Witness Reference Number SWFL8. 2

Electricity Act 1989 (Sections 36 and Schedule 8)
Town and Country Planning Act 1990 (Section 90)
The Electricity Generating Stations and Overhead Lines (Inquiries Procedure) Rules 2007

Public Inquiry to consider Section 36 Electricity Act 1989 Application by Steadings Wind Farm Ltd for consent and deemed planning permission to construct and operate a wind farm at Kirkwhelpington, Northumberland (Known as Steadings)

PROOF OF EVIDENCE OF

KENNETH GWYNNE JAMES BSc

BRASEC, on behalf of Steadings Wind Farm Ltd

BERR Reference: GDBC/001/00278C

Tynedale Council Reference: 20060540

Northumberland Council Reference: 06/00023/CPC

18 January 2008, for Inquiry starting 15 January 2008

(Updated 24 January 2008 – See Change Record on Page 2)

Contents

Change Record

24/01/2008	Deleted reference to "air defence radars" in 4.1
	Inserted missing images in 9.2

1 Introduction

1.1 My name is Kenneth James. I have a degree in Mathematics, and have over 40 years of experience in the fields of Radars and other sensors and their integration into Command and Control systems. The time span includes 18 years in industry, 6 years on the staff of a NATO research agency, and 19 years as an independent consultant.

2 Experience

2.1 After graduating in 1964, I joined the Naval Systems division of Elliott Space & Weapon Systems (later part of Marconi Space and Defence Systems) as a software engineer, eventually becoming Chief Systems Engineer. The majority of the projects on which I worked were radar-related, and included radar displays and automatic tracking systems.

2.2 I then spent two years abroad, heading the development of one of the first marine radar tracking systems, known today as Automatic Radar Plotting Aids. In 1973 I returned to the UK, as Systems Engineering Manager of Marconi Radar's Leicester division. My department's primary responsibilities were the translation of customers' operational requirements into system design specifications, the design of radar displays and automatic radar data extraction and track processing systems. Nine years later, after a short period as Advanced Projects Manager of another defence systems company, I joined a NATO research centre as a radar consultant to the NATO Airborne Early Warning System, For 6 years on NATO's staff, and for a further 12 years part time as a private consultant, I gave key technical advice to that project as it went through 2 major performance improvement programmes.

2.3 As a private consultant, I have acted (and continue to act) as a radar adviser to various companies in the UK, USA and Europe in the defence, aerospace and wind energy sectors, and also to two different groups within QinetiQ, the now-privatised portion of the former Defence Evaluation & Research Agency. I have also developed and supplied experimental radar displays and fully automatic primary radar and secondary radar data extraction and track processing systems to QinetiQ and the Royal Navy's Maritime Warfare Centre. I will briefly describe these two different types of radar later. I have also helped my clients to define and develop techniques for multi-sensor integration and data fusion – basically ways in which the deficiencies of single radars can be overcome by combining data from other radars. One of my clients, with my help, recently won a major contract to develop and supply a system networking together all the radars (and other sensors) in a European country, and I continue to support that project. The primary purpose of this system is to exploit the overlapping coverage of the radars to provide a unified nationwide air situation picture.

3 Instructions from Client

3.1 My instructions are to examine the likely radar impacts of the proposed Steadings Wind Farm, having particular regard to the objections raised by Newcastle International Airport (NIA), the Ministry of Defence (MoD) and NATS En-Route Ltd (NERL).

4 Scope of Evidence

4.1 My evidence starts with a brief, not-too-technical description of the types of radars used to support air traffic management operations. The overview highlights the advantages and disadvantages of each type. It goes on to explain the unwanted impacts on primary radar of natural and man-made objects and phenomena other than the aircraft of interest to an air traffic controller. It then considers the general concerns about wind turbines and wind farms, as described in the document "Wind Energy and Aviation Interests – Interim Guidelines" (commonly referred to simply as the "Interim Guidelines") and the Civil Aviation Authority's CAP 764. Finally, I address specifically the proposed Steadings wind farm and its likely impacts on the previously-mentioned primary surveillance radars and, more importantly, on how these impacts will be seen on the air traffic control displays. The assessment is extended to include the cumulative impacts of the other nearby wind farms included in this joint hearing.

