 AND 2.

Property	*Easting*	*Northing*

Note to Table 3: The geographical coordinate references are provided for the purpose of identifying the general location of dwellings to which a given set of noise limits applies.

Guidance Notes for Noise Conditions

These notes are to be read with and form part of the noise condition. They further explain the condition and specify the methods to be employed in the assessment of complaints about noise immissions from the wind farm. The rating level at each integer wind speed is the arithmetic sum of the wind farm noise level as determined from the best-fit curve described in Guidance Note 2 of these Guidance Notes and any tonal penalty applied in accordance with Guidance Note 3 ***and any amplitude modulation penalty applied in accordance with Guidance Note 4****. Reference to ETSU-R-97 refers to the publication entitled "The Assessment and Rating of Noise from Wind Farms" (1997) published by the Energy Technology Support Unit (ETSU) for the Department of Trade and Industry (DTI).*

Guidance Note 1

(a) Values of the $L_{A90,10\ minute}$ noise statistic should be measured at the complainant's property, using a sound level meter of EN 60651/BS EN 60804 Type 1, or BS EN 61672 Class 1 quality (or the equivalent UK adopted standard in force at the time of the measurements) set to measure using the fast time weighted response as specified in BS EN 60651/BS EN 60804 or BS EN 61672-1 (or the equivalent UK adopted standard in force at the time of the measurements). This should be calibrated in accordance with the procedure specified in BS 4142: 1997 (or the equivalent UK adopted standard in force at the time of the measurements). Measurements shall be undertaken in such a manner to enable ***any required*** *tonal penalty to be* ***derived*** *in accordance with Guidance Note 3* ***and to enable any required amplitude modulation penalty to be derived in accordance with Guidance Note 4 (with both tonal and amplitude modulation penalties to be applied in accordance with Guidance Note 5).***

(b) The microphone should be mounted at 1.2 – 1.5 metres above ground level, fitted with a two-layer windshield or suitable equivalent approved in writing by the Local Planning Authority, and placed outside the complainant's dwelling. Measurements should be made in "free field" conditions. To achieve this, the microphone should be placed at least 3.5 metres away from the building facade or any reflecting surface except the ground at the approved measurement location. In the event that the consent of the complainant for access to his or her property to undertake compliance measurements is withheld, the wind farm operator shall submit for the written approval of the Local Planning Authority details of the proposed alternative representative measurement location prior to the commencement of measurements and the measurements shall be undertaken at the approved alternative representative measurement location.

(c) The $L_{A90,10\ minute}$ measurements should be synchronised with measurements of the 10-minute arithmetic mean wind and operational data logged in accordance with Guidance Note 1(d), including the power generation data from the turbine control systems of the wind farm.

(d) To enable compliance with the conditions to be evaluated, the wind farm operator shall continuously log arithmetic mean wind speed in metres per second and wind direction in degrees from north at hub height for each turbine and arithmetic mean power generated by each turbine, all in successive 10-minute periods. Unless an alternative procedure is previously agreed in writing with the Planning Authority, this hub height wind speed, averaged across all operating wind turbines, shall be used as the basis for the analysis. All 10 minute arithmetic average mean wind speed data measured at hub height shall be 'standardised' to a reference height of 10 metres as described in ETSU-R-97 at page 120 using a reference roughness length of 0.05 metres . It is this standardised 10 metre height wind speed data, which is correlated with the noise measurements determined as valid in accordance with Guidance Note 2, such correlation to be undertaken in the manner described in Guidance Note 2. All 10-minute periods shall commence on the hour and in 10- minute increments thereafter.

(e) Data provided to the Local Planning Authority in accordance with the noise condition shall be provided in comma separated values in electronic format.

(f) A data logging rain gauge shall be installed in the course of the assessment of the levels of noise immissions. The gauge shall record over successive 10-minute periods synchronised with the periods of data recorded in accordance with Note 1(d).

Guidance Note 2

(a) The noise measurements shall be made so as to provide not less than 20 valid data points as defined in Guidance Note 2 (b).

