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HLW85/2111/50177/ID
Date: 13th Feb 2008

ADATS IPT TB3B FEASIBILITY ASSESSMENT OF THE POSSIBLE TILT OPTIONS FOR THE RAF SPADEADAM WATCHMAN RADAR SYSTEMS

References

A. Mark Spencer Proof of Evidence in support of MoD objection for Northumberland (Green Rigg/ Ray/ Steadings) Windfarm Public Inquiry.
B. WPD/6/2 – Alan Collinson Proof of evidence on behalf of Wind Prospect Development Ltd.
C. WPD/5/2 – John Taylor Proof of evidence on behalf of Wind Prospect Development Ltd.

INTRODUCTION

1. Under Work Request (WR50177) the Air Defence and Air Traffic Systems Integrated Project Team Technical Branch (ADATS IPT TB) was tasked to complete a technical study on the possible effects of three proposed Windfarms on the Air Traffic Control (ATC) Radar Systems owned and operated by the Ministry of Defence at and around RAF Spadeadam. The results of the study are detailed at reference A.

2. At Reference B and C, a number of possible mitigation measures against the proposed windfarms were suggested. This document is designed to address one of those possibilities: the “tilting mitigation”. This involves tilting the antenna of one of the Spadeadam Watchman radar systems sufficiently so that the signal strength from the wind turbines is less than the minimum discernable signal of the Watchman radar. Then, using a Range Azimuth Gating (RAG) facility on the other Watchman radar, remove the wind turbines from the operators display.

3. If this option is believed feasible a further feasibility study would need to be conducted to determine how the two watchman radar systems could be configured to provide a composite picture.

AIM

4. The aim of this report is to:

a. Identify the predicted radar coverage for the Berry Hill Watchman currently installed at RAF Spadeadam.

b. Determine the amount of mechanical tilt that would be required to ensure the predicted signal strength for the proposed wind farms are reduced sufficiently so that they would not be displayed on the Berry Hill radar operators' console.

c. Identify the predicted radar coverage for the Berry Hill Watchman radar with the required tilt applied.

d. Identify the predicted radar coverage for the Deadwater Fell Watchman currently installed at RAF Spadeadam.

e. Determine the amount of mechanical tilt that would be required to ensure the predicted signal strength for the proposed wind farms are reduced sufficiently so that they would not be displayed on the Deadwater fell radar operators' console.

f. Identify the predicted radar coverage for the Deadwater Fell Watchman radar with the required tilt applied.

PREDICTED RADAR COVERAGE FOR BERRY HILL WATCHMAN RADAR

5. At reference A the predicted signal strength from each of the proposed wind turbines as presented to the Berry Hill Watchman radar was calculated. For convenience, Table 1 shows the strongest predicted signal strength from each of the windfarms. The Turbine Number given identifies the turbine which produces that signal.

Windfarm	Turbine Number	Turbine position			Predicted Signal Strength		Radar Beam in which the windfarm is located
					Moving	Static	
Green Rigg	6	NY	391067	582202	-108.2	-109.3	Aux beam
Steadings	16	NY	395895	581277	-94.1	-91.4	Main beam
Ray Estates	10	NY	395031	586263	-96.3	-115.9	Main beam

Table 1 – strongest wind turbine predicted signal strength for Berry Hill Radar

6. Figure 2 illustrates a typical Watchman radar antenna pattern (shape), the antenna pattern is such that the gain reduces rapidly for targets at very low elevations. This region of the antenna can be exploited to control the returned signal strength of low elevation targets; for example if the radar is to be used to control aircraft flying at low altitudes it is common to tilt the antenna downward so that the wanted returns from low level aircraft are closer to the antenna peak of beam and the signal strength is therefore increased. Similarly when a radar system is sited in a location where increased clutter is expected then, if the operational requirement permits, the antenna could be tilted up slightly so that the unwanted returns from the clutter are further from the antenna peak of beam and therefore reduced in signal strength.

7. The MoD currently have 34 Watchman radar systems in service as ATC Radar systems, 12 of which have been mechanically tilted to allow for local terrain related issues, historically the Watchman antenna has been mechanically tilted from -1° to +1° in ½° increments, Table 2 details all current Watchman radar systems which are not aligned to 0°.

Radar	Current Tilt	Radar Beam switch setting
Akrotiri	+1.0°	14.0nm (Non Rag Setting)
Brize Norton	+0.5°	15.0nm
Cambridge	-0.5°	23.0nm (Non Rag Setting)
Cranwell	+1.0°	14.0nm
Culdrose	-0.5°	23.0nm (Non Rag Setting)
Deadwater Fell	-1.0°	19.0nm (Non Rag Setting)
Honington	-0.5°	19.0nm (Non Rag Setting)
Portland	-0.5°	19.0nm (Non Rag Setting)
Valley	-0.5°	19.0nm (Non Rag Setting)
Waddington	-0.5°	16.0nm
Yeovilton	+0.5°	15.0nm (Non Rag Setting)

Table 2 – Mechanical tilts employed in MoD Watchman systems

8. It is important to note that the Aux beam to Main beam switching range (beam switch) is directly linked to the mechanical tilt of the radar i.e. when a mechanical tilt is employed on a Watchman radar system it is common practice to adjust the beam switch range to account for the change in expected low level performance.