4.2 Where appropriate, points raised in my evidence are illustrated by images recorded from typical air traffic control radar displays.

4.3 My evidence should be read in conjunction with that of Messrs Trott and Spaven. Under Mr Spaven's leadership, we have jointly produced a draft Aviation Report, and this is appended to his proof. At the time of writing, the Aviation Report remains as a draft, pending receipt of additional information we have requested but have either not yet received or which was not received in time for full consideration.

4.4 Those parts of that draft report relating in particular to detailed radar technical matters should be considered as part of my evidence. Given the continuing state of flux, I reserve the right to add to or amend my evidence as appropriate.

5 Primary & Secondary Surveillance Radars

5.1 Radar surveillance coverage of aircraft for civil and military air traffic control purposes is provided by a combination of Primary Surveillance Radars (PSR) and Secondary Surveillance Radars (SSR). At NIA, radar coverage is provided on-airport by a Marconi S511 PSR plus a nearby SSR. The MoD's EWTR at RAF Spadeadam has two ATC radar sites, each equipped with a Plessey Watchman PSR. The PSR at Deadwater Fell has its own co-mounted SSR, while a second, stand-alone SSR is located at Grey Mare, approximately 1.7nautical miles from the other PSR at Berry Hill. The Great Dun Fell radar site is owned and operated by National Air Traffic Services (En-Route) Ltd. (NERL), and comprises an HSA D-band long-range en-route PSR with co-mounted SSR.

5.2 The following greatly simplified description of radars is intended to describe the similarities and differences between PSR and SSR, and to show how they are used for air traffic control purposes

5.3 It should be noted that the terms “primary” and “secondary” serve only to distinguish between the types, and do not indicate their relative importances.

5.4 Both types of radar transmit radio-frequency signals through a rotating antenna which concentrates most, but not all, of the radiated signal in a particular direction, and which captures the returned signal. Both measure the direction to any detected object by taking the direction in which the antenna is pointing when the return is detected, and both measure range by timing the interval between the transmission from the radar and receipt of the return.

5.5 Primary radars use the reflected energy from the object as the returned signal, and hence are capable of detecting so-called non-cooperative targets, i.e. ones not fitted with any special equipment. A primary radar can therefore detect aircraft that may not wish to be detected, but the maximum range at which small aircraft can be reliably detected is much less than that for large aircraft such as airliners. Note that aircraft are not the only types of objects that can be detected, although they are the ones of interest to an air traffic controller. We use the term “clutter” when referring to any radar detections caused by reflections from objects which are not of interest to the radar user.

5.6 It is important to note that the types of PSR used for ATC purposes can measure only the range (actually the slant range) and direction (or bearing) to an aircraft; they do not provide any indication of the aircraft’s height. This means that two aircraft at the same slant range and bearing but at different heights will appear to be in the same position on a radar display.

5.7 An SSR relies for its operation on cooperative targets, i.e. aircraft fitted with a piece of equipment known as a transponder (an amalgamation of the words "transmitter" and "responder"). The signal from the SSR is detected by the transponder, which then replies by transmitting its own signal back to the radar. The advantage of this approach is that the signal strength received back at the radar is governed by the power of the transponder and not the size or reflective properties of the aircraft, so maximum detection range is not dependent on aircraft size. Clutter is not a problem with SSR, as only aircraft carry transponders. These two points add up to much more reliable performance at long ranges with cooperative transponder-equipped targets.

5.8 We should all be aware that the Civil Aviation Authority already encourages all aircraft, no matter what their size, to carry and use transponders, although this is not yet a legal requirement. The CAA plans to make transponders mandatory in controlled airspace from 31st March 2008, but there will be a transition period before full implementation is possible. Unlike primary radars, SSRs are not affected by clutter reflections, although other problems may arise if strongly-reflecting objects like turbines or buildings are sited close to the radar. Steadings wind farm is well away from any SSR site, and these problems will not occur.

