4c. Amplitude Modulation (AM) and Low Frequency Noise (LFN)

Reason for rejection last time:

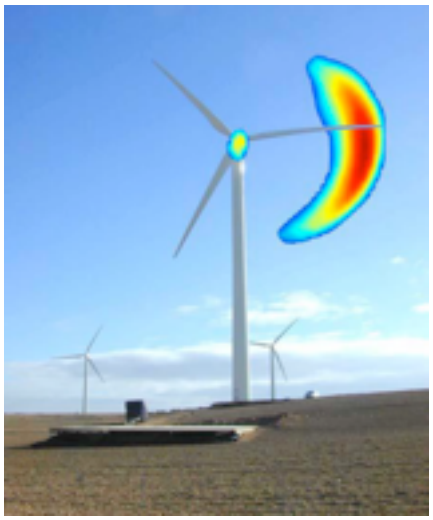
> *1. The applicants have failed to demonstrate that there would not be an **unacceptable impact on the amenity of nearby residents by virtue of the noise** generated by the proposed turbines, and the proposed development would therefore be contrary to Policies DVT11 and DVT13 of the Torridge District Local Plan and Policy CO16 of the Devon Structure Plan.*

This chapter shows that Amplitude Modulation (AM), the pulsating swishing and (sometimes) thumping noises which are characteristic of large, working wind turbines, is now clearly recognised as one of the main cause of annoyance, sleep deprivation, distress and other health-related issues in wind farm neighbours worldwide. It shows that the wind industry, whilst continuing to deny that AM is a problem, cannot predict with any certainty whether or not it will be evident or intrusive in any specific development before the wind farm becomes operational. The chapter shows that Low Frequency Noise (LFN) is also present in the spectrum of sound emitted by the turbines and that LFN travels much further through the air without attenuation, penetrating the solid walls of nearby buildings with ease and, in so doing, adversely affecting the health and well-being of the occupants. Where these phenomena are found to be present, complaints are inevitable. The closer the turbines are placed to occupied property, the more likely are AM and LFN to cause problems.

This chapter has 4 sub-sections:

4c.1 Amplitude Modulation

4c.1.1 Amplitude Modulation (AM) is a variation in the magnitude of a sound emitted from a source. All upwind-configured wind turbines (where the blades are upwind of the tower) produce AM. As a rotating blade descends towards the horizontal position the swishing sound of the blade carving the air intensifies temporarily, reaching a maximum at the horizontal position before returning to its original value as the blade moves on towards the lowest point of its swept circle.



Noise sources from a wind turbine. Red colour indicates loudest noise, through yellow to blue (least noise). From DEFRA report: Wind Farm Noise Statutory Nuisance Complaint Methodology, Page 11 Figure 3, by AECOM. 6th April, 2011.

Turbine blades rotating clockwise as seen.

4c.1.2 It is postulated that the AM occurs because the plane of the rotor blade assembly is not parallel to the tower, nor is the main rotor shaft perpendicular to the tower. The shaft is slightly higher at the front of the nacelle (the gearbox and/or generator housing behind the centre of the rotor assembly) and this angles the plane of the rotor assembly away from the tower so that there is less chance of the blades hitting the tower in the lower part of the sweep. With the wind blowing onto the rotor assembly this means that the blade moving downwards is actually moving into the wind whilst the blade moving upwards is moving away from the wind. This changes the relative speed of the blade in the incident wind which in turn changes the amount of swishing noise produced (a Doppler effect). Each single rotation of the blade will have one short increase in noise. With three blades on a turbine rotating at normal working speed (around 19 rpm) this will give rise to a pulsing sound approximately once every second.

4c.1.3 This need not be a problem. AM, like all noise, attenuates (dies down) with distance. If the distance is great enough, no AM will be heard at nearby properties. The problems arise when there is *excess* AM coming from the turbines or when the separation distance is too small.

4c.1.4 Where AM is heard at nearby properties, the annoyance it causes can be a serious concern. It can cause an increase in noise of +6dB per pulse. If it lasts for any length of time, or occurs every time the wind reaches a certain speed from a certain direction, it will trigger complaints. People who have suffered AM noise have variously described it as 'the noise equivalent of Chinese Water Torture' or, where more than one turbine is involved, 'listening to the beating noise of a Chinook helicopter which is coming your way but never arrives'. It is excess AM which has led many people in Canada and Australia to abandon their homes to escape the noise. In the UK, Jane and Julian Davis in Lincolnshire suffered the same distress and subsequently won an undisclosed amount, believed to be around £3 million, in an out-of-court settlement with the wind farm owner, operator and landowner (see Chapter 4a, paragraphs 4a.1.2, 4a.1.3 & 4a.1.5 of this report).

4c.1.5 Two of the most recent wind farms to begin operation in Torridge and North Devon have already triggered noise complaints. The complainants' descriptions indicate that AM, as well as the overall noise impact (see Chapter 4b), is part of the problem. In Torridge, it is the Darracott Wind Farm which is problematic, as this extract from a newspaper website below shows:

North Devon Gazette24

Home | News | Sport | What's on | Buy and sell | North Devon life | Contact

North Devon news | Features | Chemotherapy Unit Appeal | Tributes | Surf and tide times | Weather

homes24
jobs24
drive24
mydate24
myphotos24
familynotices24
My Money 24
MyVouchers24

4C Winks
Today's Dream
The Capstone Hotel, Ilfracombe, Devon
Just £95 for Dinner, Bed and Breakfast For Two.
BUY IT!

Reader travel
Great holiday offers
BOOKMY

Our sleepless nights with the wind turbines

Andy Keeble
Wednesday, June 8, 2011
12:06 PM

Recommend 2 Tweet 4

Torrington couple kept awake at night by new 'neighbours'

Patricia and Arthur Poulton say they are kept awake at night by the noise from three wind turbines erected in a field opposite their home at Higher Darracott, near Torrington.

Comments | Email | Print | Got a story?

A TORRINGTON couple are selling their home and business following the erection of a wind farm in a field opposite their bungalow.

Patricia and Arthur Poulton say they are being kept awake at night by the noise from a trio of giant turbines less than 500 metres from their home at Higher Darracott.

The trio of wind turbines at Higher Darracott, near Torrington.

The couple, who have operated their Deepmoor Metal Processors scrap metal business from the site for the last 21 years, said they now had no option but to sell up and move on.

"I can hear the turbines through my pillow at night," said Mrs Paulton, 70.

"It's a droning whooshing sound and as the blade passes the upright, the windier it gets, the noisier it gets. I have to close the window but you can still just about hear it through the double glazing.

4c.1.6 In North Devon District, it is the Fullabrook Wind Farm which has triggered complaints:

Turbine noise 'destroying' our lives

North Devon Journal Follow Thursday, September 22, 2011

PEOPLE living near the new Fullabrook wind farm claim their lives are being "destroyed" by the noise generated from each of the 22 turbines.

