The effects of almost 20 years of operation on the performance of the Aberystwyth MST Radar

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1. Introduction

The MST Radar at Aberystwyth, a 46.5 MHz Doppler Beam Swinging instrument, was constructed in 1989/1990. The hardware has remained virtually unchanged ever since. For the first few years the radar was operated on a campaign basis, i.e. for up to a few days at a time (using one of a number of different observation formats) and with gaps of up to a few days in-between. Since late 1997 it has been operated on a quasi-continuous basis with a typical down-time of no more than 2%, i.e. an accumulation of less than 8 days in a year. Although it is still a powerful system, the performance has noticeably decreased over the past few years. As can be seen in Figure 1, whereas the typical maximum useful altitude for wind-profiling purposes (using an off-vertical angle of 6.0°) was around 20 km in 1999 (top panel), it is now closer to 15 km almost a decade later (bottom panel). Consequently a detailed review of the entire system was undertaken in late 2008 with a view to renovating the system. This extended abstract focuses on those components of the system which have degraded significantly over the lifetime of the radar.

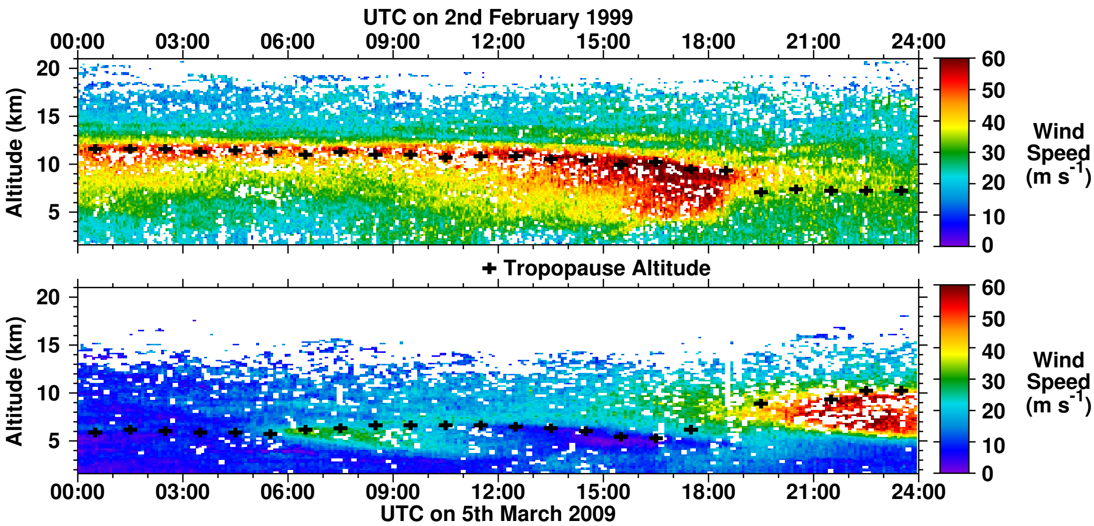

Figure 1: An illustration of how the maximum useful altitude for wind-profiling purposes has reduced from nearly 20 km in 1999 (top panel) to around 15 km a decade later (bottom panel).

2. System Overview

Figure 2 shows the principal functional components of the Aberystwyth radar. The design is fairly typical for an instrument of late-1980s vintage. Owing to the relatively limited computer power available, dedicated hardware units were designed to carry out the high speed functions. The Radar Control Unit generates all of the control signals needed by the other radar components in order to automatically acquire the necessary data for a single dwell. The principal role of the Pre-Processor Unit is to carry out coherent integration.

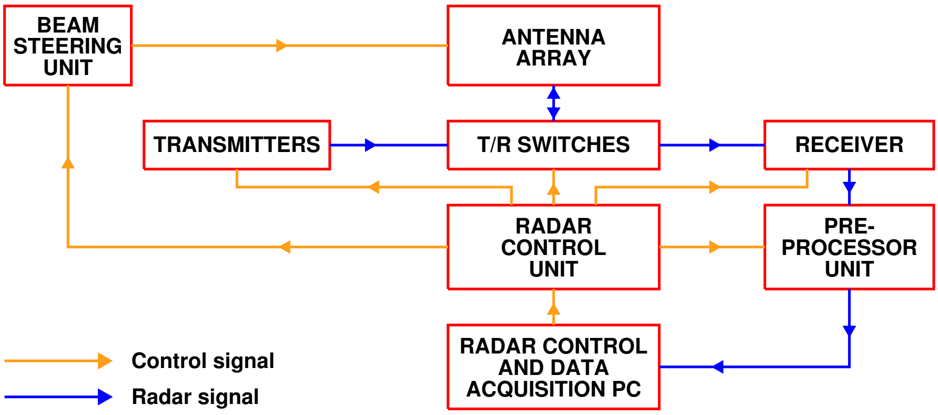

Figure 2: The principal functional components of the Aberystwyth MST radar.