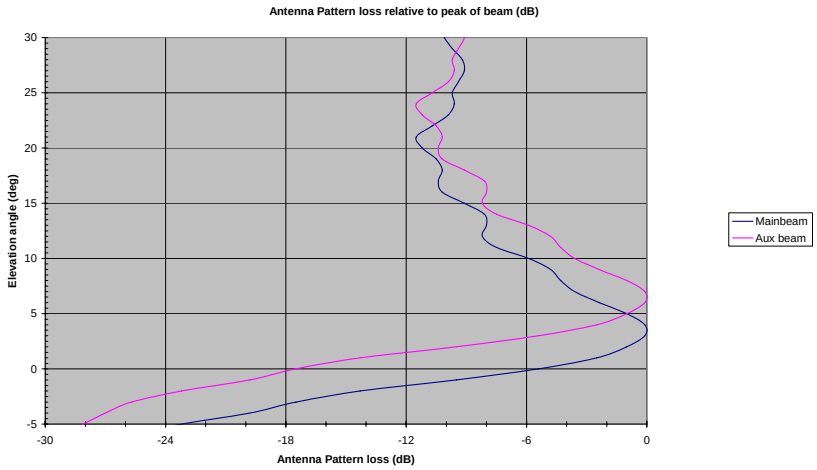


Figure 2 - Berry Hill relative antenna losses

9. Table 3 details the reduction in signal strength that may be expected if the Berry Hill antenna is tilted in ½° increments.

TILT WRT current setting	*MB antenna pattern loss*	*AB Antenna Pattern Loss*	Signal Strength reduction Main Beam	Signal Strength reduction Aux Beam
0.0	-5.4	-17.5	0.0	0.0
0.5	-7.3	-18.9	-3.8	-3.3
1.0	-9.5	-19.8	-8.2	-6.4
1.5	-12.0	-21.5	-13.2	-10.6
2.0	-14.3	-23.2	-17.8	-14.6
2.5	-16.1	-24.7	-21.4	-17.9
3.0	-17.5	-25.7	-24.2	-20.3
3.5	-18.8	-26.5	-26.7	-22.4
4.0	-19.8	-27.0	-28.8	-23.9

Table 3 - Berry Hill Signal Strength Reduction versus antenna tilt

10. The minimum discernable signal for the Berry Hill Watchman radar is -121dBm therefore, to remove each of the wind turbines from the operators' display, the following reduction in signal strengths and subsequent mechanical tilts are required;

Windfarm	Turbine Number	Predicted Signal Strength		Beam in which windfarm is located	Required reduction in signal strength	Required tilt
		Moving	Static			
Green Rigg	6	-108.2	-109.3	Aux	12.8	2.0°
Steadings	16	-94.1	-91.4	Main	29.6	>4.0°
Ray Estates	10	-96.3	-115.9	Main	24.7	>3.0°

Table 4 – Berry Hill required tilt

11. Figures 3 shows the current predicted radar coverage for a 1m^2 target[1] flying at an attitude of 500 metres above ground level.

[1] RSC of a Hawk fighter jet.

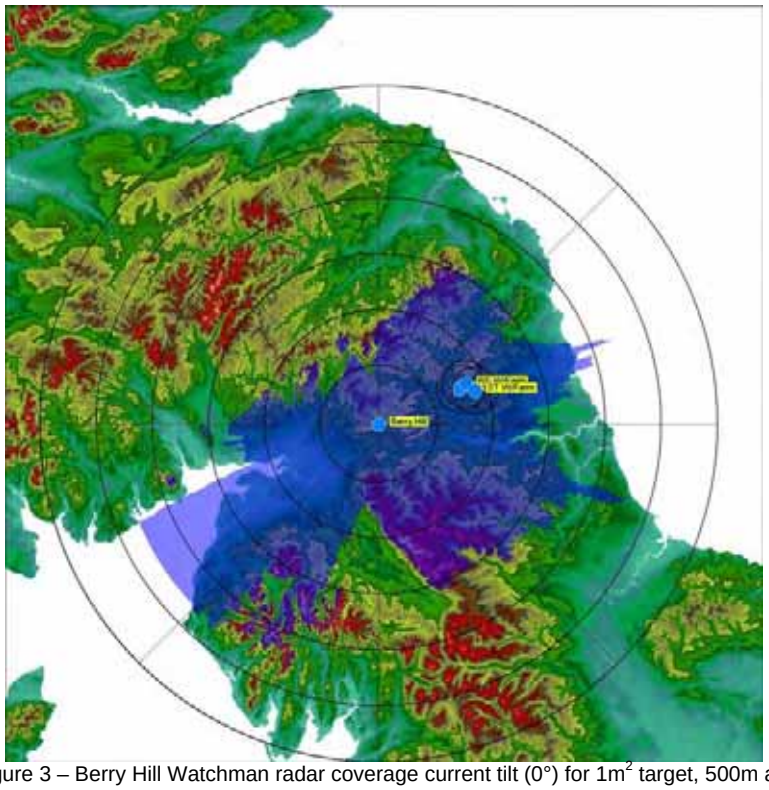


Figure 3 – Berry Hill Watchman radar coverage current tilt (0°) for 1m^2 target, 500m agl
Scale: Radar Range Rings at 10nm intervals, Windfarm Range Rings at 5nm from Windfarm centre
Key: White =sea level; Green = low-medium ground; Red = high ground; Blue = radar coverage

12. Figures 4 to 6 shows the predicted radar coverage for a 1m^2 target flying at an attitude of 500 metres above ground level for each of the mechanical tilts detailed at table 4.