The residents, some who live only 400m from the structures, say they can no longer sleep as a result of the intrusive sound.

UNHAPPY: Fullabrook resident Nick Williams. Picture: Rob Tibbles. To order this photograph call 0844 4060 269 and quote Ref: BNRT20110916D-010_C

But despite numerous registered complaints about the noise at Fullabrook, North Devon Council (NDC) is unable to act until the whole site is complete and commissioned, which may not be for another three weeks.

Once the site is commissioned officers from the council will visit Fullabrook to monitor the sound levels in order to ascertain whether they meet the requirements set out by the Secretary of State.

Jeremy Mann, head of environmental health and housing services at NDC said: "I can confirm that a number of the residents near to the wind farm have now expressed concern regarding the noise levels.

"The operator has strict noise limits imposed on their operation and is required to give evidence to the council of their compliance with these controls when the site is no longer working intermittently."

In the meantime several residents feel they are trapped living with the noise because if they tried to move house few people would be interested in buying a property next to a wind turbine.

Nick Williams lives at Fullabrook itself with six of the turbines near his house. He claimed the wind farm had destroyed the area he lives in as well as his life.

He said: "It is like having tumble dryers in my bedroom and so I mostly have to sleep on the sofa in my front room - why should I be forced out of my bed?

"I can't afford to double glaze the whole house - why can't the people behind the turbines use this community fund to triple glaze all our houses? I have also had to buy a digital box for the television because the turbines interrupt the signal so badly it is impossible to watch."

Another resident, who wanted to remain anonymous, has lived at Halsinger for over 23 years and can see three turbines from her kitchen window. She said: "I can feel the sensation from the blades turning through my pillow when I am trying to sleep at night.

"There is no option of keeping the window open any longer. It is just too noisy to sleep - we were told they would be silent.

"And I have some chickens, I can't prove it is related, but they laid eggs everyday before July (when the turbines started to be tested) but since then we have had just two laid."

Kim Parker owns a stables with 15 horses at Pippacott and she believes the noise is a problem because it is unpredictable.

She said: "Most of the horses have got used to it now but it is not a constant sound so often unnerves them. Then they are jumpy and constantly looking up to where the noise is coming from."

A spokesman for ESB International, which owns the site, confirmed it was working closely with the district council and that remedial steps could be taken if, once tested, it was found noise levels exceeded the limit.

4c.1.7 The Fullabrook problem has led to the local MP, Nick Harvey, becoming involved. He set up an online survey which showed that nearly 80% of those living near to Fullabrook Wind Farm are affected by the noise of the turbines. *(North Devon Journal, November 17th, 2011, 'Wind Farm Noise Affects Residents')*

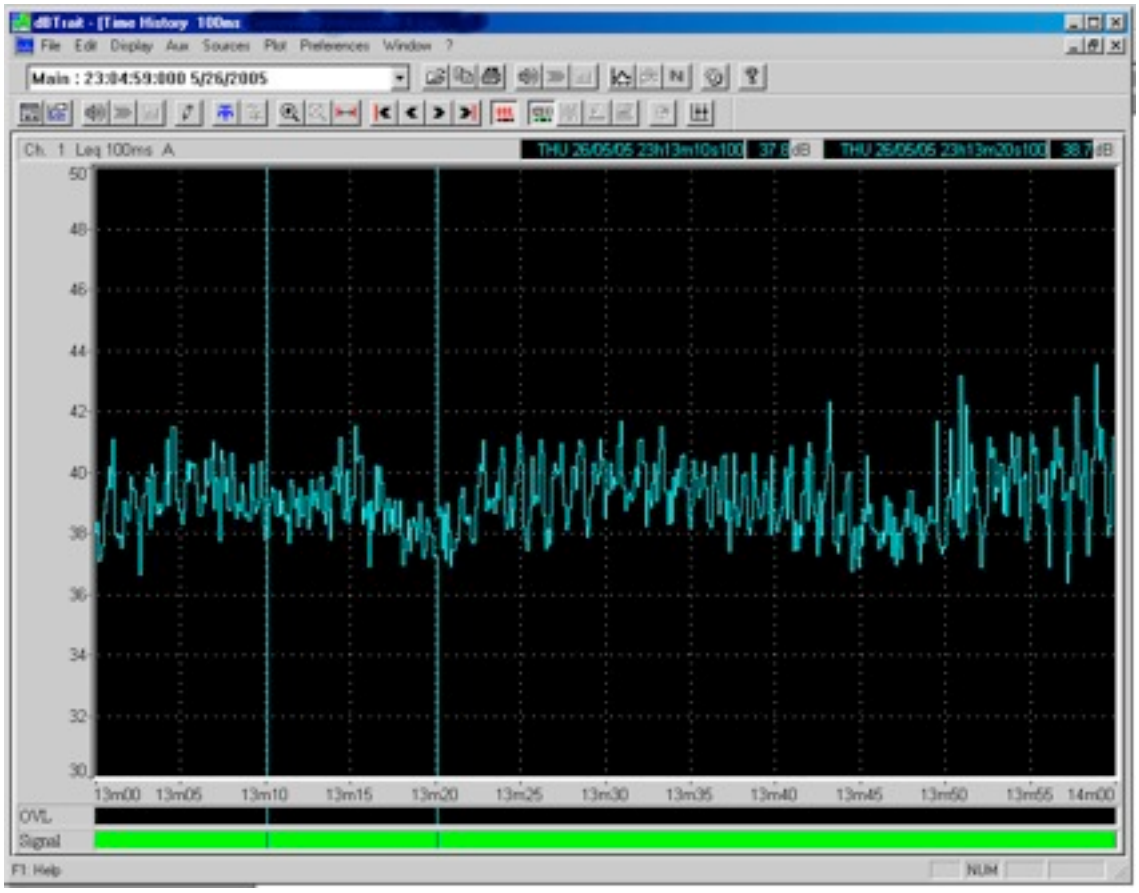
4c.1.8 It is noticeable that the distances between turbines and affected properties in the reports above are similar to the distances proposed at Dunsland Cross. The turbine heights at Fullabrook are 110m, 10m taller than Dunsland Cross, but at Darracott they are smaller, at 81m, yet they are still causing noise nuisance.

4c.1.9 Anyone wishing to listen to AM in order to appreciate what it sounds like should visit

http://penbay2010.podomatic.com/entry/2010-07-17T01_27_09-07_00

where a recording of wind turbine noise at a property approximately 800 metres from the nearest turbine in a 3-turbine wind farm is available. The noise level, taken on a sound meter, was 48-49 dB and the time of the recording is just after midnight. It is likely that this is the worst-case scenario of a temperature inversion and high wind shear (little or no wind at ground level, plenty of wind at turbine hub height) and is probably a special case, because comments at the bottom of the page from other local people say the noise is not usually a problem. It enables the listener to appreciate the pulsing AM characteristic of the noise being discussed in these paragraphs, nevertheless.

