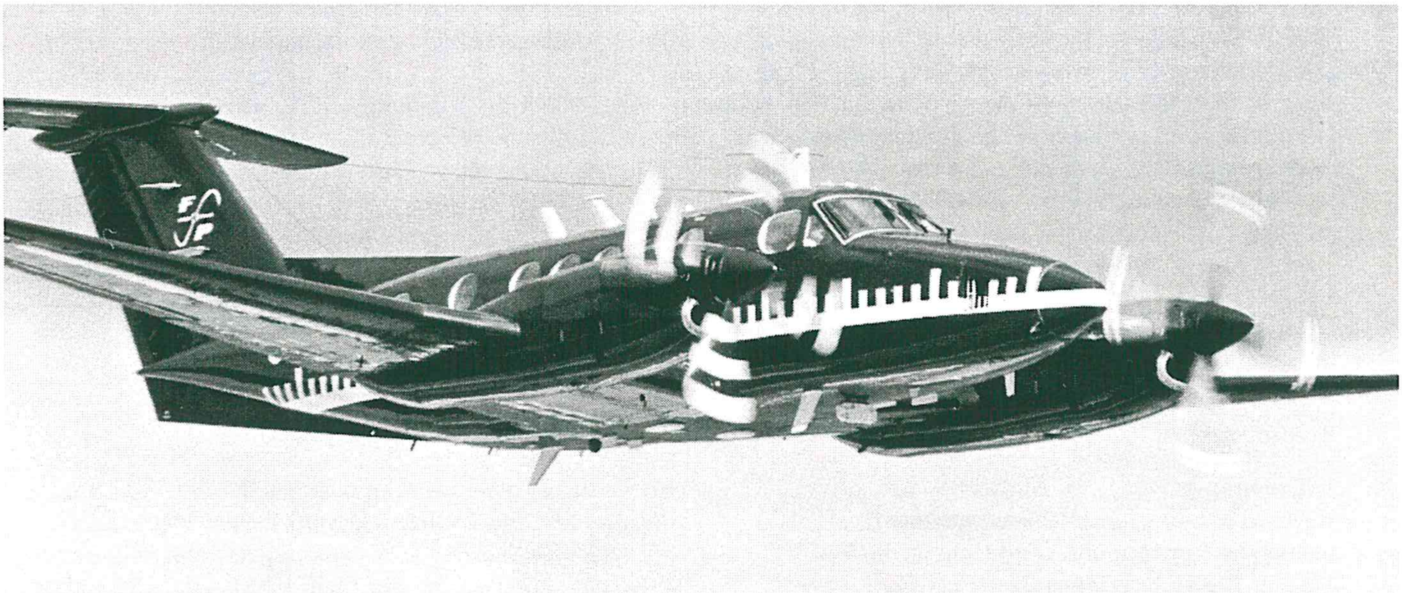
Primary Surveillance Radar Flight Inspection Using Calibrated Attenuators
17 May 2004



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Andrew Radforth joined the Royal Air Force in 1972 as a Direct Entrant Air Traffic Control Officer. He then undertook routine controlling duties, in time-honoured military tradition, at various locations in the UK and overseas. This time including a tour of duty at the London Air Traffic Control Centre (a sleepy hollow next to a place called London-Heathrow) where he was the Standards Officer, Training Officer and, finally, Examining Officer. Promotion to senior rank and a Staff tour then ensued, followed by 2 tours as Senior Controller at 2 major locations, each responsible for Air Traffic Services at multiple airfields. Posted to be the RAF's last officer with responsibility for flight inspection tasks, he retired from the RAF in 1999 to become Flight Precision Ltd's Contract Support Manager and more recently Sales and Marketing Manager.

ABSTRACT

1. The calibration of surveillance radar systems can be a time-consuming and therefore costly process. The performance of modern surveillance radars also requires the use of high performance aircraft; frequent requests are made for radar target aircraft capable of flight at FL 450 and above. This level of performance always comes at a price.

2. For many years FPL has calibrated the UK MoD's fleet of airfield ATC radars effectively using its fleet of King Air and Conquest aircraft using techniques developed with the Customer's electrical engineering development unit.

