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Renovation of the Aberystwyth MST radar - Technical Description

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Introduction:

The MST Radar at Aberystwyth, a 46.5 MHz Doppler beam swinging instrument, was constructed in 1989/1990. The RF hardware has remained virtually unchanged ever since. As previously reported at MST12, the performance has noticeably decreased in recent years and a detailed review of the entire system was undertaken in late 2008 with a view to carrying out an upgrade. The review identified the beam steering system as an important contributor to system performance degradation and also to increased maintenance cost.
In February 2010 Atrad was awarded a contract to replace the beam steering components at Aberystwyth with an upgraded system providing enhanced beam steering capability and new system monitoring features.
After a preliminary site inspection in March 2010 to verify the original MST radar's configuration and performance was compatible with the proposed upgrade, the new system was designed, constructed and successfully installed in March 2011.

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Fig2. An original Phase Shifter unit showing the 3 delay cables and the hybrid loads for the 4-Way Splitter.

Fig1. Part of the Aberystwyth antenna array showing the original Phase Shifter units

Fig3. Side view of an old Phase Shifter unit showing the associated 4-Way Splitter.

The Original Beam Steering system:

The original system consisted of 3 major components:

- 100 Phase shifter units each using 3 coaxial relays to switch in binary weighted cable delays (180,90 and 45 degrees). Each Phase Shifter drove 4 adjacent antennas via an external 4-way power splitter. The 3 hybrid balance resistors required by the Splitters were housed in the Phase Shifter boxes. (See Figs. 1, 2 and 3)
- Each Phase Shifter had a multi-wire cable to the central radar hut. The cables provided power to the 3 relay solenoids and also connection to “tell-back” contacts on the relays which were intended to provide confirmation of correct relay operation. The “tell-back” feature proved too unreliable to provide useful maintenance diagnostic information.
- In the radar hut the 100 individual control cables were connected to an “Antenna Phasing Unit” (see Figs. 4 and 5). This unit translated a 4-bit “beam select” signal from the radar control computer into the required phase shift relay drives via a PROM-based lookup table. The antenna array geometry and the use of 3-bit phase shifters meant that only 17 beam directions were realistically available, of which 16 were mapped into the 4-bit control word. (see Fig. 6)

Fig4. Front view of the original “Antenna Phasing Unit” and Status Display

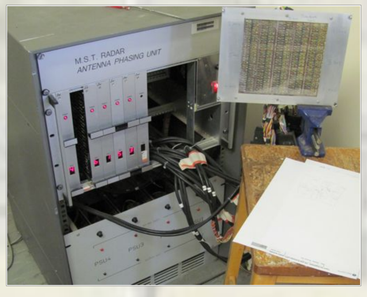
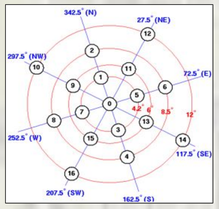


Fig5. Rear view of the original “Antenna Phasing Unit” showing the 100 interface cables to the Phase Shifters.

Fig6. Diagram of the beam directions available in the old system.



Features of the upgraded system:

- The new Phase Shifter units incorporate an embedded micro-controller module with on-board Zigbee network interface and ADC. This approach allowed several new capabilities to be added to the system.
- The Phase Shifters use commercial PCB mounted power relays in place of the original coaxial relays for greater reliability, lower cost, lower power consumption and smaller size. (see Fig. 15) These advantages allowed the Phase Shifter to be extended to 6 bits precision (5.5° phase step).
- Use of these relays reduces the number of coaxial connectors in the signal path by 10 (minimum).
- Each Phase Shifter has an “address input” connector used to give each unit it's unique identity (location) within the array. The 100 unique “ID” plugs in the Aberystwyth system are attached to their respective mounting poles by lanyards to avoid mix-ups. This means all Phase Shifter units are identical and interchangeable. A suspected faulty unit can be easily swapped with a spare unit in a few minutes.
- Each Phase Shifter can report internal supply voltage, temperature, forward and reverse power, and 2.4GHz control signal quality. These parameters are logged by the Beam Steering PC and can be displayed in graphical format providing for easy system status checks and problem diagnosis. (see Fig.17)
- The Phase Shifters also include an internal 4-way Wilkinson Hybrid Power Splitter replacing the original external splitter.
- The reuse of the existing coaxial network to provide power and control communications to the new Phase Shifters removes the extra initial cost and on-going maintenance issues of a separate power and control cable network.
- The improved 6-bit phase precision and flexible TCP/IP command interface mean the new system is no longer limited to 16 beam directions and can support virtually any beam direction within the capability of the antenna array geometry.
- The finer phase precision allowed the addition of a phase offset table to the beam control software, this was used to compensate for the small variations in phase in the Aberystwyth RF distribution network. (see Fig. 16)
- The new Phase Shifters can be quickly replaced for maintenance purposes so system down-time is minimised.