5.9 An SSR asks various questions of an aircraft's transponder. It does this by modifying the signal it transmits. The transponder recognises the type of transmission or interrogation, and sends the appropriate reply. In a civil aviation environment, the main modes (questions) are Mode A ("who are you") and Mode C ("how high are you flying"). The Mode A interrogation causes the transponder to transmit the "squawk code" assigned to the aircraft by the air traffic control authorities, and allows particular aircraft to be identified on the ATC screens. Mode C causes the transponder to report the aircraft's Flight Level, a value from which height above sea level can be derived when corrected for sea level barometric pressure. By mixing the two interrogation modes, an SSR can identify and keep track of aircraft in three dimensions.

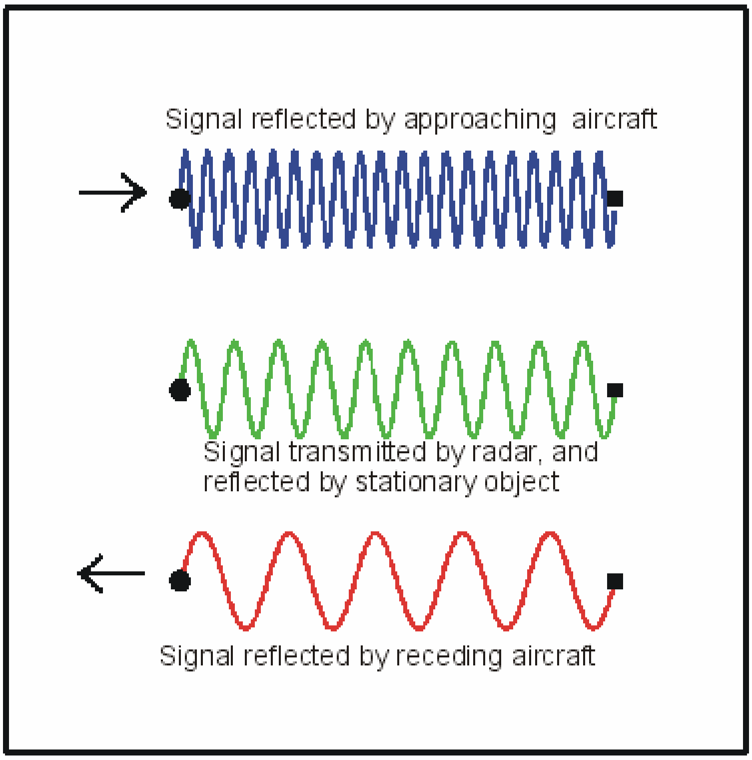
5.10 Some SSRs operate in isolation, as do some PSRs. A PSR on its own can detect targets not fitted with transponders and, of course, those whose transponders are defective or which have been turned off. It does not, however, have the range performance advantages that come with the use of transponders. An SSR on its own has the range advantages that come with the use of transponders, but cannot detect targets not fitted with transponders or those whose transponders are defective or which have been turned off.

6 Radar Clutter

6.1 As an SSR only detects transponders, it is immune to what is known as “clutter”, i.e. the detections of real radar echoes which come from objects that are of no interest to the radar user. In the case of a land-based PSR, clutter may be caused by radar detection of trees, buildings, rain, road traffic vehicles, flocks of birds, hills, industrial chimneys, TV transmitter masts, reflections from the ground itself, waves and ships at sea, and wind turbines. Depending on where it appears on the radar display, clutter may be a distraction to the radar operator. It may also make it more difficult for the operator to recognise the presence of an aircraft in the immediate vicinity of the clutter or, if the clutter reflections are strong enough, even stop the radar detecting the aircraft. For this reason current ATC radars incorporate sophisticated processing techniques for eliminating as much of the clutter as they reasonably can, while still detecting and reporting aircraft.

6.2 To achieve this, a PSR relies on two related features that serve to distinguish an aircraft from the unwanted clutter – the aircraft is moving fairly fast, and hence it is in a different position each time it is seen by the radar. The PSR incorporates two different processing techniques to exploit these distinctions. The first is called Moving Target Detection (MTD) or Moving Target Indication (MTI) depending on its detailed technical implementation, the second is called Clutter Mapping (sometimes known as Area MTI). For our purposes, the differences between MTI and MTD are immaterial, so in what follows just the abbreviation MTI is used.