4c.1.10 Since AM can be heard it can also be measured and recorded graphically. The screen grab below shows such a plot:



The whole trace represents 1 minute in time. The trough to peak values of the AM range from approximately +2dB at 13m 18s to +6dB at 13m 57s. The pulses are occurring approximately every second.

4c.1.11 Predicting with certainty whether or not excess AM will occur in a wind farm still at the design stage is not yet possible. The known causes are too variable. Blade design is critical, with the REpower MM82 turbines (one of the candidate turbines for Dunsland Cross in 2008) installed in the last few years being particularly prone to AM. The proximity of turbines to each other is also a factor. The turbulence of the wake from the next turbine upwind means any downwind turbine sited too close is working in disturbed air and this can cause AM. False readings by nacelle-mounted wind vanes in unstable air can result in the yaw motors failing to align the rotor assembly squarely to the wind. As well as causing the swishing sound to fluctuate, blades working in unstable air can also introduce a lower frequency thumping sound into the mix (see also section 4c.3 below). This is very unpredictable and highly disturbing.

4c.1.12 Critically, wind shear caused by ground factors which create turbulence can also cause AM. As has been shown in Chapter 4a, paragraph 4a.4.18, the applicant does not know the full wind shear profile for Dunsland Cross so cannot possibly say that excess AM will not be a problem, especially when the separation distances between the turbines and the properties are so small on a confined site like this.

4c.1.13 AM is not a new problem. In 2004, press reports began to appear saying people living near 3 wind farms were experiencing health problems and that they seem to be caused by noise from the turbines. The Government commissioned the Hayes McKenzie Partnership (HMP) to investigate the complaints. It was initially thought that low frequency noise (LFN) and infrasound might be to blame, but HMP said it was more probable that AM, a relatively unknown phenomenon at the time, was the more likely cause of the complaints. HMP recommended that further study into AM was needed but pointed out that complaints matching the description of AM noise had only been expressed in complaints at 5 out of 126 wind farms in the UK.

4c.1.14 In paragraph 11.2.2.5 of the ES the applicant has quoted this research as justification for dismissing the problem of LFN (rather than AM) in one single sentence. As this chapter, Chapter 4c is now showing, much more research has been undertaken in the UK and worldwide as a result of actual wind farm noise complaints between 2006 - 2012. The applicant simply chooses to ignore this extremely important work.

4c.1.15 In 2006 the Government brought the Noise Working Group (NWG), many of whom had written the original ETSU-R-97 document, back together to review the AM problem. The NWG commissioned Salford University to research how extensive the problem really was. The University concluded that the causes of AM were not fully understood and that AM cannot be predicted given the current state of the technology. However, it pointed out that AM was only considered to be a factor in 4 of the 133 wind farms examined and a possible factor in another 8. Of the 4 known cases, complaints had since subsided at 3 of them, in one case because a turbine control system had been installed. The remaining unresolved case was that of Mr. & Mrs. Davis, previously mentioned in paragraph 4c.1.4, 4a.1.2, 4a.1.3 & 4a.1.5, at Deeping St. Nicholas in Lincolnshire, now finally resolved at the end of 2011 with the Davises having been paid a very large sum of money in compensation. The report finished by saying that as AM complaints were so rare it was not worth committing further research funds to the problem, but that the matter should be kept under review.

4c.1.16 When the Salford University report was published, Dick Bowdler (see paragraph 4a. 1.4), one of the members of the NWG which commissioned it, resigned in disgust at its content, findings and recommendation.

4c.1.17 Reference to the Salford University research is made in all current wind farm applications as a way of trying to dismiss the unpredictable AM problem. The current application is no exception (paragraph 11.2.2.6 of the ES). The question has to be asked' 'If AM is not a real problem, why has it been an agenda item at 4 International Conferences on Wind Turbine Noise, in Berlin 2005, Lyon 2007, Aalborg 2009 and Rome 2011? It has been a problem for at least eight years. Indeed, the Rome 2011 post-conference report states:

> *'Swish, and its related thump, are the remaining problems in wind turbine noise. However, there has been real development in the understanding of these since the first Wind Turbine Noise Conference in Berlin in 2005, and a solution may not be far away.' (http://www.windturbinenoise2011.org/)*

4c.1.18 The Salford University Report has now been totally discredited and has been shown to be deeply flawed. In 2007, the Renewable Energy Foundation (REF) submitted Freedom of Information requests to Salford University relating to the AM research undertaken. REF wanted to know the list of wind farms surveyed, which ones had noise complaints and the responses from local authority Environmental Health Officers detailing those complaints. The university refused the request and held out for two years before it was ordered by the Information Commissioner to comply, which it did in 2009.

4c.1.19 Analysis of the Salford data led REF to conclude that AM noise complaints had also been made in 21 of the 129 wind farms reported as not having AM complaints in the University's report. The Salford study had been simply a desk-based exercise in which questionnaires were sent out to EHO's asking them to *describe* the complaints they had received. No attempts to *actually measure AM* at the wind farm sites were made. AM can only be verified by measurement on site, not by a desk-based theory exercise.

4c.1.20 Speaking at the Den Brook Inquiry, Mr. Stigwood (see paragraph 4a.1.4) said he has measured AM causing increases of +3dB up to 1500 metres away from turbines on 4 separate wind farms. He has measured AM causing a +6dB increase only 900 metres away from a turbine on another wind farm. At the Environmental Protection UK (EPUK) Noise Management Conference in Birmingham in 2009 he gave further figures to illustrate the extent of the problem:

EPUK CONFERENCE

Amplitude modulation is real

Further claims have been made that the phenomena of amplitude modulation is being underestimated.

Amplitude modulation is when the blades cause a rise and fall in noise that feels like low frequency noise. Mike Stigwood told the Epuk conference that his measurements at various sites showed that there can be 6dB differences between high and lows and this can occur at single turbines, not just when turbines are located in straight lines or on short towers.

He says there are assumptions in Etsu that do not hold true for large turbines: Etsu restricts amplitude modulation to 3dB peak to trough – he says it is up to 10dB. Etsu says amplitude modulation is in the frequency range 800-1000Hz, Stigwood says it is actually 125-400Hz, finally he says Etsu is wrong to say that amplitude modulation reduces over distance by the time it reaches nearby homes.

He told the conference: "Excess amplitude modulation seems to be a much wider problem than is argued by the industry. The Salford study looked at this but following a freedom of information release many complaints were mis-labelled as not being amplitude modulation when they were (*NB Feb/Mar p3*).