3. Using carefully calibrated attenuators, inserted into the radar system just before the flight check, FPL is able to conduct a thorough radar calibration. Its economical turbo-prop fleet and on-board flight inspection equipment provides the customer with a cost-effective solution to an ongoing requirement while simultaneously providing the end-user (the ATCO at the 'sharp-end') with confidence in the performance of his or her radar sensor.

4 This paper and presentation will outline the methodology used by FPL and UK MoD and describe the cost benefits, in reduced flying time, achieved using this process.

BACKGROUND

5. The UK MoD has always practised a policy of conducting a very thorough commissioning check of its newly installed Primary Surveillance Radars (PSRs) and, for that matter, its Secondary Surveillance Radars (SSRs). This paper is specially directed towards the PSR element of an airfield's sensor suite and the SSR aspect is therefore outside of the scope of this paper and will not be covered further. The PSR commissioning check was, and effectively still is, managed by the Royal Air Force Signal Engineering Establishment (RAFSEE), although this historical unit is now known as the **Directorate of Engineering, Interoperability & Information Systems** (DEI & IS). DEI & IS is responsible for analysing the flight inspection data, assessing the performance of the radar and, finally, releasing the equipment into service when satisfied that the radar is performing satisfactorily for the specified role.

6. After commissioning, UK MoD PSRs are subject to a routine annual maintenance programme. This maintenance programme, conducted by the RAF's **Ground Radio Servicing Centre** (GRSC – now **Expeditionary Radar & Airfield Section** – [**ERAS**]), is always followed by a flight check of the radar to ensure that the sensor was achieving optimal performance. This process is assisted by cross checking annual results against the commissioning data and, as historical data accumulates, the results of previous routine flight checks.

7. Since 1996, Flight Precision Ltd (FPL) has been the UK MoD's Flight Inspection Service provider. This responsibility has required FPL to liaise with ERAS to coordinate their servicing schedule with aircraft and Flight Inspection resource availability to enable the post-maintenance flight checks to be tasked effectively.

CUSTOMER REQUIREMENT

8. FPL's military customer has a remit to continue to reduce costs wherever possible. Due to the special partnering relationship that exists between FPL and its military customer, FPL has been able to work with its client to refine its inherited PSR flight check profiles, reduce flying time and therefore cost associated with this requirement. Moreover, these savings had to be realised without sacrificing standards, which, paradoxically, had to be maintained or preferably improved.

SOLUTIONS

9. The solution to MoD's requirements came in 3 phases:

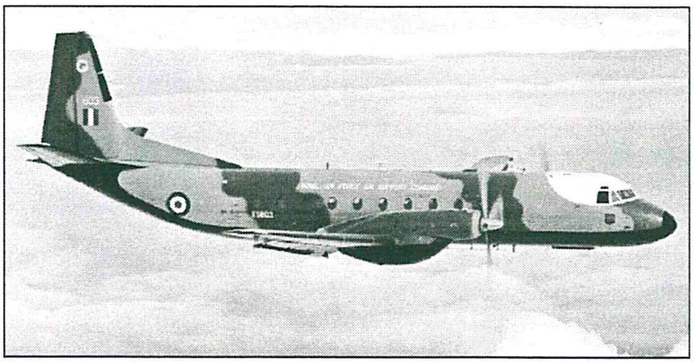
   a. Adoption of a turbo-prop aircraft fleet with a (relatively) high level cruise capability, in lieu of pure-jet aircraft and low performance turbo-prop types.

   b. Further development of radar attenuation techniques to 'shrink' the radar by an accurately known amount to reduce the amount of flying required checking the radar's lobe.