(b) Valid data points are those measured in the conditions specified in the agreed written protocol under paragraph (d) of the noise condition, but excluding any periods of rainfall measured in the vicinity of the sound level meter. Rainfall shall be assessed by use of a rain gauge that shall log the occurrence of rainfall in each 10 minute period concurrent with the measurement periods set out in Guidance Note 1. In specifying such conditions the Local Planning Authority shall have regard to those conditions which prevailed during times when the complainant alleges there was disturbance due to noise or which are considered likely to result in a breach of the limits.

(c) For those data points considered valid in accordance with Guidance Note 2(b), values of the $L_{A90,10\ minute}$ noise measurements and corresponding values of the 10- minute wind speed, as derived from the standardised ten metre height wind speed averaged across all operating wind turbines using the procedure specified in Guidance Note 1(d), shall be plotted on an XY chart with noise level on the Y-axis and the standardised mean wind speed on the X-axis. A least squares, "best fit" curve of an order deemed appropriate by the independent consultant (but which may not be higher than a fourth order) should be fitted to the data points and define the wind farm noise level at each integer speed.

Guidance Note 3

(a) Where, in accordance with the approved assessment protocol under paragraph (d) of the noise condition, noise immissions at the location or locations where compliance measurements are being undertaken contain or are likely to contain a tonal component, a tonal penalty is to be calculated and applied using the following rating procedure.

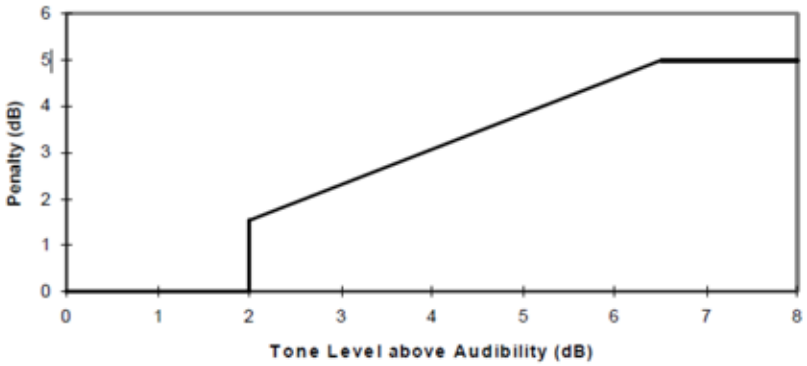
(b) For each 10 minute interval for which $L_{A90,10\ minute}$ data have been determined as valid in accordance with Guidance Note 2 a tonal assessment shall be performed on noise immissions during 2 minutes of each 10 minute period. The 2 minute periods should be spaced at 10 minute intervals provided that uninterrupted uncorrupted data are available ("the standard procedure"). Where uncorrupted data are not available, the first available uninterrupted clean 2 minute period out of the affected overall 10 minute period shall be selected. Any such deviations from the standard procedure, as described in Section 2.1 on pages 104-109 of ETSU-R-97, shall be reported.

(c) For each of the 2 minute samples the tone level above or below audibility shall be calculated by comparison with the audibility criterion given in Section 2.1 on pages 104-109 of ETSU-R-97.

(d) The tone level above audibility shall be plotted against wind speed for each of the 2 minute samples. Samples for which the tones were below the audibility criterion or no tone was identified, a value of zero audibility shall be used.

(e) A least squares "best fit" linear regression line shall then be performed to establish the average tone level above audibility for each integer wind speed derived from the value of the "best fit" line at each integer wind speed. If there is no apparent trend with wind speed then a simple arithmetic mean shall be used. This process shall be repeated for each integer wind speed for which there is an assessment of overall levels in Guidance Note 2.

(f) The tonal penalty is derived from the margin above audibility of the tone according to the figure below.



Guidance Note 4

(a) Where, in accordance with the approved measurement protocol under paragraph (d) of the noise condition, noise immissions at the location or locations where compliance measurements are being undertaken contain or are likely to contain an amplitude modulation component, the requirement for an amplitude modulation penalty is to be assessed and if necessary calculated using the following procedure.

