BRIEF

MWA PROJECT

LIGHTNING EVENTS AND IMPACT MITIGATION

For the purposes of this discussion, we now describe the current MWA earthing implementation. This was primarily designed with Australian outdoor mains safety considerations in mind, but also forms the basis of the electrostatic and lightning discharge paths. The specific quoted information regarding earthing comes from the Electrical Services Manual and associated as-built drawings provided by GCo Electrical, who were the prime contractor for the site-works underlying the MWA telescope.

The MWA is fed from a 6.6kV incomer from the CSIRO power infrastructure, which is transformed down to 415/230V at a single transformer station roughly centrally located in the land area covered by the 128 antenna tiles (approx 3km North-South by 2km East-West). The individual single-phase power feeds to the 16 receivers locations are buried in seven radial trench lines each of approximately 1.5km in length with depths determined per AS3000 standards.

The soil conditions are known to be generally fairly poor with some areas having soil resistivity in excess of 2 x 10^6 Ohm.m (30m spacing, 20cm probe depth). Therefore the mains earthing system was designed by the consulting electrical engineers to ensure acceptable values were reached.

To meet the needs associated with the 6.6kV incomer there is a “buried ring, radials and earth-spikes” arrangement. As quoted in [ref 1] “Substation earthing is by 120mm copper grading ring around the perimeter of the substation, four radials extending to approximately 33m, which forms a 50m square. At the end of each radial is a 25m deep, drilled earth rod with earth enhancement compound”.

Each of the 16 receiver pads has its own earthing system, again designed to address the poorly conductive soil on site. Quoting [ref 1], this consists of “... its own earth rod drilled to 3m deep and earth enhancing compound,...”.

Each receiver supports eight antenna tiles, each of which is connected back via a dual-coax-plus-drain-wire cable typical of CATV reticulation systems. We use six standard lengths of these cables depending on the distance between receiver and tile, three shorter lengths of RG-6 cables are 90m, 150m or 230m of RG-6, and three longer lengths of LMR-400-75 being 320m, 400m, 524m. The coax outer braids and drain wire are all connected solidly to the exterior of the receiver metal enclosure at the receiver end, and bonded to the outside of the metal beam-former box at the tile end. Furthermore, at the tile end, a short (approx 1m long) 6mm^2 building-earth wire connects the beam-former case to the 5m x 5m mesh ground-screen to which the dipole antennas are mechanically attached.

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Therefore, the electrostatic and lightning discharge path from near a tile is via the coax outer conductors and drain wire, back to the receiver enclosure and immediately to the buried earth rod adjacent to the receiver.

At the time of installation, it was deemed to be too expensive and unknown perceived benefit, to drill a local earth rod at each of the 128 antenna tile locations. Apart from the cost of relocating the drill rig 128 times, it would have required a bladed access track from each receiver to the tile location which in turn would have more long-lived environmental impact. Beyond the implementation cost of blading the track and drilling and installing rods, would have been additional land-clearing permit and heritage survey/monitor costs.

Having described the earthing system, we now consider the experience gained over the current operating life of the telescope (being approximately thirty months to date).

MWA has suffered five lightning events that have resulted in moderate, but repairable damage to the instrument. In each case, several things appear to happen simultaneously.

1. Some mains circuit breakers supplying the receivers are tripped due simply to current surges. This removes power from the affected receivers, and until the breakers are reset, means that the associated sets of eight antenna tiles are not accessible in any way. This also means we cannot determine if any individual tiles have failed until the receiver is powered up again.

2. Mains supply circuit breakers are tripped due to an internal power board shunting surges, and 'failing short' due to internal components failing. This condition is not reset when the breakers are cycled, requiring the internal COTS power board to be replaced before the breaker will reset. Again, until this condition is remedied, the associated eight antenna tiles are not accessible and we cannot determine if individual antenna tiles have failed until the receiver is restored.

3. Once the receivers have been restored, we have found that some number, typically between 30 and 45 antenna tiles, fail in one of two main ways, as a result of a circuit board failure in either the associated receiver slot, or the associated beam-former, or both. In every case, the affected tiles do not respond to 'pointing' commands. Of these some remain pointing to the zenith and continue to pass RF signal, while others are 'flat-line', that is, supply no RF signal at all.

Failures are detectable within seconds of occurrence, due to a status web-page visible anywhere in the world. However, tripped circuit breakers require a person on site to recycle them, which in turn means that any further damage 'masked' by downed receivers cannot be determined at a minimum until the next working day after the event.

Failed COTS power boards have been stripped, and it has been determined that in every case, Metal-Oxide Varistors (surge suppression devices) have failed short, and physically disintegrated, protecting any attached devices from further damage, but, as noted above, preventing the circuit breakers from being recycled until the damaged power board has been replaced. These power boards are moderately cheap, fail relatively infrequently, and are easily replaced, so we do not believe it is worth taking measures to reduce their rate of failure.

However the time, effort and cost to repair and replace the circuit cards in the receiver and beam-former slots warrants some consideration as to mitigation methods that might reduce the number of overall failures. In most cases there is no visible sign of damage, but lab diagnosis points to a small number of analog semiconductor components which fail. While the components themselves are of the order of a dollar or so in value, and are easily replaced, the associated cost of site visits and nuisance value of many cover screws required to access the cards in the field justifies some expense if it reduces the rate of failure.

With this in mind, we have trialled two types of F-type in-line, gas-discharge tube based, external lightning arrestors available commercially. Four units of each type were fitted, two at the receiver end and two at the tile end of the Data-over-Coax cables, external to the enclosures that require many screws to access. We realise this is not a statistically significant test with regard to their ability to prevent damage. The primary purpose of the test was to identify the effect of the arrestors on the RF signal chain and determine if their use would affect the signal quality. One type of arrestor, however, has already failed to prevent damage to the associated tile, while the other (more expensive) has prevented damage so far.

The second advantage of the more expensive unit, is that it has a higher surge current rating and the actual discharge/arrestor device is testable and replaceable without removing the lightning arrestor from the cables.

Datasheet specifications, and early analysis indications show that there is no discernible effect on the RF signal quality after the lightning arrestors are installed.

With all the foregoing in mind, and with the understanding that these are still not a guaranteed method of mitigating the effects of lightning, but that even a moderate reduction in damage is advantageous, it is proposed that we purchase sufficient units of the modular lightning arrestors (estimated to USD$12,200 as at 18-Mar-2015) to fit out all 128 tiles and then further revisit the issue in the future.

Apart from potentially protecting the MWA telescope from further damage, or at least reducing the severity, lessons learned will inform future large-N telescope designs with surface laid cables over distributed areas.

Ref 1: Gco Electrical MWA Project Electrical Services Manual and associated as-built drawings.

Ref 2: The Murchison Widefield Array: the Square Kilometre Array Precursor at low radio frequencies, htt