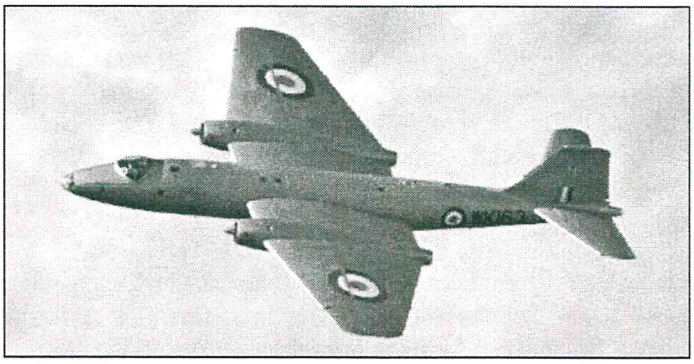
   c. Optimisation of the attenuation values to reduce further the high level flying in the face of increasing ATC restrictions on "Unusual Air Activities" in the Upper Airspace.

Aircraft Types

10. Under its previous arrangements the MoD had used Andover and Canberra aircraft for the 'low and slow' and 'high and fast' scenarios respectively. Both these types were well beyond their 'best before' date and were therefore very expensive to operate and increasingly difficult to maintain.



Andover C Mk 1



Canberra B Mk 2

11. FPL's solution was to select the very fuel-efficient and economical-to-operate Cessna Conquest II for its fleet. With a capability of achieving FL350 and a cruise speed of 280/290 kts, together with a bladder-stretching 7- hr endurance at that level, the Conquest showed great promise at meeting the contradictory MoD requirements. Fuel burn at high altitude is a miserly 500 lbs per hour, which is one sixth of the consumption of a Canberra's and one third of that of the Andover! Even modern, highly efficient, turbo-fan powered aircraft are very much more expensive to operate than an equivalent twin turbo-prop and, although capable of cruising at FL 470, the operating cost of such aircraft would usually make most military budget holders weep.

Cessna Conquest II

Radar Attenuation

12. The second solution was to develop further the technique of using attenuators to reduce the performance of a radar site by an accurately known amount.

13 The basis of the radar attenuation process is simple to understand: The performance of radar is basically determined by its power output and receiver sensitivity. Therefore, the place where the performance of the radar has to be assessed is at its fringes; ie:

a. At its maximum range.

b. At its maximum height.

c. At the zenithal gap (the overhead).

For a UK MoD 'Standard' Watchman PSR, the maximum range is 60 nm (with many going to 80 nm) and it has theoretical maximum height coverage up to 45,000 ft. See Fig 1 below.

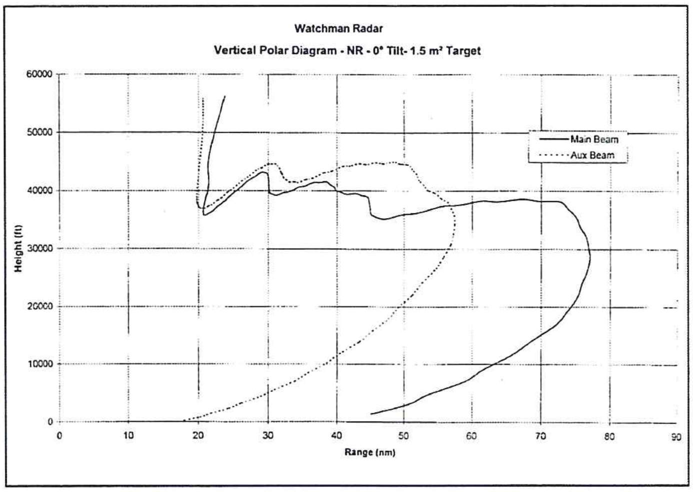


Fig 1

Of course, the maximum range of ATC En Route Radars is significantly more (200/250 nm/ 60,000 ft) and Air Defence Radars even greater.

14. To inspect these radars' fringe areas would require significant flying time. Moreover, the altitude requirement for an unsuppressed radar is obviously beyond the capability of even the Conquest II, which is why the Canberras were used to check the upper limits. However, uniformly reducing the radar's power output by introducing a precisely calibrated attenuator of known value into the waveguide, allows the suppressed radar's performance to be checked at much reduced ranges and heights. See Fig 2.