3. Transmitters

The 5 valve-based transmitters are of type WPT-50, manufactured by Tycho Technologies. Each has a peak power of 32 kW and a maximum duty cycle of 5%. They were designed for operation from a mains supply of 110 V and 60 Hz. Although they were modified for the UK standard of 240 V and 50 Hz, the difference in mains frequency led to the valve heater voltages being too low. This resulted in the valves initially suffering from cathode poisoning. The heater circuits were subsequently modified and the valves no longer suffer from this problem.

Although the reduction in radar altitude cover had initially been attributed to a degradation in transmitter performance, these units appear to still be in a good working condition. Their reliability has increased considerably since a 3 kVA Uninterruptible Power Supply unit was installed for each one in 2007. The Aberystwyth radar is located in a rural location where mains fluctuations, as opposed to complete losses of power, are relatively common. Such fluctuations have proved to be the principal cause of transmitter component failure.

Figure 3: Examples of vermin damage to RG 213 cables.

4. Antenna Array

The antenna of the Aberystwyth radar is composed of a 20 by 20 array of 4-element Yagis at 0.85λ spacing, where λ is the radar wavelength. From a control point of view the antenna is configured as a 10 by 10 array of Quads, i.e. 2 by 2 sub-arrays of Yagis which act collectively as single units. Each Quad has an associated Phasing Unit, which allows the radar beam to be steered off-vertical - see next Section. Each Quad belongs to one of five variable-sized sectors and each sector is powered by one of the five identical transmitters. The signal from each transmitter is distributed equally to each Quad within the sector using a cascade of power splitters. Most of the interconnecting cables are of type LCF 7/8″ or LCF 1/2″. They are primarily routed underground, but those sections which are visible appear to be in a good condition. The final sections of cable are of type RG 213. Some of these shown signs of mild vermin damage and the outer PVC jackets of all of those inspected show signs of degradation due to solar UV light and leaching of plasticiser.

5. Beam Steering Unit and Phasing Units

The Phasing Units are composed of three electro-mechanical Relay Units, which can switch equivalent cable lengths of $\lambda/2$, $\lambda/4$, and $\lambda/8$ in to or out of the signal feed. The Relay Units (top-left panel of Figure 4) are N-type, DPDT transfer relays, part number R 563703230, manufactured by Radiall of France. They are designed to switch from a dc control voltage of between 24 and 30 V.