6.3 MTI relies on the fact that an object moving towards or away from the radar will reflect an echo back to the radar that is at a slightly different frequency to that transmitted by the radar. This frequency change is known as the Doppler Shift.



6.4 The MTI process tries to cancel signals that do not have this Doppler shift while preserving those that do have it, on the assumption that clutter-causing objects move slowly and aircraft move rapidly. The technique is extremely effective, but does have its limitations. Firstly, some clutter is moving clutter, for example wind-blown rain, birds, high speed road traffic, and rotating wind turbine blades. Secondly, the Doppler shift is caused only by the component of the aircraft's velocity directly towards or away from the radar. An aircraft flying at high speed tangentially to the radar causes no Doppler shift. In practice, MTI does not fully cancel the near-stationary clutter, but it does significantly attenuate its signal strength compared to the signal reflected by the moving aircraft. If the background clutter is not too strong, this reduction is often enough to allow the detection of an aircraft that would otherwise be hidden by the clutter. This process provides what is known as "sub-clutter visibility".

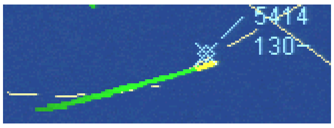
6.5 Clutter Mapping is used to suppress clutter signals and prevent them reaching the radar displays. It is also used to help detect moving aircraft, especially those on flight paths almost tangential to the radar which do not cause a large enough Doppler shift for detection by the MTI. The clutter map operates by remembering the radar signals it sees over and over again at every point in the radar's coverage. By comparing these memorised signals with the ones it has just received, it can decide if there is a signal present now that was not there previously. The clutter map is dynamic, i.e. it is constantly updated as the radar is operating. Clutter Mapping is also extremely effective, hiding from the radar displays the clutter that is constant from radar look to radar look, but it can only detect a real moving target whose echo is significantly stronger than the signal expected to be found in the clutter map at that position. This is known as "super-clutter visibility".

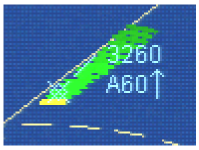
6.6 It is important to remember that the Clutter Map does not attenuate or cancel clutter in the same way as MTI – it simply hides it from the displays. Whether or not the clutter appears on the displays, it causes a loss of sensitivity in the radar at its position and so, depending on how strong the clutter signal is, it may reduce the radar's ability to detect aircraft above the area of clutter.

6.7 In areas where there is no clutter or only very weak clutter, aircraft not causing any significant Doppler shift can, of course, be detected. We call this "inter-clutter visibility".

6.8 The signals remaining in the MTI and Clutter Map channels are combined, and passed on to the radar displays. Some radars also include a device referred to as a "plot extractor". A plot extractor attempts to automatically recognise targets in the radar signal remaining after clutter processing in the MTI and Clutter Map, and to calculate their positions relative to the radar. These plot-extracted positions could be subjected to further processing to determine whether they were targets of interest (i.e. aircraft) or clutter, and used for automatic tracking. This further processing has been the basis of some of the proposed additional techniques that have been tested. The radars at NIA and EWTR do not incorporate plot extractors, although these were available as options when the radars were purchased. The GDF radar does have a plot extractor, and it is the plot extracted information, not the radar video, that is usually distributed to users.

6.9 At NIA and EWTR, the latest PSR positions are shown as bright radar echoes on the displays, while older ones from several previous turns of the radar antenna are shown at reduced intensity. This results in an aircraft's track being shown on the display as a trail of detections headed by one bright one indicating its current position, and a progressively darker "tail" behind it indicating aircraft direction and speed, the latter from the length of the tail or the spacing between previous detections. The illustrations, captured on a Flight Refuelling RDS1600 radar display similar to those used at EWTR but connected to an S511 radar as used at NIA, show this for aircraft flying directly away from the radar, tangentially, and diagonally respectively. In each of the three illustrations, the tail length represents 60 seconds of aircraft movement. Each of these aircraft is being detected simultaneously by the airport's primary radar (yellow head and green tail), and by a remote SSR (small, light blue symbol, with pointer to a text information block). The NIA displays are similar, but show the present aircraft position as bright green instead of yellow. The slight misalignment between the PSR echo and the SSR position symbol is due to the use of remote SSR information. At NIA and The Berry Hill site at EWTR, the SSR and PSR are close together and this misalignment does not occur.