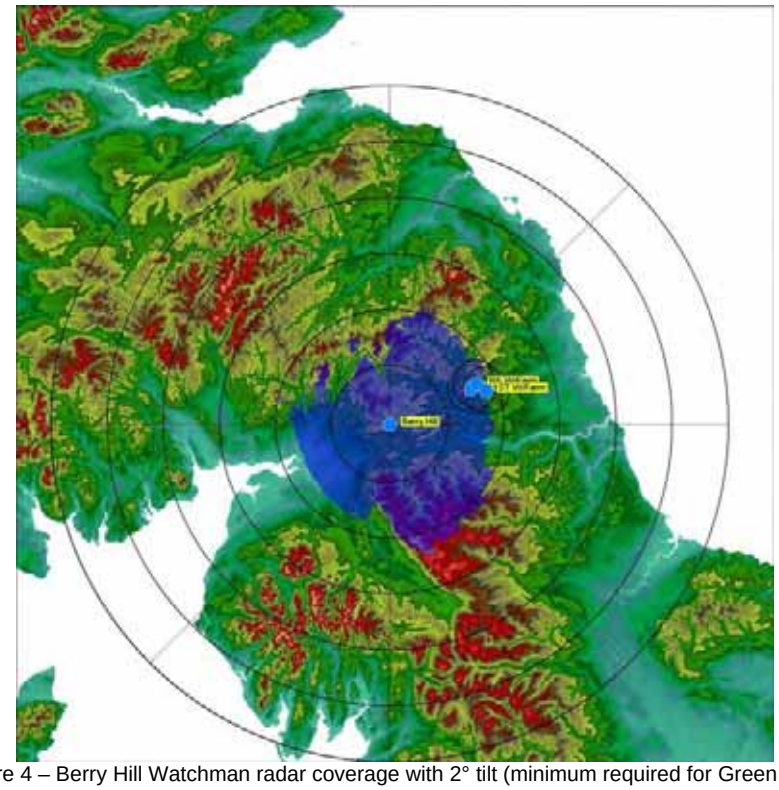


Figure 4 – Berry Hill Watchman radar coverage with 2° tilt (minimum required for Green Rigg)

Scale: Radar Range Rings at 10nm intervals, Windfarm Range Rings at 5nm from Windfarm centre

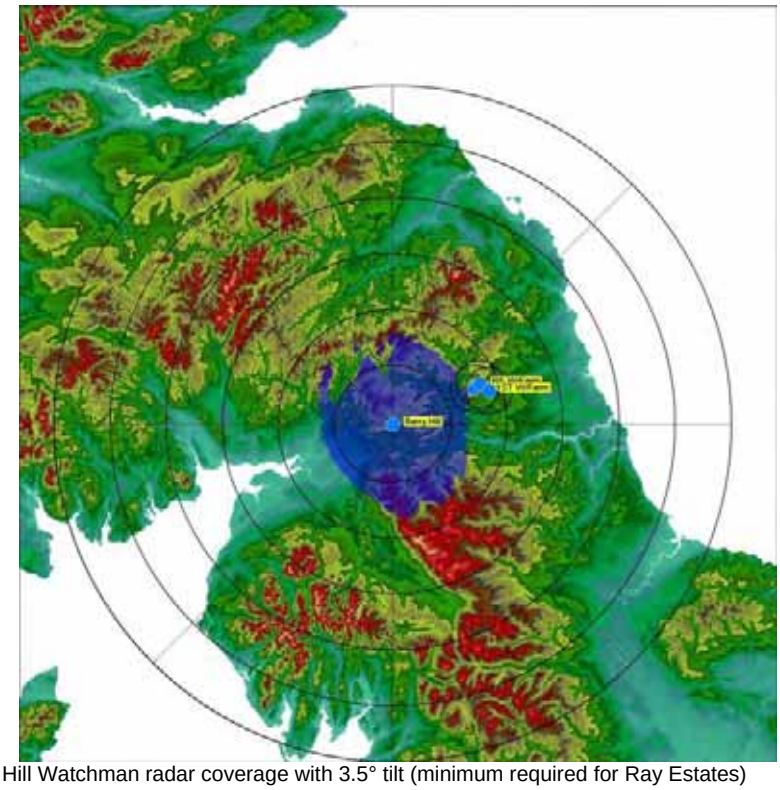


Figure 5 – Berry Hill Watchman radar coverage with 3.5° tilt (minimum required for Ray Estates)

Scale: Radar Range Rings at 10nm intervals, Windfarm Range Rings at 5nm from Windfarm centre

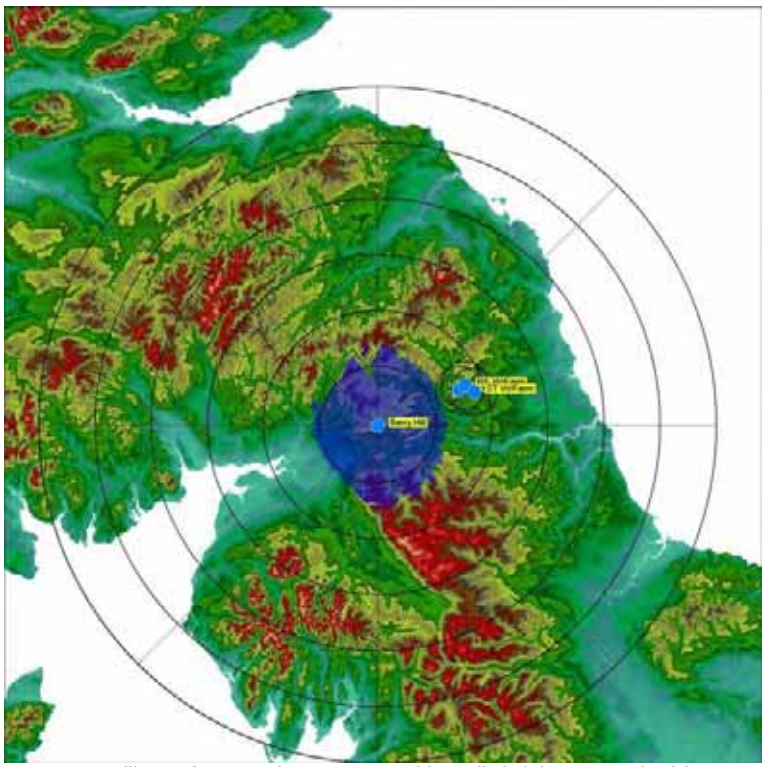


Figure 6 – Berry Hill Watchman radar coverage with 4° tilt (minimum required for Steadings)

Scale: Radar Range Rings at 10nm intervals, Windfarm Range Rings at 5nm from Windfarm centre