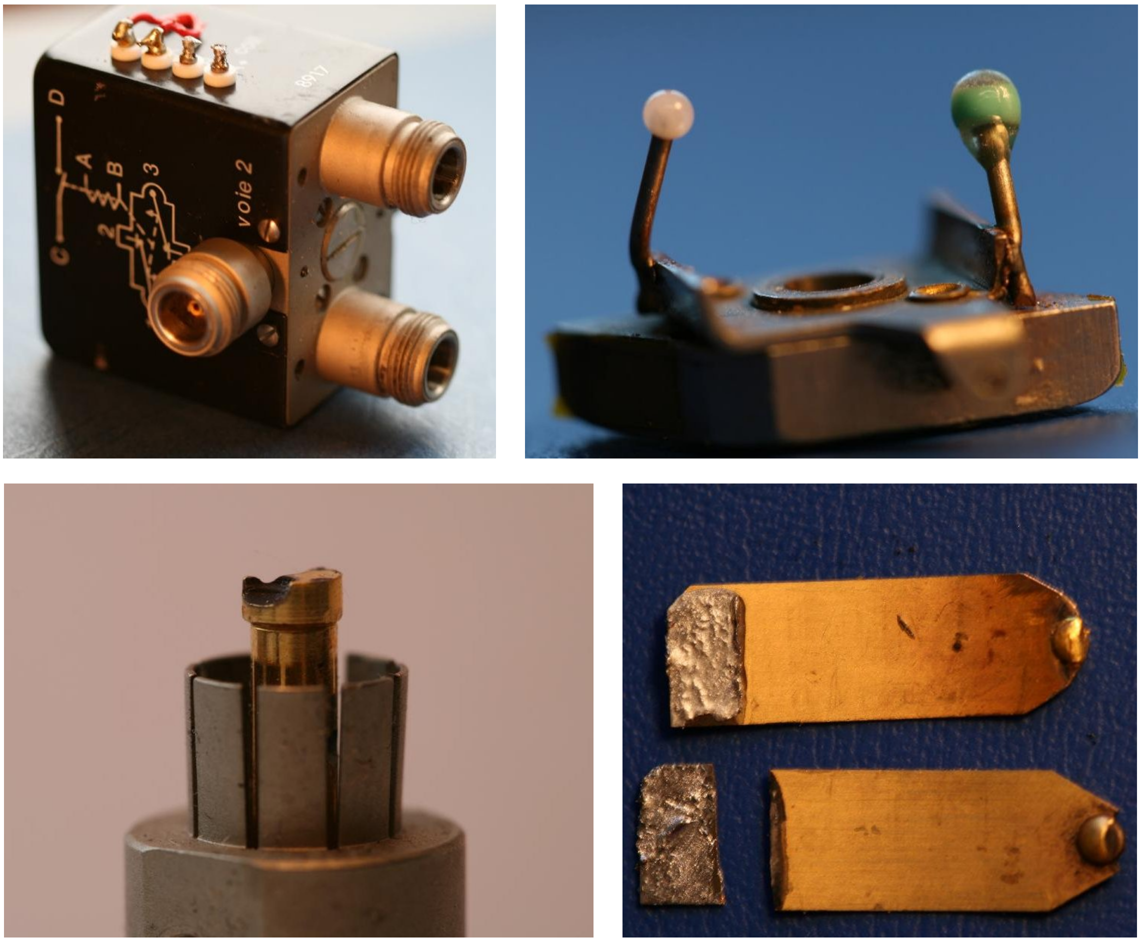

Figure 4: (top left) A complete relay unit; (top-right) the rotor mechanism; (bottom-left) an RF cable connector contact pin which has suffered from severe contact erosion; (bottom-right) an intact and a snapped contact blade.

The Relay Units in use today are all from the original stock, which included a number of spare units. They each perform approximately a million switching operations a year. Consequently they are subject to continuous, albeit gradual, degradation. The most common problem is an increase in the mechanical resistance experienced by the rotor mechanism (top-right panel of Figure 4). This can be solved by simply removing the accumulated debris (principally metal filings) from around the mechanism. Occasionally the rotor pins snap off. A new pin, which uses the plastic bead from a child's toy necklace as an insulator, can be welded back on as a replacement. The pin with a white bead seen in the top-right panel of Figure 4 is an original, whereas the one with a green bead is a replacement.

A more serious problem is that Relay Unit contacts are prone to erosion. RF arcing, which leads to evaporation of the contact metal, is believed to be responsible. As shown in the bottom-left panel of

Figure 4, this is a particular problem for the contact pins at the back of the RF connectors. The degree of erosion can range from being superficial through to the loss of material to a depth of over 1 mm (the contact pins are approximately 3 mm in diameter). The lifetime of a connector can typically be extended by rotating it slightly so as to present a more-robust portion of the pin to the contact blade. Nevertheless, a number of connectors have become so badly eroded that they have had to be removed from service. The contact blades (bottom-right panel of Figure 4) are also prone to contact erosion, albeit to a lesser degree. Nevertheless, they also have a finite lifetime and must be removed from service when they snap (as in the lower example).

The role of the Beam Steering Unit is to energise the appropriate Relays Units in order to achieve each of the pre-programmed beam pointing directions. Power is supplied from four 28 V dc, 10 A units. It appears that an allowance of 0.4 A has been made for each Phasing Unit, i.e. 0.13 A per Relay Unit. Although the Beam Steering Unit is in a good working condition, virtually no documentation is available for it. This will make it time-consuming to repair in case of a failure. It has twice suffered from extensive damage after lightning struck in the close vicinity of the radar site.

Figure 5: Examples of (left) a vermin-damaged relay control cable and (right) one of the probable culprits.

A single 18-core control cable connects each of the 100 Phasing Units to the Beam Steering Unit. They are primarily routed underground but are visible in the vicinity of their destination Phasing Units. Many of these sections show signs of vermin damage. In mild cases only the braiding wire is exposed. However, in a few severe cases, such as the one shown in the left panel of Figure 5, the copper of the individual wires is exposed. Most of this type of damage appears to be confined to the NE quadrant of the array. Rabbits (see right panel of Figure 5), which are plentiful on the site, are thought to be the primary culprits. No active steps have been taken to control the on-site population owing to fact that it would be difficult to prevent re-colonisation at this rural location.

Some of the longest relay control cables, which run over 100 m to the western side of the antenna array, have been found to significantly attenuate the voltage (28 V) generated by the Beam Steering Unit. The Relay Units have a specified minimum of 24 V for switching to take place, whereas some of the measured voltages are as low as 21 V. It is not clear as to how much this is a result of the vermin damage. Regardless, such low voltages are likely to result in sub-optimal contact pressure of the Relay Units and so could be aggravating the problems described above.

6. Conclusions

In conclusion, after twenty years of operation, the Relay Units, the Relay Control Cables, and all RG-213 RF cables have reached the end of their useful working lives and are in urgent need of replacement. Moreover, it would be highly desirable to replace the Relay Control Unit since its almost-complete lack of documentation will make it difficult to repair in the case of a failure.

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