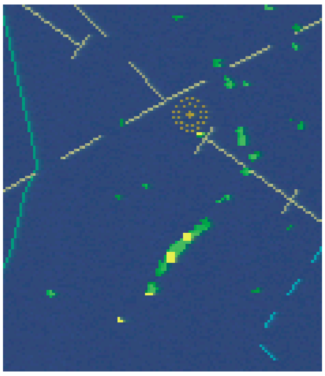
6.10 NIA has Park Air Nova 9000 displays – to a layman the only immediately obvious difference between the Nova 9000 and RDS1600 displays are the use of different colours.

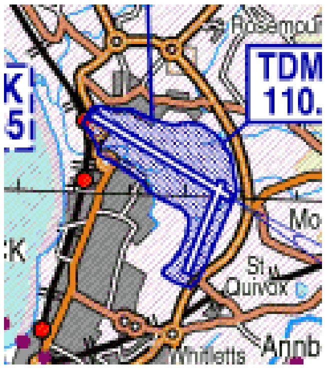
7 General Impacts of Wind Turbines

7.1 This section of my evidence addresses the general concerns about the possible problems that may arise when wind turbines are located close to radars. These concerns are summarised in Appendix D of the Interim Guidelines.

7.2 This states that "Radar systems are designed to detect moving targets and a wind turbine, when it is rotating, has the same characteristics as a moving aircraft". This is partially true, in that the turbine will be detected in both the Clutter Map and MTI channels of the radar (as I described earlier), but there is one essential difference. The turbine detections, although intermittent, will always occur at exactly the same position, whereas a moving aircraft will be seen to progress across the radar screen. Knowledge of where turbines are located will guide the air traffic controller's judgement as to whether or not a detection is an aircraft or turbine clutter.

7.3 Wind turbines are not the only cause of clutter to air traffic control radars. For example, high speed road traffic vehicles are also often detected by ATC radars and appear on the displays, as seen here, where the road traffic clutter (green and yellow blobs) is mapping out the shape of the bypass round Prestwick Airport. To help the air traffic controller to distinguish road traffic from aircraft, roads carrying such traffic are sometimes marked as lines on the displays.





7.4 The Interim Guidelines also refer to radar echoes from aircraft being "masked". Masking can be caused either by clutter (in this case the turbine reflections) or shadowing. With a moving aircraft, the clutter masking by an individual turbine will be fairly short-lived and therefore of little impact. In the case of relatively small area wind farms, aircraft cross the area in quite a short space of time, and their history trails serve as a reminder of their presence even if they are temporarily obscured by visible turbine echoes

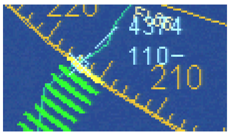
7.5 The shadow caused by each turbine (and other mast-like structures) is very narrow in angle horizontally, and little higher than the turbine vertically, and does not persist as a deep shadow for more than a few hundred metres beyond the structure, thanks to the way in which electromagnetic waves propagate. Section B5.14 of "Wind Farms Impact on Radar Aviation Interests – Final Report" [CD291] describes this effect.

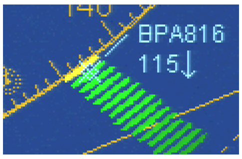
8 Radar Resolution Capabilities

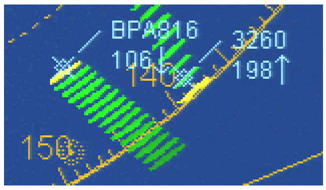
8.1 Turbines in a wind farm are typically spaced several rotor diameters apart. This immediately raises the question "Why can't radars see aircraft between the turbines?" The simple answer is that current air traffic control radars lack the ability to separately distinguish (resolve) closely spaced objects. In order to resolve two objects, the radar must be able to recognise a difference between them in either or both range and angle.