13. Figures 4 to 6 demonstrate the various tilt options have significantly reduced the expected Berry Hill radar coverage and that at 500m agl the

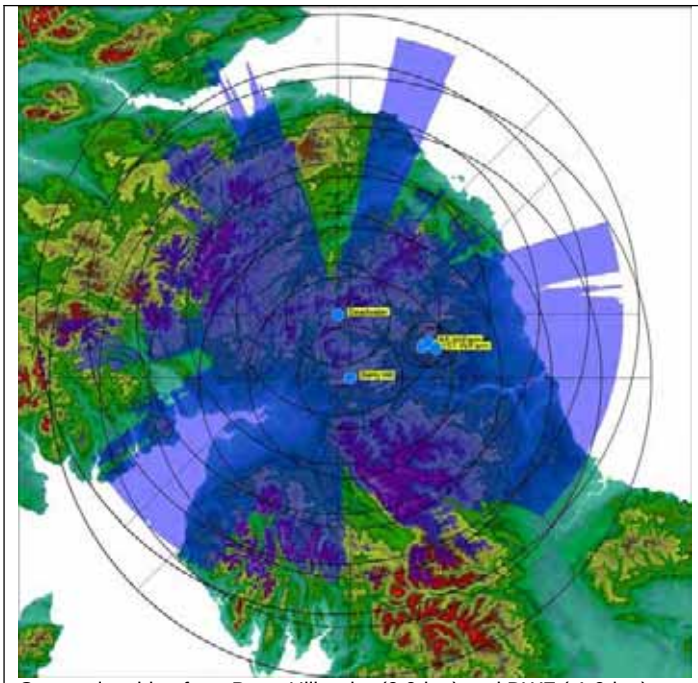
predicted coverage is such that there is insufficient coverage around the Windfarm (10nm from centre of the proposed Windfarm).

14. Table 5 details the predicted height at which a $1m^2$ target would have solid radar coverage around the proposed windfarm regions

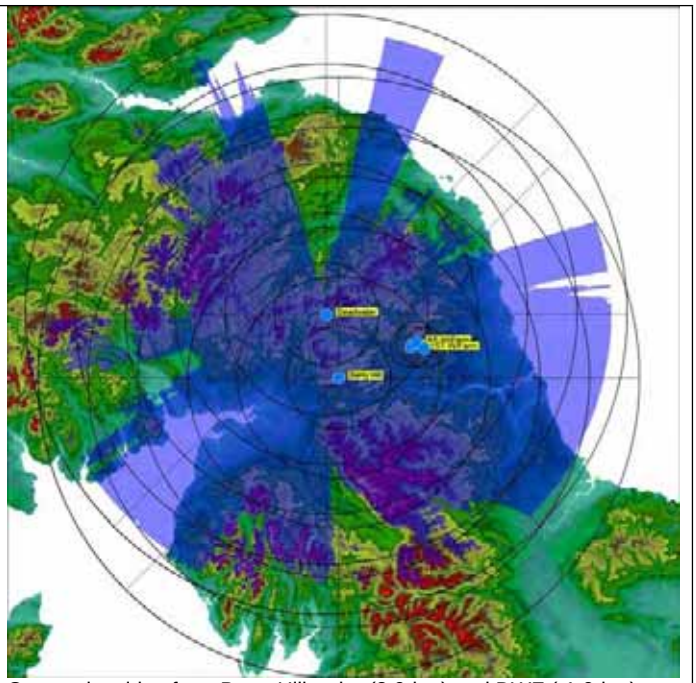
Antenna Tilt	*Windfarm removed*	*Height at which the predicted radar coverage surrounds the Windfarms by 5nm*	*Height at which the predicted radar coverage surrounds the Windfarms by 10nm*	Comments
0.0	None	300m (985ft) agl	375m (1230ft) agl	Current setting
2.0	Green Rigg	1000m (3280ft) agl	1500m (4920ft) agl	
3.5	Green Rigg and Ray Estates	1600m (5250ft) agl	2300m (7546t) agl	
4.0	Green Rigg Ray Estates and Steadings	2000m (6560ft) agl	2750m (9022ft) agl	

Table 5 – Radar coverage around proposed windfarm with various antenna tilts

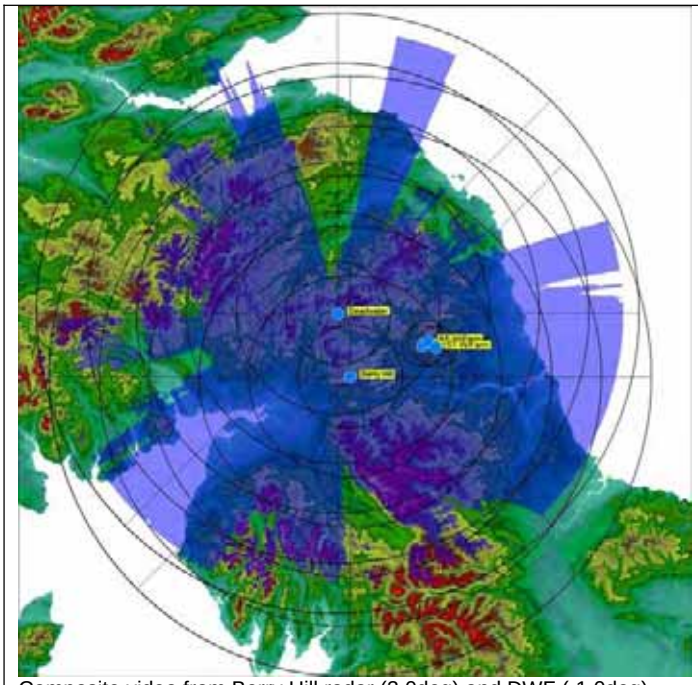
15. Figure 7 shows the composite video which could be made available to the operators at RAF Spadeadam if the various required tilts were employed on the Berry Hill Watchman radar.