"Current estimates indicate about 35 wind farms are causing problems. This is a very high percentage, and may be an underestimate given that many householders may not complain fearing they will be blighting their own homes."

4c.1.21 It should be noted that the deleted section of the HMP report featured in *The Sunday Times* article shown in Chapter 4a, paragraphs 4a.6 2 and 4a.6.3 stated that **where AM is present the night time ETSU-R-97 noise limit should be reduced to 33dB**:

> ***'The report said the best way to protect locals was to cut the maximum permitted noise to 38 decibels, or 33 decibels if the machines created discernible "beating" noises as they spun.'***

4c.1.22 If this dual limit were to be adopted then a precautionary minimum distance between turbines and houses would have to be set at around 1,000 - 1,500 metres, since distance is the only way to guarantee that excess AM will not be a problem. The night time noise limit cannot realistically be reduced after the wind farm is built because the only mitigation available at that time would be to turn the turbines off for most of the time. This is what has had to happen in the township of Mt. Bryan, in Australia. When operators AGL had to shut down 16 of the 34 turbines at Hallett Stage 2 Wind Farm between 7 pm and 7 am the residents of the town and the surrounding area, who had previously been publicly vilified and labelled as serial complainers (and worse), reported some excellent sleeps. This solution was never available for over 20 families in Australia who had already left their homes and farms because of ill health. Some were bought out and gagged by the wind developers (like the Davises in the UK) so they cannot talk about their health problems publicly, unless they are subpœnaed to give evidence in court. Others have just walked away from their homes to preserve what is left of their sanity. *(http://northgowerwindactiongroup.wordpress.com/2011/11/06/news-release-from-australia-turbines-turned-off-at-night-10-km-setback-recommended/)*

4c.1.23 Having to turn turbines off at night, or at least run them in noise reduction mode (as the applicant for Dunsland Cross has said he will have to do) will have severe consequences for the output of the wind farm. Investors, who might previously have carried out due diligence checks assuming full power output, would feel that they have been misled by the developer saying that excess AM would not be a problem once the wind farm is built. Litigation between investor and developer would be inevitable.

4c.1.24 In order to protect the public, planning officers should apply the Precautionary Principle when assessing applications for wind farms. That means an adequate distance between turbines and properties should be maintained. TDC's Wind Energy Policy and the Devon Strategic Planning Authority sets a distance of 600 metres. From what has been written above, this may prove to be completely inadequate.

4c.2 The Need for a Separate AM Planning Condition

4c.2.1 The inspector at the Den Brook Inquiry was sufficiently concerned about AM that, despite protests from Mr. Marcus Trinick, Q.C., the barrister representing the appellant, he set a planning condition which was prepared by Mr. Stigwood, acting for the Den Brook Judicial Review Group (DBJRG). The following is from the Inspector's report:

> *'181. However, as is evident from my consideration of the possible noise impact of the proposed wind farm, I am concerned about the effect of greater than anticipated AM arising at the site. At my instigation DBJRG has drafted a condition designed to regulate this possibility and prepared a reasoned justification, and this has been the subject of a response by the appellant.*
>
> *182. The appellant objects in principle to the inclusion of a condition designed to regulate AM on the grounds that excessive AM is rare; stable atmospheric conditions are rare at the appeal site; it is not recommended in ETSU-R-97; and there is insufficient knowledge to achieve the necessary balance between the preservation of amenity without causing profound damage to the UK wind industry.*
>
> *183. In my opinion these misgivings are either overstated or misleading. I do not see that the rarity of the circumstance constitutes a valid reason to object to such a condition. If it is unlikely, then it is equally unlikely that it would be necessary to enforce the condition. On the basis of the evidence I have heard I am satisfied that the phenomenon is not fully taken into account in ETSU-R-97, and the condition proposed is of a precautionary nature. I would have more sympathy with the appellant's view had the purpose of ETSU-R-97 been merely the preservation of amenity, but it is not. From the viewpoint of wind farm*

neighbours the most important purpose of ETSU-R-97 would be more accurately described as the preservation of sleep. Taking account of both this and the uncertainties to which I have already referred, it is for these reasons that in my opinion the imposition of conditions is both necessary and reasonable.

184. The appellant complains that the condition drafted by DBJRG contains subjective elements, but I cannot see this. I fear the psycho-acoustic approach suggested by the appellant would be likely to be significantly more subjective. The possibility of a penalty approach is suggested similar to that included in ETSU-R-97 for a tonal component and as cited in Note 3. However, I have received no details of an appropriate sliding scale. I do accept nevertheless that the proposed condition would benefit from redrafting in order to clarify its content and purpose. I have amended it to this effect.

4c.2.2 The Inspector did take the original DBJRG AM condition and amended the wording in an effort to simplify it before putting it in his report. The amended AM condition is shown below:

20. At the request of the local planning authority following the receipt of a complaint the wind farm operator shall, at its expense, employ a consultant approved by the local planning authority, to assess whether noise immissions at the complainant's dwelling are characterised by greater than expected amplitude modulation. Amplitude modulation is the modulation of the level of broadband noise emitted by a turbine at blade passing frequency. These will be deemed greater than expected if the following characteristics apply:

a) A change in the measured $L_{Aeq,\ 125\ milliseconds}$ turbine noise level of more than 3 dB (represented as a rise and fall in sound energy levels each of more than 3 dB) occurring within a 2 second period.

b) The change identified in (a) above shall not occur less than 5 times in any one minute period provided the $L_{Aeq,\ 1\ minute}$ turbine sound energy level for that minute is not below 28 dB.

c) The changes identified in (a) and (b) above shall not occur for fewer than 6 minutes in any hour.

Noise immissions at the complainant's dwelling shall be measured not further than 35m from the relevant building, and not closer than within 3.5m of any reflective building or surface, or within 1.2m of the ground.

(d) The wind farm operator shall continuously log arithmetic mean wind speed and arithmetic mean wind direction data in 10 minute periods from the hub height anemometer on the site to enable compliance with the conditions to be evaluated. Such data shall be 'standardised' to a reference height of 10m as described in ETSU-R-97 at page 120 using a reference roughness length of 0.05m.

4c.2.3 The DBJRG was not happy with this amendment and sought to have it changed back to the original wording, saying that the amended version could be misinterpreted leaving the residents unprotected against an unscrupulous developer. DJBRG had to do this by taking the case to the High Court in London (not for the first time in this long drawn out and very expensive saga).

4c.2.4 High Court Judges Lord Justice Mummery, Lord Justice Elias and Lord Justice Patten ruled that, whilst the wording of the condition could have been better, there was no doubt as to its meaning and that it is perfectly enforceable as it stands. So although DBJRG appeared to lose the case, they had actually succeeded in making the condition actionable in a court of law.