8.2 In the range dimension, the theoretical range resolution capability is set by the effective received pulse width of the radar. For the radars of interest, the effective received pulse widths are approximately equivalent to ranges of 150 metres (Great Dun Fell), 60 metres (EWTR) and 240 metres (NIA). Good sampling practice (Shannon's Theorem) dictates that the received signal should be sampled at least at twice the bandwidth, so a "gap" between adjacent objects of half the pulse width should suffice for resolution. Unfortunately, most ATC radar designs of this vintage do not seek to provide the excellent resolution capabilities that would go a long way towards helping to deal with any "wind farm problem". Their resolution capabilities seem to be geared solely towards comfortably meeting the aircraft to aircraft separation requirements of several nautical miles that you will hear about from others.

8.3 A similar problem exists in the angular dimension. The NIA and EWTR radars are each specified as having a beam width of 1.5 degrees, while the Great Dun Fell radar's is 1.2 degrees. However, there is no sharp cut off in radar detection performance outside this angle. In practice, aircraft echoes typically extend over twice the radar's beam width, as shown here by the displayed echoes from a radar that also has a 1.5 degree beamwidth. The radar echoes are clearly seen to be 3 degrees wide.



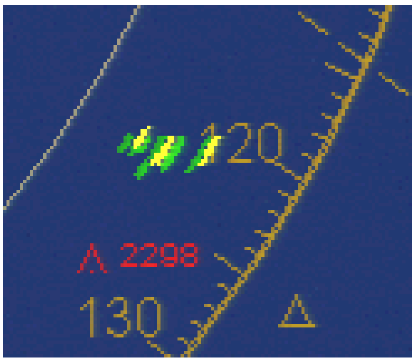


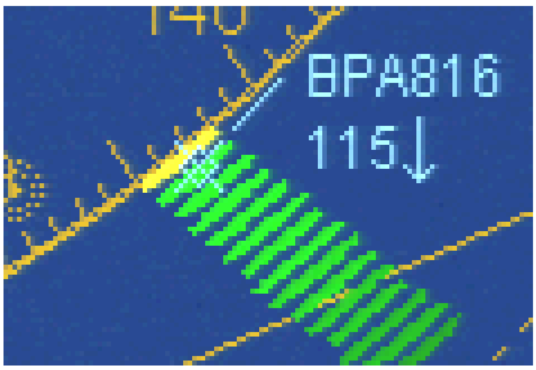


8.4 Although it is possible to improve the range resolution capabilities of radars at the design stage, improvements in angular resolution are limited by the physical size of the antenna.

8.5 The EWTR and NIA radars also incorporate the previously mentioned Clutter Maps. These divide the radar coverage into range-azimuth cells which, because of digital memory constraints when the radars were designed in the 1980s, are larger than they should be compared to the radars' theoretical range and angle resolution.

8.6 Wind turbines are radar reflecting objects, but their echoes are regarded as clutter and therefore as a nuisance by the air traffic control community. As with other forms of clutter, the radar processing attempts to suppress their radar reflections. Unfortunately the designers of radars of the same vintage as those we are considering did not consider the future need for coping with wind turbines which simultaneously exhibit the characteristics of both stationary and moving objects, and neither the clutter map nor the MTI processing is fully successful at suppressing turbine echoes. The end result is that wind farms are often clearly visible on the air traffic control radar displays, as on the left, below. Nevertheless, a windfarm seldom looks like an aircraft track, shown on the right.





8.7 In the clutter map channel, the reason for this frequent detection and display of turbine echoes is that a turbine, although stationary, changes its shape as its blades rotate, and so the strength of its radar echo fluctuates. This fluctuation is sometimes, but not always, large enough for the clutter map to think that there is a previously undetected echo at that position, which then gets reported instead of cancelled. General experience suggests that an individual turbine may be falsely reported roughly once every 6 to 8 scans of the radar, although there can be quite wide variations in this. The experience is supported by appropriate theoretical prediction techniques.