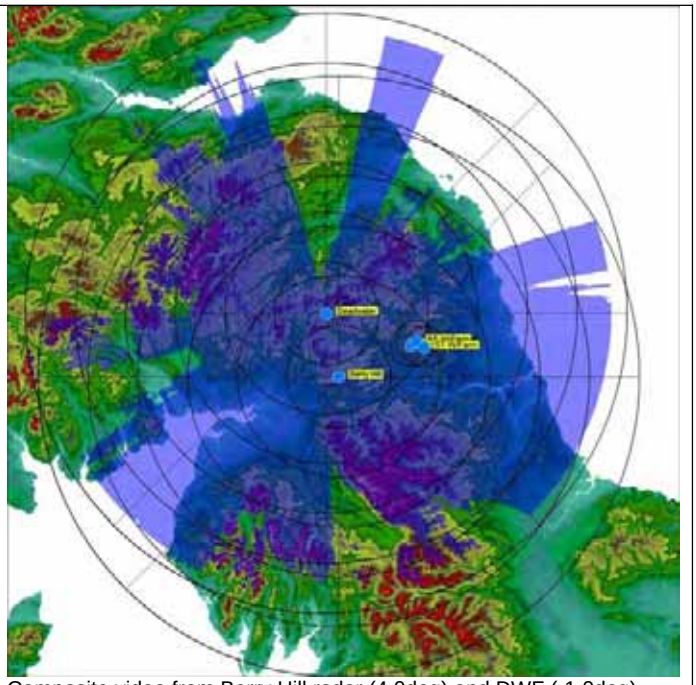
Composite video from Berry Hill radar (0.0deg) and DWF (-1.0deg)



Composite video from Berry Hill radar (2.0deg) and DWF (-1.0deg)



Composite video from Berry Hill radar (3.0deg) and DWF (-1.0deg)



Composite video from Berry Hill radar (4.0deg) and DWF (-1.0deg)

Figure 7 - composite predicted radar coverage 1m2 target at 500m agl

Scale: Radar Range Rings at 10nm intervals, Windfarm Range Rings at 5nm from Windfarm centre

16. Figure 10 suggest that despite tilting the Berry Hill Watchman radar there is very little difference in the overall radar coverage which is available at Spadeadam ATC however it is important to note that due to limitations in the Radar coverage prediction software the coverage from the Deadwater Fell radar could not be removed from the proposed Windfarm regions, therefore it is vitally important to note that the coverage in this area is not as it appears and should be read in conjunction with Table 5 above.

PREDICTED RADAR COVERAGE FOR DEADWATER FELL WATCHMAN RADAR

17. At reference A the predicted signal strength from each of the proposed wind turbines as presented to the Deadwater Fell Watchman radar was calculated. For convenience, Table 6 below shows the strongest predicted signal strength from each of the windfarms. As before, the Turbine Number given identifies the turbine which produces that signal.

Windfarm	Turbine Number	Turbine position			Predicted Signal Strength		Radar Beam in which the windfarm is located
					Moving	Static	
Green Rigg	6	NY	391067	582202	-108.2	-109.3	Aux beam
Steadings	16	NY	395895	581277	-94.1	-91.4	Main beam
Ray Estates	10	NY	395031	586263	-96.3	-115.9	Main beam

Table 6 – strongest wind turbine predicted signal strength for Berry Hill Radar

18. Figure 7 illustrates the expected Deadwater Fell Watchman radar antenna pattern, whilst Table 7 details the reduction in signal strength that may be expected if the Deadwater Fell antenna is tilted in ½° increments.

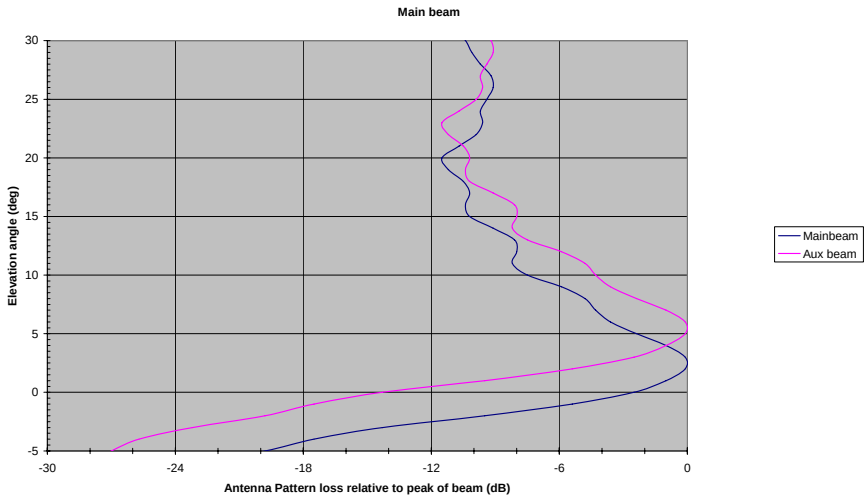


Figure 7 – Deadwater Fell relative antenna losses

TILT WRT current setting	*MB antenna pattern loss*	*AB Antenna Pattern Loss*	Signal Strength reduction Main Beam	Signal Strength reduction Aux Beam
0.0	-2.5	-14.3	0.0	0.0
0.5	-3.8	-16.0	-2.6	-3.0
1.0	-5.4	-17.5	-5.8	-6.1
1.5	-7.3	-18.9	-9.6	-9.4
2.0	-9.5	-19.8	-14.0	-12.5
2.5	-12.0	-21.5	-19.0	-16.7
3.0	-14.3	-23.2	-23.6	-20.7
3.5	-16.1	-24.7	-27.2	-24.0
4.0	-17.5	-25.7	-30.0	-26.4

Table 7 - Deadwater Signal Strength Reduction

19. The minimum discernable signal for the Deadwater Fell Watchman radar is -121dBm therefore to remove each of the wind turbines from the operators' display the following reduction in signal strengths and subsequent mechanical tilts are required;

Windfarm	Turbine Number	Predicted Signal Strength		Beam in which windfarm is located	Required reduction in signal strength	Required tilt
		Moving	Static			
Green Rigg	6	-106.9	-105.1	Aux	15.9	2.5° (1.5° above horizon)
Steadings	16	-101.7	-101.7	Main	19.3	3.0° (2.0° above horizon)
Ray Estates	10	-107.1	-104.0	Aux	17	2.5° (1.5° above horizon)

Table 8 – Deadwater Fell required tilt

20. Figures 8 shows the predicted radar coverage for a 1m^2 target flying at an attitude of 500 metres above ground level.