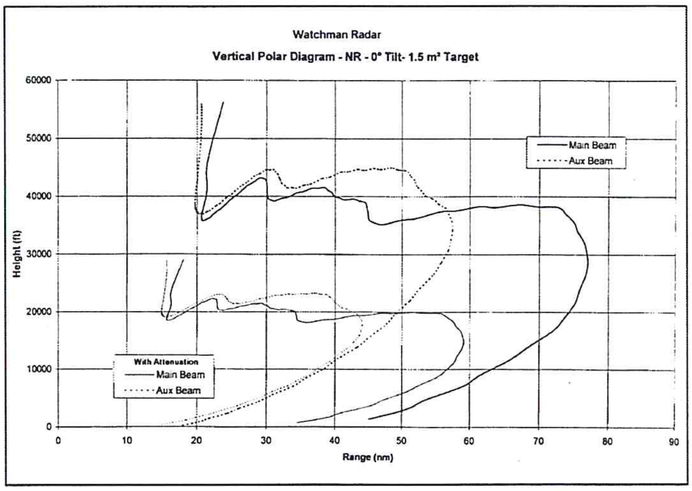


Fig 2

15. This technique had previously been used with the Andovers. However, the Andover had been restricted to around 22,000 ft (maximum height) and its substantial natural RCS required very significant levels of attenuation. On the other hand, the much-improved high-level performance of the Conquest II made the inspection of the radar's upper lobe more practical on a routine basis and the far smaller natural RCS of the Conquest did not require the extreme levels of attenuation required of the Andover. When first introduced the Conquests and more recently FPL's King Airs, routinely checked Watchman PSRs at 33,000 ft and higher. As a result, extensive and thorough flight inspections were conducted after annual maintenance had been completed leaving ATCOs confident that their main tool of the trade was in as good a condition as they could want.

Optimisation

16. Experience showed the new procedures to be valid. Failure rates of radars passing 'unrestricted' at the first attempt stayed constant but then showed a disconcerting increase as the fleet of radars aged and maintenance experience levels reduced.

17. FPL wanted to assist its customer further so that flying time was minimised. The slowly increasing numbers of repeat inspections to de-restrict radars and return others to service had an upward effect on the number of flying hrs expended on this aspect of the Contract and had started to cause concern to the customer. Additionally, FPL had begun to experience operational difficulties of a different kind. To ensure accuracy and repeatability, the blip/scan ratio method of flight checking a radar requires that the target aircraft to fly at a standard height above the aerial datum. Additionally, pressure correction errors have to be allowed for on a day-to-day basis. This resulted in FPL's aircraft being required to fly:

a. At non-standard flight levels, in the UK Class A Upper Airspace.

b. On non-deviating tracks to the radar head.

c. Tracks that presented a drift angle of less than 5° to the radar to ensure that the presented radar cross-section (RCS) integrity was maintained.

To say that FPL was not on the Christmas card list of the London and Scottish Air Traffic Control Centres would be to understate the situation, just ever so very slightly..........

18. As UK airspace capacity became more and more congested, it became increasingly difficult to be able to plan and negotiate the successful execution of a PSR flight check. The only option was to get out of the ever more busy Upper Airspace and into airspace where we would be less of an embarrassment to the UK ATC System and less reliant on obtaining permission to conduct our legitimate operations. Therefore, the decision had to be taken to modify FPL's flight profiles to ensure that our operations would remain below FL 245, clear of the UK Upper Airspace. This would have the additional benefit of further reducing the number of flying hours, per check, countering the upward trend resulting from the slowly increasing failure rate caused by the aging of the radar equipment.

19. This requirement meant that slightly higher attenuation values would be needed, although these values were still not as high as required for the Andover. DEI & IS arranged for these values to be calculated and the necessary hardware obtained. Flight profiles for the new attenuation values had to be designed for each model of radar for which FPL had inspection responsibility. Fortunately, these new profiles, did indeed, have the effect of reducing the overall time on task, to the benefit of the customer's budget.