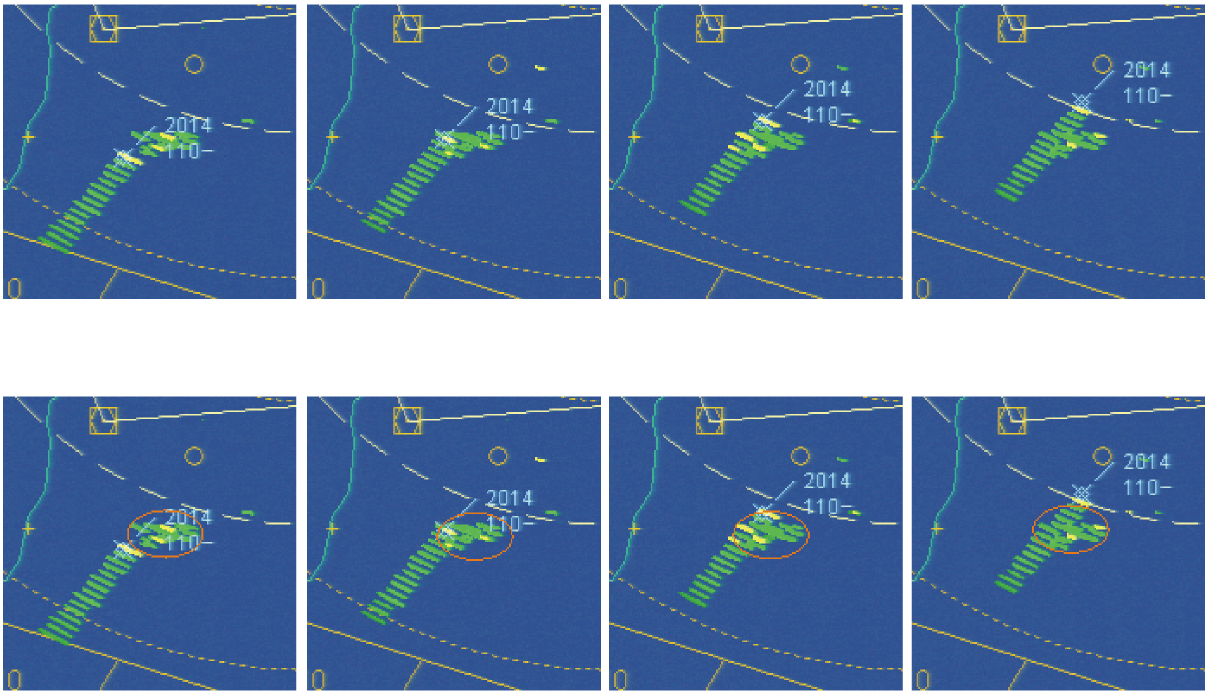
8.8 Observe that there is no obvious history trail in either of these images, thanks to the randomness of turbine detections and the irregular layout of the windfarms in question.

8.9 In the MTI channel, turbine detections sometimes occur because of turbine blade movement causing a continuous spread of Doppler returns corresponding to radial speeds ranging from near-zero at the blade roots to 75 metres per second (150 knots) or more at the blade tips. The upper limit is governed by blade speed and wind direction, and also blade positions at the instant that the radar looks at the turbine.

9 Conclusions

9.1 I do not propose to repeat extensively the matters already set out in sections 4, 5 and 6 of the draft Aviation report, relating to NIA, NERL and MoD/EWTR respectively. These include, for example, the possibility of establishing a particular local area within which the carriage and use of transponders would be mandatory. These matters, although not repeated here, still form part of my evidence. For present purposes, I will amplify just two matters.