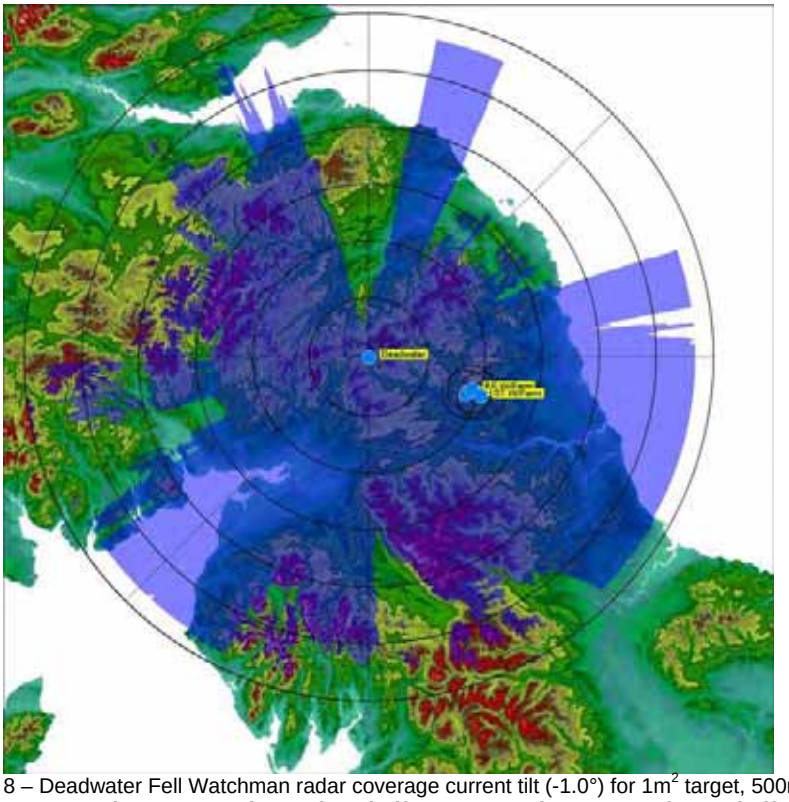


Figure 8 – Deadwater Fell Watchman radar coverage current tilt (-1.0°) for 1m^2 target, 500m agl
Scale: Radar Range Rings at 10nm intervals, Windfarm Range Rings at 5nm from Windfarm centre

21. Figure 9 shows the predicted radar coverage for a 1m^2 target flying at an attitude of 500 metres above ground level for a 2.5° tilt above the current setting (1.5° above the horizon).

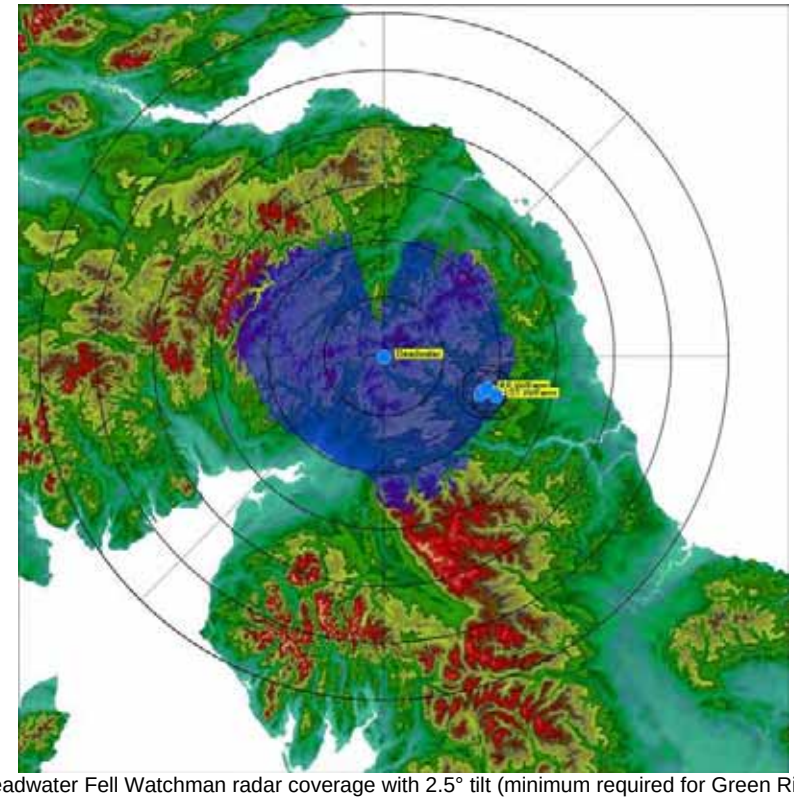


Figure 9 – Deadwater Fell Watchman radar coverage with 2.5° tilt (minimum required for Green Rigg and Ray Estates)
Scale: Radar Range Rings at 10nm intervals, Windfarm Range Rings at 5nm from Windfarm centre

22. Figure 10 shows the predicted radar coverage for a $1m^2$ target flying at an attitude of 500 metres above ground level for a 2.5° tilt above the current setting (1.5° above the horizon).