4c.2.5 Realising that the issue of AM is not going to go away and is, indeed, now being taken out of its hands, the wind industry's trade association and lobby group, RenewableUK (RUK, formerly BWEA, the British Wind Energy Association) has hastily set up its own research programme to try to regain influence on AM issues, the aim being to prevent the imposition of the Den Brook AM Condition on wind farm developers in the future by replacing it with one of their own which, no doubt, will offer less protection to wind farm neighbours.

4c.2.6 The applicant has clutched at this straw in the hope that this research would have been concluded and its recommendations implemented by the time the Dunsland Cross application was submitted. In paragraph 11.2.2.6 of the ES he states:

> *'It is hoped that this research will be available to the determining authority at the time of consideration of the application, in order to assist in the formulation of conditions. However, it is considered that the state of knowledge is such that there is sufficient information before the decision maker in the absence of this report.'*

4c.2.7 As of 1st March, 2012, the RUK research team had not filed its report. The applicant is correct in his last comment, however. There is sufficient information before the decision maker and it is all in Chapters 4a, 4b, 4c and 4d of this DTOG report. It shows clearly that this application should never be granted planning permission in the belief that the noise assessment is even remotely acceptable.

4c.2.8 The RUK research project was actually introduced at the Rome Conference (see paragraph 4c.1.17 above). RUK presented a paper entitled *'Fundamental Research in Amplitude Modulation - a Project by Renewable UK'.* The paper cited Jeremy Bass of RES, the Den Brook developer, acoustician Dick Bowdler and Maria McCaffery and G. Grimes of RUK as the authors. The abstract from this paper shows the panic in the industry and the residual sense of denial that AM is even a problem:

> *'This paper outlines a research project designed to improve our understanding of the phenomenon known as 'amplitude modulation' (AM), and presents key results.*
>
> *The frequency and severity of AM in the UK is such that there has been no need for a specific planning condition to control its emission. Regardless, there is increasing pressure from planning authorities and local residents for developers to accept such a condition for AM. The problem for the wind power industry is that there is currently insufficient knowledge on which to base a condition without potentially causing unnecessary difficulties in future.*
>
> *The project aims to improve understanding of the AM phenomenon, so that a suitable condition can be developed, based on an objective method for quantifying levels of AM and a well-defined dose-response relationship for AM.*
>
> *In parallel with this, fundamental research will be pursued so that the key drivers that cause AM in the first place can be identified. This knowledge will enable developers and manufacturers to predict when AM is likely to occur, and reduce or possibly even avoid entirely the potential for it.*
>
> *The aim of this project, therefore, is to be highly targeted and to provide clear, definitive recommendations on AM for use by the industry, planners and the public, on a rapid timescale.*

4c.2.9 The Rome Conference was held in April, 2011. In Manchester in October, 2011, RUK held its annual conference with AM again prominent among the issues to be discussed. Mr. Bowdler, together with Dr. Bullmore (see paragraph 4a.1.4), Matthew Cand (who works with Dr. Bullmore at Hoare Lee Acoustics), Malcolm Smith of Southampton University and Jeremy Bass of RES, contributed to a session on Onshore Acoustics, dedicated to AM. In the preamble to his contribution, *'Why Amplitude Modulation of Turbine Noise is an Issue?'*, Mr. Bowdler states:

> *'Turbine noise is recognised as being more of a problem, decibel for decibel, than most other noise sources. Most wind farm noise is heard as steady broadband noise not unlike distant road traffic but at a significant minority of locations it is heard as "swishing" or "thumping". This periodic noise makes the turbine noise more noticeable and potentially annoying. Since we know little about either how AM really affects the perception of turbine noise or how we can mitigate it should it be a problem, the formulation of a suitable planning condition is not possible.' (RenewableUK 2011 Annual Conference Programme p 35)*

But it is possible and it has already been done and it has been upheld by the High Court.

4c.2.10 Responding to a claim by RES that it would be difficult to distinguish wind farm noise from other noises in the environment, The Renewable Energy Foundation, REF, looked into this and produced an information note on 31st October, 2011, entitled *'The Den Brook Amplitude Modulation Noise Condition'*. *(http://www.ref.org.uk/publications/242-the-den-brook-amplitude-modulation-noise-condition)*

4c.2.11 This report demonstrates that it is a perfectly straightforward exercise to measure AM in isolation and test the Den Brook AM Noise Condition in the field. The conclusion states:

> *'We believe that this exercise demonstrates that the Den Brook condition is straightforward and that it is possible for this condition to be employed in a transparent and objective manner to demonstrate the existence of excess AM in wind turbine noise. The point of the current analysis is simply and solely to demonstrate the technical application of the key elements of the Den Brook noise condition to real wind farm noise data and we have shown that this is possible and can be conducted in a clear and objective manner.*
>
> *… These findings should be welcomed by both wind-farm neighbours, developers, and decision makers in the planning process. AM noise provokes complaints and heated debates, and an enforceable, objective, condition to cap such noise gives all parties clarity, as well as sparing neighbours and developers the trouble, expense, and uncertainty of private nuisance actions. The Den Brook condition appears to be a readily workable solution to this very real problem.'*

4c.2.12 Mid-Devon Council is now taking AM seriously and is imposing a zero tolerance approach to it. The Environmental Health Officer, as a consultee to wind farm applications, now includes the following paragraph in the standard noise conditions set:

> *'Where the assessment information confirms that a tonal noise or any form of amplitude modulation is distinguishable 3.5 metres from the façade of the complainants dwelling, the wind turbine operator shall carry out works to mitigate such effect to the extent that any tonal noise or* ***any form of amplitude modulation is no longer distinguishable*** *3.5 metres from the façade of the complaints dwelling.' (See, for example, Application No. 11/00075/FULL, 8th March, 2011)*

4c.2.13 There is no reason why the TDC Environmental Protection Officer should not be doing the same. Whilst the Mid-Devon AM Noise Condition is better than nothing, it is not as precise or as robust as the Den Brook AM Noise Condition, which has been upheld in the High Court and, as such, should be included automatically as part of any consent decision notice issued by planning officers in any wind farm application.

Recommendation: CONDITION

The minimum distances between turbines and properties in the current application are insufficient to enable the applicant to guarantee that there will be no excess AM problem. If TDC is minded to approve this application, the Den Brook Noise Condition must be included in the decision notice for the protection of the amenity of local residents.

4c.3 Low Frequency Noise

4c.3.1 The broadband audible noise coming from wind turbines comprises a range of frequencies. High frequency sounds attenuate relatively quickly with distance in open air. Of greater concern are the lower frequency sounds in the range 20 - 200 Hz (Hertz, or vibrations per second) since these are more penetrating and carry further, as anyone subjected to pounding bass music nuisance from neighbours can testify.