9.2 One possible operational measure, applicable to the radar displays at NIA and EWTR, would be to provide the air traffic controller with visual cues and reminders that there are turbine echoes in areas of the display, and to act as an aide-memoire when distinguishing between turbine returns and those returns which controllers call “unknown traffic”. Images in this evidence have already given examples of how aircraft tracks and wind farms appear on ATC displays. The two groups of images below show an aircraft passing over a wind farm. The display is set up to show 1 minute of history behind the tracks, and the images were captured at 10 second intervals, so cover a period of 30 seconds. In each group, from left to right, the pictures show the aircraft approaching, inside, just exiting and clear of the wind farm. The only difference between the two rows of images is that an outline for the wind farm boundary has been added to the radar screen, as a reminder to the air traffic controller that any radar return shown outside this boundary is not turbine clutter, and that interpretation of what is inside the boundary should take into account the history trail from outside. The types of radar displays used at Spadeadam and Newcastle, although from two different manufacturers, both include readily updatable background maps that allow such areas of interest to be defined and displayed. The wind farm boundary can be drawn as a regular shape as shown, or as an irregular polygon, and the interior of the shape can optionally be shaded.



9.3 Where wind farm delineation, as just outlined, or other measures addressed in the draft Aviation Report are not considered to be sufficient, another possibility, in appropriate cases, is to use an existing radar, if one exists in a suitable location, to provide low altitude radar coverage above the proposed windfarms, but not so low that the turbines would be detected. Although not required here, such a remote source of radar data, free from turbine detections, could be used instead of or in addition to the local PSR data, and in combination with wind farm delineation as I have just described.

9.3.1 Aircraft (with a few exceptions) are required by the Air Navigation Order to keep at least 500 feet above obstacles except when taking off or landing, so this sets a target for the lower limit of radar coverage from the additional radar of 500 feet above turbine tip height. The exceptions include police, air ambulance, search & rescue and pipeline & power line inspection helicopters and military low flying. This second radar could then act as “gap filler” above the areas affected by wind farm clutter. This is the solution being implemented to overcome Glasgow Airport’s problems with the Whitelees wind farm, using a supplementary radar at Kincardine.

9.3.2 Accommodating this existing additional source of radar data can be achieved in one of several ways. As the remote radar’s data would be in plot-extracted format, it can be displayed in the same way as the local SSR data is handled at present, as symbols and labels. The display systems' existing source selection capabilities allow different sources of radar data to be switched on or off across the whole of the display coverage, permitting them to be used individually or in combination. Changes to the ATC display system software would allow areas to be defined on the displays in which selected sources would be displayed as an alternative to full-coverage selection.

9.3.3 An existing radar that could act as a gap filler above the Steadings wind farm is the NATS en-route radar at Lowther Hill. The wind farm is terrain shielded from Lowther, but the radar provides coverage down to a reasonably low level above the turbines. The NATS Lowther Hill radar data is, of course, already available to NATS and some of its clients, either as the main radar feed or as a backup feed when the preferred main feed (e.g. Great Dun Fell) is not available. The EWTR at RAF Spadeadam already uses NATS data from Great Dun Fell. On the day of our visit to Spadeadam (9 January 2008) the radar data backup from Lowther Hill was, in fact, being used

9.4 Raytheon, the supplier of the new radars being installed by NERL, are investigating ways to enhance the performance of these new radars in the presence of wind farms.

9.5 In conclusion, the easily achievable marking of wind farm outlines on the ATC displays can, on its own, help the air traffic controller to avoid confusing turbine clutter with aircraft returns. Athough not required here, a potential additional and existing source of radar data, free of turbine clutter from Steadings and the other two wind farms, is the NATS radar at Lowther Hill. This is already available and used at RAF Spadeadam.

9.6 Based on my experience in the areas of radars and their associated processing and display systems and the potential availability of practical measures such as those I have outlined, I do not consider that there is any justification for refusing Steadings, in isolation or cumulatively, on radar grounds.

This concludes my evidence and finally, I confirm the following:

- I understand my duty to the Inquiry and have complied, and will continue to comply, with that duty.
- I confirm that this evidence identifies all facts which I regard as being relevant to the opinion which I have expressed, and that the Inquiry's attention has been drawn to any matter which would affect the validity of that opinion.
- I believe the facts stated within this proof are true and that the opinions expressed are correct.

Signed………………………………… Dated…………………………………