(b) For each 10 minute interval for which $L_{A90,10minute}$ data have been determined as valid in accordance with Guidance Note 2, an amplitude modulation assessment shall be performed on noise immissions on consecutive, non-overlapping 10 sec periods within each 10 minute interval. Where a particular 10 sec period is corrupted, that period shall be discarded from further assessment.

(c) For each of the 10 sec samples within a particular 10 min interval, the level of amplitude modulation shall be determined using the following methodology, which is intended to determine the 'average' level of AM, at the blade passing frequency, within each sample:

(i) The 10 sec data shall be reduced to a time series of 100 values of $L_{Aeq,100msec}$.

(ii) The time series is to be de-trended using a 5^{th} order polynomial.

(iii) A single-sided, power spectral density function, using a Rectangular window, shall be calculated from the de-trended $L_{Aeq,100msec}$ data. A frequency resolution, Δf, of 5/128 Hz shall be used, and the spectrum shall comprise 128 lines, with a maximum frequency of 5 Hz.

(iv) For 10 sec periods where no amplitude modulation is observed, either in the time series of step (c)(i), or where there is no obvious peak in the modulation spectrum, from step (c)(iii), then the objective measure of the level of amplitude modulation, for that 10 sec period, A_i, shall be set as zero.

(v) The energy in the band from $0.9f_c$ to $1.1f_c$ shall be calculated and denoted E_c, where f_c is the blade passing frequency in hertz.

(vi) The objective measure of the level of amplitude modulation, for each 10 sec period, i, is then derived as A_i, where:

$$A_i = 2 \cdot \sqrt{2 \cdot \Delta f \cdot E_c}$$

(d) The overall, objective measure of the level of amplitude modulation, A, for that 10 min interval shall be taken as the arithmetic mean of the 12 highest levels of amplitude modulation, A_i, from step (c)(vi), excluding any periods discarded as in (b) above. This is intended to determine an indicative level of AM, over each 10 min period, which is the average of the top 20 % of measured AM levels.

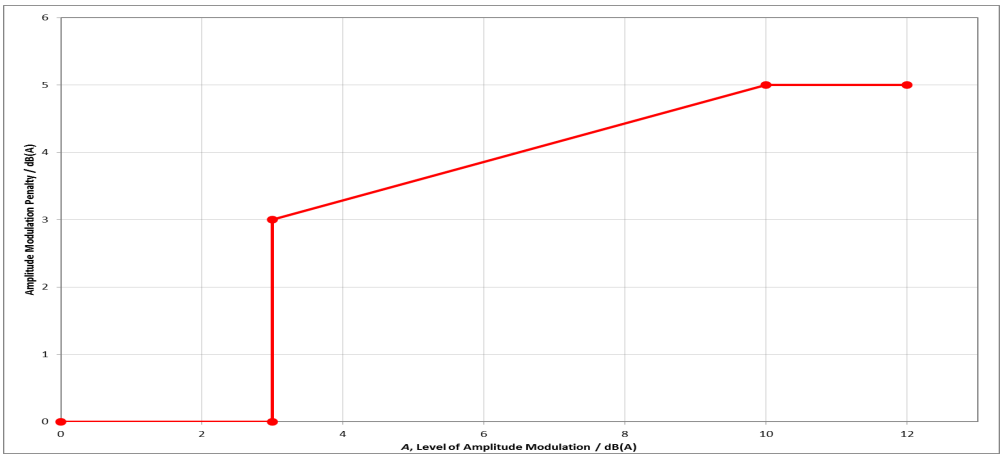
(e) If a value of A greater than 0 dB results from the above, the Independent Consultant shall investigate the SCADA data for that period and verify that the peak in the modulation spectrum, f_c, is consistent with the rotational frequencies of the turbines' rotors.

(f) Where there is doubt about the validity of a 10 min interval result, for example due to extraneous sources of noise, the Independent Consultant shall listen to the 10 minute of recorded noise data from which the amplitude modulation penalty was derived. If it is clear that the amplitude modulation is generated by such an extraneous source then the amplitude modulation penalty shall be discarded.