4c.3.2 20 Hz is the lower threshold for human hearing. Noise at frequencies below this value are inaudible to humans (but not necessarily to animals). Whilst audible noise from a wind turbine can be the cause of serious annoyance and distress to nearby residents, inaudible noise, or **infrasound**, is an area of equal concern to medical and other professionals investigating ill health in wind farm neighbours. **Wind turbines emit both audible noise above this frequency threshold and inaudible noise below it. Like the lowest audible frequencies, this infrasound penetrates buildings and human bodies with ease.**

4c.3.3 The research paper by G. Rasmussen, *'Human Body Vibration Exposure and its Measurement'* lists symptoms when people are exposed to infrasound of different frequencies:

Frequency	Symptom
4-8 Hz	Influence on breathing movements
4-9 Hz	General feeling of discomfort
4-10 Hz	Abdominal pains
5-7 Hz	Chest pains
10-18 Hz	Urge to urinate
12-16 Hz	Lump in throat
13-20 Hz	Head symptoms, Influence on speech

4c.3.4 In Cadillac, Michigan, acoustics expert Rick James has been researching the low frequency noise problem. In an article about Mr. James by Ashley Box on the Cadillac News website on 5th December, 2008, the following was written:

> *'The second health concern related to wind turbines is connected to the inaudible, low-frequency sound produced. While this concern has been rejected by wind companies, James himself has done research that proves that windmills produce a constant low-frequency sound. "I found it dominant, omnipresent.* ***Unlike the audible whooshing, which is there only part of the time when the wind is just right, the low frequency is there all of the time****," James said.' (www.cadillacnews.com)*

4c.3.5 Infrasound is measured on the dB(C) and dB(G) scales. The dB(G) weighting is most appropriate for measuring infrasound but the dB(C) weighting is more common. Only the dB(A) weighting is used in predicting derived noise limits at noise-sensitive properties for wind farm developments. **The dB(A) weighting, the only one used by the applicant at Dunsland Cross, misses most of the infrasound content in any individual measurement.**

4c.3.6 In the abstract of their 2010 paper *'Low-frequency Noise from Large Wind Turbines'*, Henrik Møller and Christian Sejer Pedersen from the Section of Acoustics, Aalborg University in Denmark, stated:

> *'As wind turbines get larger, worries have emerged that the turbine noise would move down in frequency and that the low-frequency noise would cause annoyance for the neighbors. The noise emission from 48 wind turbines with nominal electric power up to 3.6 MW is analyzed and discussed. The relative amount of low-frequency noise is higher for large turbines (2.3–3.6 MW) than for small turbines (2 MW), and the difference is statistically significant. The difference can also be expressed as a downward shift of the spectrum of approximately one-third of an octave. A further shift of similar size is suggested for future turbines in the 10-MW range. Due to the air absorption, the higher low-frequency content becomes even more pronounced, when sound pressure levels in relevant neighbor distances are considered. Even when A-weighted levels are considered, a substantial part of the noise is at low frequencies, and for several of the investigated large turbines, the one-third-octave band with the highest level is at or below 250 Hz. I**t is thus beyond any doubt that the low-frequency part of the spectrum plays an important role in the noise at the neighbors.'** *(VC 2011 Acoustical Society of America. [DOI: 10.1121/1.3543957] PACS number(s): 43.50.Rq, 43.28.Hr, 43.50.Cb, 43.50.Sr [ADP] Pages: 3727–3744)*

4c.3.7 The applicant at Dunsland Cross intends using 2.5MW turbines. The paragraph above shows that the LFN from such machines is significantly higher than the LFN emitted from machines just 0.5MW smaller.

4c.3.8 The Danish Ministry of the Environment's Environmental Protection Agency is now taking the issue of LFN from wind turbines very seriously. Following discussions by Østerild test centre's conciliation committee, the Danish Minister for the Environment, Karen Ellemann, decided that a limit for low frequency noise from wind turbines must be set, acknowledging that clearer and more precise regulations for this type of noise will provide more security for people living near wind turbines. The revised Statutory Order on Wind Turbines was submitted for public hearing last autumn and was due to come into force by the end of 2011.

4c.3.9 The proposed Danish regulation is based on **a new 20 dB limit indoors** for wind speeds of 6 and 8 m/s. The present limit for noise from wind turbines in Denmark is 44 dB outdoors near residences in the open country and 39 dB in residential areas, for a wind speed at 8 m/s. *(http://www.mst.dk/English/Noise/wind_turbine_noise/low_frequency_noise_from_wind_turbines/low_frequency_noise_from_wind_turbines_FAQ.htm)*

4c.3.10 On 29th June, 2011, Ditliv Engel, CEO of Vestas Wind Systems A/S, one of the biggest turbine manufacturers in the world, wrote to Minister Elleman expressing his dismay at the new lower limit for LFN. In the letter he states (DTOG emphases):

> *'In fact, according to our analyses, the most economical turbines, the 3 MW category, are the ones that will be strongly affected by the new rules. This applies to open terrain in particular, where **in future low frequency noise will dictate and increase the distance requirements to neighbours for close to half of the projects that we are already aware of over the next 2 to 3 years.***

> *In a small country such as Denmark this means that a significant number of projects will not be viable as the increased distance requirements cannot be met whilst maintaining a satisfactory business outcome for the investor.*
>
> *The Danish market for wind turbines is of minor importance for Vestas in terms of sales, typically less than 1% of our sales per year. However, the Danish market provides a number of other functions for Vestas which are of considerable value from a business point of view. By means of its high wind penetration, 24% in 2010 – still a world record – Denmark has a role as a forerunner country and a full scale laboratory for conversion to renewable energy.*
>
> *This means that* ***other countries often look to Denmark when adjusting their legislation regarding wind energy.*** *We are therefore concerned – justifiably so as history shows – that the proposed Danish regulations for low frequency noise from wind turbines will spread to a large number of other markets with much higher commercial impact for Vestas and consequently for employment in the business.'*

4c.3.11 At no point in his letter does Mr. Engel show any concern for the victims of the LFN from his turbine generators. His only concern is for the future profits of Vestas. This is in marked contrast to the Minister and the Danish Government, who clearly have the human impact of LFN uppermost in their minds.

4c.3.12 Anticipating the obvious question as to why Vestas does not make less noisy turbines, Mr. Engel finally comes clean and admits that LFN from large turbines is real, it is a problem **and there is nothing they can do about it**:

> ***'At this point you may have asked yourself why it is that Vestas does not just make changes to the wind turbines so that they produce less noise? The simple answer is that at the moment it is not technically possible to do so****, and it requires time and resources because presently we are at the forefront of what is technically possible for our large wind turbines, and they are the most efficient of all.'*

4c.3.13 Five years ago, when infrasound coming from a sample of UK operational turbines was measured using the dB(C) weighting, the readings were inevitably higher than those obtained for audible noise on the dB(A) weighting. The results appeared in a report by John Stewart for the UK Noise Association (UKNA) published in August 2006. The report is called 'Location, Location, Location' (downloadable from http://www.windaction.org/documents/4281) and it has two pages of conclusions and recommendations based on the findings, one of which is that turbines should not be sited **within a mile** of where people live.