Fig15. Old coaxial relay and the PCB mounted relay used in the new Phase Shifter.

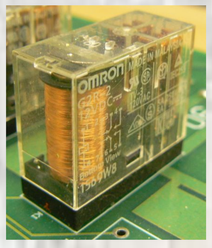
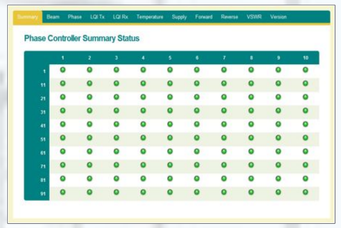


Fig. 17 Examples of Beam Steering System status information available on a web-page



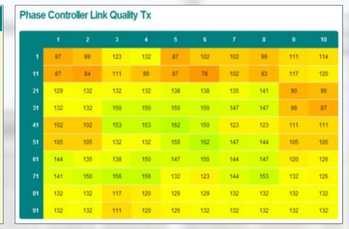


Fig. 16 Phase Calibration table web-page

Fig7. CAD graphic of the new Phase Shifter unit.

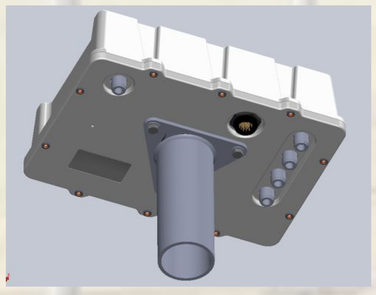


Fig 8. Internals of the new Phase Shifter unit.

The Upgraded Beam Steering system:

The new system consists of 4 major components:

- 100 new “smart” Phase Shifters with 6-bit precision (5.6 degree phase step size) and added monitoring and diagnostic capabilities (see Figs. 7 and 8).
- The new system makes use of the existing radar antenna array's coaxial network to provide power and control communications (2.4GHz Zigbee) to the new Phase shifters. To couple the DC and 2.4GHz signals to the antenna array network, custom-designed multi-couplers were added to the existing 5 radar antenna array feed points.(see Fig. 9)
- A new Beam Controller unit provides the DC power for the beam steering system and translates the Zigbee communications to a USB serial protocol. (see Fig. 10)
- A standard Industrial PC interfaces between the USB serial protocol and a TCP/IP Ethernet connection to the existing Radar Control computer. This PC also logs diagnostic information from the Beam Steering system and hosts a web-page interface to provide maintainers with graphical displays of the system status.

Fig 9. Custom designed multi-couplers installed on the rear of the Aberystwyth Transmitters.

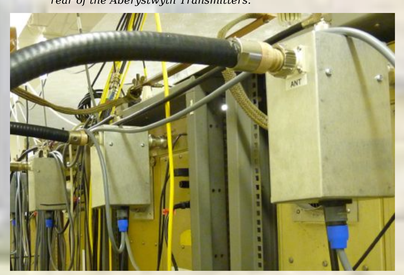


Fig 10. View of the Beam Controller during manufacture.

Fig11. Old and new Phase Shifter units side-by-side during the installation

Installation of the upgraded system:

- The original Phase Shifter units and their associated 4-way Splitters were removed and replaced by the new Phase Shifter units. (see Figs. 11 and 12)
- The original control cables were removed.
- Part of the original RF cabling which was made from RG-213 coaxial cable and had suffered from deterioration and vermin damage was removed and replaced with new Heliax cables.
- All hardware removed in the renovation was sent for recycling and/or approved disposal. (see Fig. 13)

Fig12. Some members of the ATRAD installation team hard at work!

Fig14. View of the antenna array after the installation

Fig 13. Old Phase Control Units and their control cables being sent for recycling.