(g) The objective measure of the level of amplitude modulation shall be plotted against wind speed for each of the 10 minute periods. For periods in which no amplitude modulation is identified, a value of zero shall be used.

(h) A least squares "best fit" linear regression line shall then be performed to establish the average level of amplitude modulation for each integer wind speed derived from the value of the "best fit" line at each integer wind speed. If there is no apparent trend with wind speed then a simple arithmetic mean shall be used.

(i) The amplitude modulation penalty is derived from the average level of amplitude modulation for each integer wind speed according to the figure below.



Guidance Note 5

*(a) If a tonal penalty **and/or an amplitude modulation penalty** is **required** in accordance with Guidance Note**s** **3 & 4** the rating level of the turbine noise at each wind speed is the arithmetic sum of the measured noise level as determined from the best fit curve described in Guidance Note 2 and the **penalties for tonal and amplitude modulation noise as derived in accordance with Guidance Notes 3 & 4** at each integer wind speed within the range specified by the Local Planning Authority in its written protocol under paragraph (d) of the noise condition. **Where penalties are indicated for both tonal noise and amplitude modulation noise, then the total penalty to be added to the measured noise level shall be the arithmetic sum of the individual penalties.***

*(b) If no tonal penalty **or amplitude modulation penalty** is to be applied then the rating level of the turbine noise at each wind speed is equal to the measured noise level as determined from the best fit curve described in Guidance Note 2.*

(c) In the event that the rating level is above the limit(s) set out in the Tables attached to the noise conditions or the noise limits for a complainant's dwelling approved in accordance with paragraph (e) of the noise condition, the independent consultant shall undertake a further assessment of the rating level to correct for background noise so that the rating level relates to wind turbine noise immission only.

(d) The wind farm operator shall ensure that all the wind turbines in the development are turned off for such period as the independent consultant requires to undertake the further assessment provided in the previous paragraph. The further assessment shall be undertaken in accordance with the following steps:

(i). Repeating the steps in Guidance Note 2, with the wind farm switched off, and determining the background noise (L3) at each integer wind speed within the range requested by the Local Planning Authority in its written request under paragraph (c) and the approved protocol under paragraph (d) of the noise condition.

*(ii) The wind farm noise (L1) at this speed shall then be calculated as follows where L2 is the measured level with turbines running but without the addition of any tonal **or amplitude modulation penalties**:*

$$L_1 = 10 \log\left[10^{L_2/10} - 10^{L_3/10}\right]$$

(iii) The rating level shall be re-calculated by adding arithmetically the tonal and amplitude modulation penalties (if any are applied in accordance with Notes 3 & 4) to the derived wind farm noise L1 at that integer wind speed.

Guidance Note 6

This section contains a glossary for Guidance Note 4, as follows:

Amplitude Modulation	*means the modulation of the level of broadband noise emitted by a wind turbine at blade passing frequency, f_c, as represented by the peak to trough level*
Amplitude Modulation Penalty	*the decibel penalty to be added to individual $L_{A90,10min}$ measurements as a result of amplitude modulation*
Blade Passing Frequency	*means the frequency, in hertz (Hz), at which the blades pass any fixed point, for example the tower*
$L_{Aeq,n}$	*means the equivalent continuous A-weighting sound pressure level over time period n*
$L_{Aeq,100msec}$	*means the equivalent continuous A-weighting sound pressure level over 100 milliseconds*

De-trending	*a function designed to remove an unwanted trend from a time series of data, resulting in a 'stationary' time series*
Modulation Spectrum	*a single-sided, power spectral density function: calculated using a Rectangular window; having a frequency resolution of 5/128 H; comprising 128 lines and having a maximum frequency of 5 Hz*
Power Spectral Density	*a function which describes how the variance (square of standard deviation) of a time series is distributed over the different frequencies*
Rectangular Window	*a windowing function used in the spectral analysis of time series data used to ensure an equal weighting to every value within the time window*
Frequency Resolution	*the size of the frequency bins used to define a frequency spectrum. The smaller the bins, the higher the resolution of the spectrum.*

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