4c.3.14 TDC should ask the current applicant what the predicted noise levels at the façades of nearby properties will be based on dB(C) weightings as well as dB(A) weightings. After deducting 10dB for the (dubious) attenuation through an open bedroom window the predicted noise levels can then be compared with the new 20dB indoor limit protecting Danish residents. (After all, the dB(C) values present in the background noise assessment should already be known to the applicant, as the Rion NL-31 sound meters which were used can capture them in a sub-processing operation alongside the main-operation which captured the dB(A) readings.)

4c.3.15 Worldwide concerns regarding the effects of wind farms on the health of people living nearby really started in February 2007, when Plymouth-based GP Dr. Amanda Harry M.B.Ch.B. P.G. Dip E.N.T. published the findings of her research in a paper entitled, *'Wind Turbines, Noise and Health'.* In it Dr. Harry concludes:

> *'From my discussions with people suffering ill health who live near wind farms, it seems that the symptoms suffered can occur up to a mile from the wind farm. Until further independent medical and epidemiological research has been carried out I would suggest that no wind turbines should be sited closer than **1.5 miles** away from the nearest dwelling.'*

4c.3.16 Since then, debate has been raging between medical professionals, epidemiologists and the wind industry as to whether LFN is a contributory factor in the health problems of wind farm neighbours. The debate is world wide but at the present time it is particularly intense in Canada and Australia. A significant point in the debate was reached with the publication by Dr. Nina Pierpont, M.D., PhD, of a book called *'Wind Turbine Syndrome'*.

4c.3.17 The wind industry seeks to discredit this book at every opportunity saying the research cases in it prove nothing. This has not halted its findings gaining greater acceptance. Although this research is still in its relative infancy, it has become established enough for conferences such as the First International Symposium of the Society for Wind Vigilance, *'The Global Wind Industry and Adverse Health Effects'* to have taken place over two days in Ontario at the end of October 2010. The concerns are not going to go away. On the contrary, they are intensifying.

4c.3.18 It would be perfectly easy at this point in this report to fill many pages with evidence validating the existence of adverse health effects in real-life wind farm neighbours. Suffice to say that Environmental Health and Environmental Protection Officers would be wise to sample the pages in the following websites to avail themselves of the magnitude and extent of the problem:

http://windconcernsontario.wordpress.com/health/
http://waubrafoundation.com.au/

and the associated video channel:
http://www.youtube.com/user/WaubraFoundation

4c.3.19 Dr. Geoff Leventhall is one of the acousticians named in Chapter 4a, paragraph 4a.1.4. He wrote the fourth section of the IOA Bulletin article mentioned several times in that chapter. In an interview in issue 20 of *real POWER*, the trade magazine of RenewableUK (formerly BWEA, The British Wind Energy Association), in April-June 2010, he says:

> *'The swishing of blades remains an issue, as does the extreme sensitivity of a handful of people living near to wind farms, but the low frequency noise cited by some opponents is merely a red herring.*
>
> *All the stuff about low frequency noise is just rubbish in my opinion. I have often been approached by objectors wanting advice on the issue and what I have said to them is "stop wasting your time on infrasound. It's not a problem and you'll only lose credibility. Put your attention into something that might be important, like the best layout."'*

4c.3.20 Dr. Leventhall is a noise and vibration expert with over 50 years experience in the field. He is not, however, medically qualified. He has no authority to comment on medical matters. Inflammatory comments such as those above are totally rejected by medical professionals much more knowledgeable than Dr. Leventhall with regard to the physiological effects of low frequency sounds penetrating the inner ear and other organs of the body.

4c.3.21 Dr. Alec Salt of the Department of Otolaryngology, Washington University School of Medicine, St. Luis, Missouri, a person much more qualified to opine than Dr. Leventhall, doesn't mince words:

'The idea that infrasound doesn't or can't affect the ear is just flat-out wrong.'

4c.3.22 Writing in the Bulletin of Science, Technology & Society in August 2011, Carl Phillips of the Populi Health Institute in Wayne, PA, USA, states in his abstract:

> *'There is overwhelming evidence that wind turbines cause serious health problems in nearby residents, usually stress-disorder-type diseases, at a nontrivial rate. The bulk of the evidence takes the form of thousands of adverse event reports. There is also a small amount of systematically gathered data. The adverse event reports provide compelling evidence of the seriousness of the problems and of causation in this case because of their volume, the ease of observing exposure and outcome incidence, and case-crossover data. Proponents of wind turbines have sought to deny these problems by making a collection of contradictory claims including that the evidence does not "count", the outcomes are not "real" diseases, the outcomes are the victims' own fault, and that acoustical models cannot explain why there are health problems so the problems must not exist. These claims appear to have swayed many nonexpert observers, though they are easily debunked. Moreover, though the failure of models to explain the observed problems does not deny the problems, it does mean that we do not know what, other than kilometres of distance, could sufficiently mitigate the effects. There has been no policy analysis that justifies imposing these effects on local residents. The attempts to deny the evidence cannot be seen as honest scientific disagreement and represent either gross incompetence or intentional bias.' ('Properly Interpreting the Epidemiologic Evidence About the Health Effects of Industrial Wind Turbines on Nearby Residents', Bulletin 31, Volume 4, August 2011.)*

4c.3.23 Dr. Leventhall might be interested to read the report, dated 14th December, 2011, by two fellow American acousticians by the names of Robert Rand and Steve Ambrose, both members of the Institute of Noise Control Engineering (INCE), who practise in the USA. The report is entitled, *'The Bruce McPherson Infrasound and Low Frequency Noise Study (Adverse Health Effects Produced By Large Industrial Wind Turbines Confirmed)*.' He should be interested, because the acousticians themselves began to suffer adverse health effects almost as soon as they started their fieldwork:

> *'The investigators were surprised to experience the same adverse health symptoms described by neighbors living at this house and near other large industrial wind turbine sites. The onset of adverse health effects was swift, within twenty minutes, and persisted for some time after leaving the study area.*
>
> *The dBA and dBC levels and modulations did not correlate to the health effects experienced. However, the strength and modulation of the un-weighted and dBG-weighted levels increased indoors consistent with worsened health effects experienced indoors. The dBG weighted level appeared to be controlled by in-flow turbulence and exceeded physiological thresholds for response to low-frequency and infrasonic acoustic energy as theorized by Salt.*
>
> *The wind turbine tone at 22.9 Hz was not audible yet the modulated amplitudes regularly exceeded vestibular detection thresholds. The 22.9 Hz tone lies in the brain's "high Beta" wave range (associated with alert state, anxiety, and "fight or flight" stress reactions). The brain's frequency following response (FFR) could be involved in maintaining an alert state during sleeping hours, which could lead to health effects. Sleep was disturbed during the study when the wind turbine operated with hub height wind speeds above 10 m/s.*