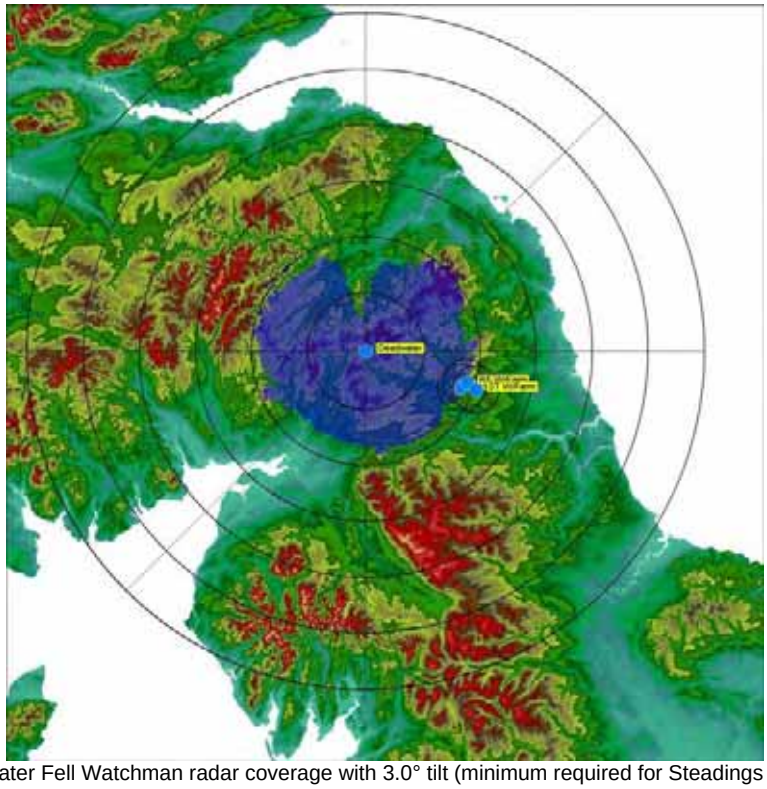


Figure 10 – Deadwater Fell Watchman radar coverage with 3.0° tilt (minimum required for Steadings Windfarm)
Scale: Radar Range Rings at 10nm intervals, Windfarm Range Rings at 5nm from Windfarm centre

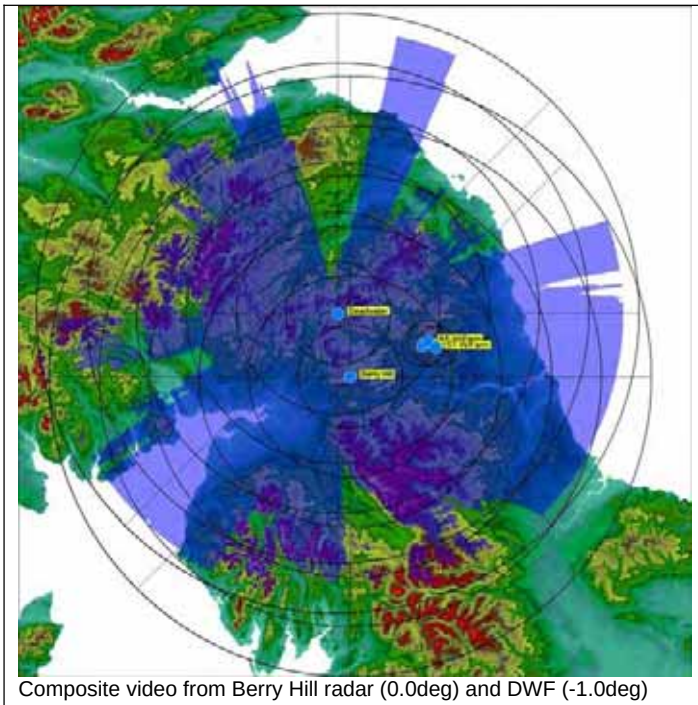
23. Figures 9 and 10 demonstrate the various tilt options have significantly reduced the expected Deadwater Fell radar coverage and that at 500m agl the predicted coverage is such that there is insufficient coverage around the Windfarm region.

24. Table 9 details the predicted base of radar coverage for each of the required tilts.

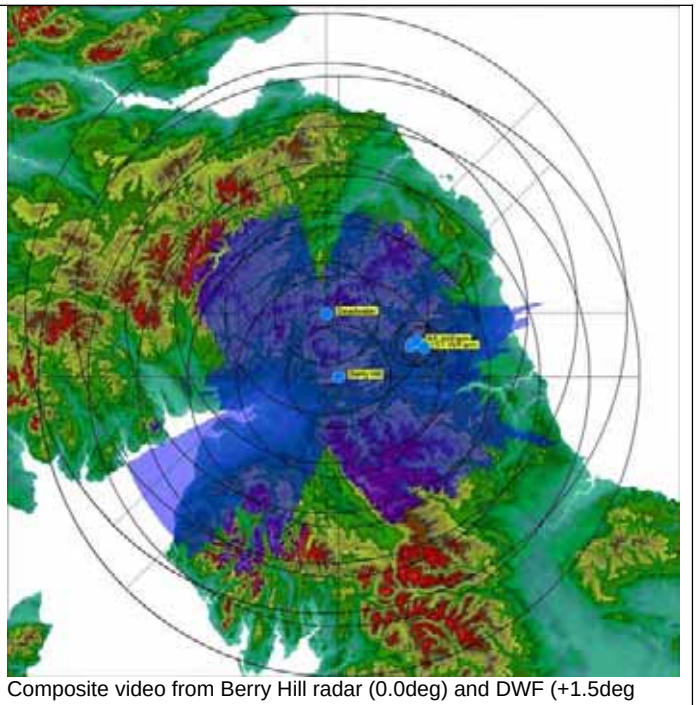
Antenna Tilt	*Windfarm removed*	*Height at which the predicted radar coverage surrounds the Windfarms by 5nm*	*Height at which the predicted radar coverage surrounds the Windfarms by 10nm*	Comments
-1.0	None	200m (656ft) agl	250 m (820ft) agl	Current setting
2.5 (+1.5 from Horizon)	Green Rigg and Ray Estates	750m (2460ft) agl	1200m (3937ft) agl	Significant loss of low level radar coverage
3.0 (+2.0 from Horizon)	Green Rigg Ray Estates and Steadings	1250m (4100ft) agl	1700m (5577t) agl	Significant loss of low level radar coverage