20. The new profiles were an immediate success. Operational difficulties were significantly reduced and, although the rate of radars failing their first check after maintenance has not changed, the cost to the customer's flying time budget has reduced appreciably:

A TYPICAL WATCHMAN PROFILE

21. FPL employs specific personnel as Flight Inspectors (Radar) (FI [R]), who are ex-ATCOs, to conduct PSR and PAR checks; this policy ensures standardisation and assists repeatability of results, and provides a 'reality check' against some of the more obscure demands of the radar 'Boffins'! On PSR tasks, the FI (R) is in charge of the mission. The radial on which the check is conducted is first determined, first thing on the morning of the check. Ideally, this should be the radial used for commissioning the PSR, however, it is more important that the drift angle of the aircraft presented to the PSR does not exceed 5° to retain the integrity of the aircraft's calculated RCS. Having arranged the airspace coordination, the FPL aircraft deploys to the unit to be checked where the FI (R) is dropped off with the appropriate attenuators. Although provided by the MoD, FPL takes responsibility for the attenuators, ensuring that their routine calibration requirements are met and reducing the numbers of attenuator sets needed. While the attenuators are being fitted to the radar, the aircraft is refuelled and FI (R) briefs the duty ATC staff on the task to be flown and order of runs; a formal handover/takeover of the radar is also agreed, so that nobody is in any doubt as to who has control of the radar's configuration and that non-radar ATC services have to be provided.

22. As stated, a standard - 0° aerial tilt - UK military Watchman radar has a range of 60 nm and a maximum height capability of above 45,000 ft. The range alone would require the target aircraft to position to at least 70 nm to confirm the probability of detection at maximum range. However, due to the attenuators, the standard check profile requires the target aircraft to position at a range of 54 miles to commence the first run, which terminates at 40 miles. Due to the max all-up weight of the aircraft at this time, medium levels runs are conducted first, with higher levels following as fuel and weight is burned off. To provide the necessary statistical sample size, 3 runs are required at each height above the radar aerial with the FI (R) noting the blip to scan ratio on each run. The height for each run is predetermined by the configuration of each individual radar, with the aerial tilt and beam switch range (between High and Low Beams) being factors that the profile takes into consideration. Typically, runs are conducted at 8,000, 15,000 and 22,000 ft heights to provide sample 'cuts' of PSR's vertical polar diagram. One 22,000 ft run is continued into the overhead and out the other side to determine the size of the zenithal gap which must not exceed the value given by the formula:

$$\frac{2 \times \text{Aircraft Height above radar (ft)}}{6076} \text{ nm}$$

Finally, the check usually concludes with Surveillance Radar Approaches (SRAs) being conducted to any runways approved for this type of approach. Detection rates for SRAs must exceed 90% and the aircraft must be within 150 m of the RW centreline. Most MoD radars easily achieve this performance level, but where doubt exists as to the accuracy, FPL's AD-FIS Flight Inspection PAR package can be used to measure and record the accuracy of the SRA line-up.

23. The results obtained from the blip/scan rations are entered into a simple MS Excel spreadsheet while the aircraft is returning to the start of the run, so that a continuous assessment can be made as the check progresses. This enables a calibration to be abandoned at an early stage if it is patently obvious that the PSR is going to fail to meet the specification. This obviously reduces nugatory flying and the pointless wasting of the customer's budget.

RESULTS & SAVINGS

24. A routine check now takes 4 hours, usually in one sortie, as opposed to the 5-hour profile, sometimes taking 2 sorties, previously used. This compares to the 6 hours taken by the Andover flying a lower-quality profile.

25. FPL is contracted to check **35** Watchman radars each year, to which can be added re-fly tasks and returns to service. This results in approximately 70 flying hours per year being saved; even at FPL's cost effective prices this results in a substantial annual saving for the UK Treasury.

26. The UK MoD is developing a version of RADAC to replace the 'mandraulic' blip/scan ratio method of recording. However, the development of this tool has not been without its problems and the FI(R) with his tickbox sheets will be around for the next couple of years.

CONCLUSION

27. The use of properly calibrated radar attenuators can reduce the time taken to flight check a radar significantly, without any reduction in the validity of the results. This procedure allows the use of more economical turbo-prop aircraft for radar calibrations. Finally, the economy achieved by using this combination allows the routine flight inspection of PSRs to be undertaken without excessive costs being incurred.

28. As an addenda and provide food for thought, we wish to pose 2 stark questions – are your ATC Service providers' PSRs providing the best results to the ATCOs using them? When were your PSRs last flight checked to confirm this?