> *It took about a week to recover from the adverse health effects experienced during the study, with lingering recurring nausea and vertigo for almost seven weeks for one of the investigators. (Executive Summary, pp2-3. The full report can be downloaded from http://www.windturbinesyndrome.com/news/2011/acousticians-confirm-wind-turbine-syndrome/)*

4c.3.24 Planning Officers, EHO's and EPO's need to deal with this issue in the common sense way, that is, to apply the Precautionary Principle once again. If LFN is known to travel some distance without significant attenuation and can penetrate buildings and people's and animals' bodies with ease, then it is incumbent on the officers to make sure that the distance between the turbines and the properties is enough for it not to be a problem.

4c.3.25 The best the current applicant can offer to counteract all of this empirical evidence is to try to throw a smokescreen around the issue by referring to LFN as if it was only a *ground borne* vibration. It is not, of course. It is both *airborne* and *ground borne*.

4c.3.26 In paragraph 11.2.2.1 of the ES, the applicant, whilst ignoring totally airborne LFN originating from the top of the turbines, forlornly quotes from the Companion Guide to PPS22, published in 2004:

> *'There is no evidence that ground transmitted LFN from wind turbines is of sufficient level to be harmful to human health.'*

4c.3.27 This is carefully worded. It does not say ground borne LFN does not exist, it just says it is not strong enough to travel any distance or harm humans. So how far can LFN travel?

4c.3.28 A number of wind farm installations have been planned for the area around Eskdalemuir in the Scottish Borders. They are now routinely being refused planning permission because there is a Government International Monitoring System (IMS) Seismic Monitoring Station there. It is the UK's contribution to the Comprehensive Test Ban Treaty (CTBT) verification regime. In other words, it listens out for vibrations which would be a signal that nuclear weapons are being tested somewhere in the world. The ground borne LFN from wind turbines creates noise in the seismometers and prevents them from doing the job they were put there for. The zone of concern around Eskdalemuir extends for 50 kilometres.

4c.3.29 Yet another paper of interest was presented at the Fourth International Meeting on Wind Turbine Noise in Rome, 2011. It was entitled, *'Monitoring and Mitigation of Low Frequency Noise from Wind Turbines to Protect Comprehensive Test Ban Seismic Monitoring Stations'* and was presented by Styles et al. It is of interest because it gives a detailed (and visual) analysis of the LFN from the Nordex N80, the very turbine upon which the Dunsland Cross application is based, and because of the following comment in the abstract:

> *'They demonstrated that small but significant harmonic vibrations controlled by the modal vibrations of the towers and excited by blade passing, tower braking and wind loading while parked, can propagate tens of kilometres and be detected by broadband seismometers.'*

4c.3.30 At Dunsland Cross we are talking about 501 and 506 metres to the nearest houses, not 'tens of kilometres'. Whilst the vibrations transmitted into and propagated through the ground might be very small, they only need to find resonant walls, floors, ceilings, window panes, doors or wardrobes inside houses to set up standing pressure waves in certain rooms. Some of these waves will constructively interfere and increase in amplitude, some will destructively interfere and decrease in amplitude. Thus, it is not impossible for different areas of the same building to have different physiological effects on the human or animal occupants, including aquatic animals in tanks inside or in ponds outside. In the 1960s and 1970s people started feeling ill in certain buildings and did not know why. It became known as 'Sick Building Syndrome'.

4c.3.31 It is the airborne LFN which causes most concern in most wind farm proposals, not ground borne LFN.

4c.3.32 Dr. Christopher Hanning, BSc, MB ,BS, MRCS, LRCP, FRCA, MD is one of the UK's leading authorities on sleep and its disorders. His expertise, acquired over 30 years in this field, has been accepted by the civil, criminal and family courts. He is an Honorary Consultant in Sleep Disorders Medicine to the University Hospitals of Leicester NHS Trust and a fellow of the Royal College of Anaesthetists. He is an Associate Member of the General Medical Council and chairs Investigation Committee hearings and Registration Panels. Before his retirement in 2007 he was Consultant in Sleep Disorders at Leicester General Hospital and Honorary Senior Lecturer to the University of Leicester. He was a founder member and President of the British Sleep Society and its honorary secretary for four years. He has written and lectured extensively on sleep and its disorders. Dr. Hanning's report, *'Wind Turbine Noise, Sleep and Health'*, dated November 2010, is essential reading for EHO's and EPO's considering wind farm applications. Its 69 pages are a comprehensive compilation and analysis of all the relevant and pertinent research so far undertaken on the issue of wind turbine noise. *(The report can be downloaded from www.windvigilance.com)*

4c.3.33 Dr. Hanning's report has a simple, one sentence conclusion:

> **'The appropriate mitigation of sleep disturbance and annoyance from industrial wind turbine noise is a maximum external turbine noise level of 35dB(A) or a setback of at least 1.5km.'**

4c.3.34 The TDC Wind Energy Policy recommendation of 600 metres is just a starting point, but the applicant at Dunsland Cross chooses to ignore even this short and inadequate distance.

Is mitigation possible for AM and/or LFN?

4c.3.35 In every instance, mitigation for AM requires significant changes to be made **after** the turbines start operating. Either there have to be changes to the operational mode of the turbines or they have to be shut down completely or (re)moved, all of which wind farm operators are very reluctant to do. Operational changes result in a loss of electrical output. This represents a diminution of the benefit which would have been given full weighting in the balancing exercise which granted the project permission. Had the likelihood of the need for such changes been known at the time of the application, it may have tipped the balance towards a refusal of planning permission. The only mitigation at present for LFN is to site the turbines further away from nearby properties. Planners should, therefore, adopt the Precautionary Principle and invoke minimum distance criteria known to be protective to wind farm neighbours following analysis of the predicted noise using dB(G), dB(C) and dB(A) weighted models.

4c.4 Summary of this Chapter and Recommendation

Amplitude Modulation and Low Frequency Noise have been shown to be real problems affecting real people living next to wind farms worldwide. The current applicant has not addressed this problem and has no strategy for mitigation should it occur at Dunsland Cross.

Recommendation: REFUSAL

The applicant has failed to demonstrate that AM and LFN will not be a problem at this site. The reason for rejection last time still stands. Policies DVT11, DVT13 and CO16 are still not satisfied by this application.