Table 9 – Radar coverage around proposed windfarm with various antenna tilts

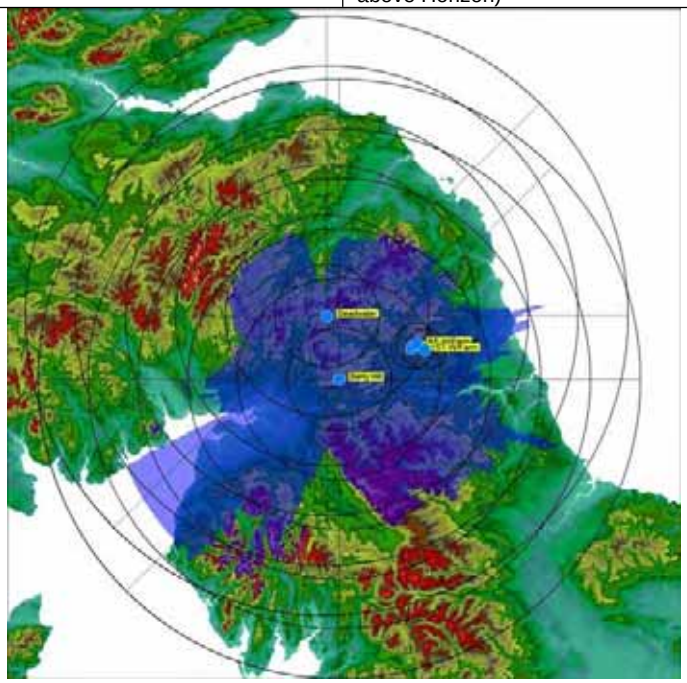
25. Figure 11 shows the composite video which could be made available to the operators at RAF Spadeadam if the various required tilts were employed on the Deadwater Fell Watchman radar.



Composite video from Berry Hill radar (0.0deg) and DWF (-1.0deg)



Composite video from Berry Hill radar (0.0deg) and DWF (+1.5deg above Horizon)



Composite video from Berry Hill radar (0.0deg) and DWF (+2.0deg above Horizon)

Figure 11 composite predicted radar coverage 1m2 target at 500m agl

Scale: Radar Range Rings at 10nm intervals, Windfarm Range Rings at 5nm from Windfarm centre

26. Figure 11 shows that by tilting the Deadwater Fell Watchman radar there is a significant reduction in overall radar coverage available at Spadeadam ATC. It is important to note that due to limitations in the Radar coverage prediction software the coverage from the Berry Hill Radar could not be removed from the proposed Windfarm regions, therefore it is vital that important to note that the coverage in this area is not as it appears and should be read in conjunction with Table 9 above.

ADDITIONAL INFORMATION

27. As stated previously the beam-switch position is linked to the mechanical tilt of the radar therefore if the tilt of the radar is increased it is required to reduce the range of the beam-switch position to compensate for a loss in low level performance close to the radar. Therefore if a windfarm is currently just outside the main beam region it is likely that the new beam switch position would place the windfarm in the main beam region, thereby increasing the predicted signal strength of the wind turbine. This would be the situation for Green Rigg with respect to Berry Hill radar and Green Rigg and Ray Estates with respect to Deadwater Fell radar.

28. The tilt required to remove the windfarm clutter from the Berry Hill radar is such that the radar is unlikely to be useable on its own; therefore it is important to note that should the predicted composite radar coverage be assessed as potentially acceptable for use at RAF Spadeadam it is likely that the Berry Hill radar would only be suitable for use in conjunction with the Deadwater Fell radar (e.g. if the Deadwater Fell Radar is unavailable or unserviceable then the Berry Hill Radar could not be re-configured to allow safe passage of aircraft).

29. Similarly, the tilt required to remove the Windfarm clutter from the Deadwater Fell radar is such that the radar is unlikely to be useable on its own; therefore it is important to note that should the predicted composite radar coverage be assessed as potentially acceptable for use at RAF Spadeadam it is likely that the Deadwater Fell radar would only be suitable for use in conjunction with the Berry Hill radar (e.g. if the Berry Hill Radar is unavailable or unserviceable then the Deadwater Fell Radar could not be re-configured to allow safe passage of aircraft).

30. The Berry Hill radar does not currently have RAG installed, therefore it is important to note there, should the Deadwater Fell Radar coverage after tilting be assessed as potentially acceptable, there would be a significant cost (both time and money) associated with upgrading the Berry Hill radar with RAG so that the windfarm clutter may be removed from the operators display.

31. It is possible to simulate the effects each of the various required tilts would have on low level targets by inserting a calibrated attenuator (value set depending on tilt to be simulated) into the receiver and then conducting a series of flight trials the particular areas of interest.

SUMMARY

32. If any of the tilts required to remove the clutter from the proposed windfarms is enforced on the Berry Hill radar then the radar coverage from Berry hill radar will be significantly reduced.

33. If any of the tilts required to remove the clutter from the proposed windfarms is enforced on the Deadwater Fell radar then the radar coverage from Deadwater Fell radar will be significantly reduced.

RECOMMENDATION

34. Air command operational staff assess the predicted coverage each of the options would give against the requirements of RAF Spadeadam ATC.

35. If any of the predicted coverages are deemed potentially acceptable then a series of flight trials should be completed assess the radar coverage with a simulated antenna tilt.

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