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To: EDGES Group
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Subject: Boolardy Site Visit Log – February 2020

1 Introduction

This is a short memo detailing activities during the February, 2020 visit to the EDGES site at Boolardy station, WA, which will be updated with the activities of each day.

2 February 18, 2020

The afternoon of February 18, 2020 a quick RFI survey of the EDGES hut was down using a FieldFox spectrum analyzer coupled to an approximately 2 feet long monopole whip antenna. Table 1 contains a summary of the measurements taken. Unless otherwise specified under the description heading, all measurements were taken with the hut door open. For measurements where the FieldFox was inside the equipment rack cabinet, it was connected to the antenna (inside the hut) via co-ax. cable[1] through the equipment cabinet wall. The FieldFox was set up to generate a spectrum sweep from 30MHz to 200MHz with a spectral resolution of 100Hz. The number of averages for each spectrum measurement was configured to be 150. It should be noted for some measurements the low frequency portion of data may be unreliable as there was no way to introduce a delayed-start to the measurement and for measurements where the spectrum analyzer was inside the equipment cabinet with the door closed, there is some non-zero time between the start of a measurement and when the door was fully closed. We estimate that this affected the first $\sim$ 10 MHz of each measurement. For a rough idea of the setup (with cabinet door open) see figure 2. Note that for measurements A through E, there were two smart phone devices (in airplane mode) inside the hut a few feet from the antenna as well as a handheld UHF radio (not-transmitting) outside the hut. For measurements F and onwards, these devices were switched off and placed inside a car $\sim$ 20 feet away. For all measurements A through F, we also had two car key transponders nearby in the hut, these were removed for measurement G onwards and placed outside the hut about $\sim$ 25 feet away. During measurement G, a vehicle approached and parked about 40 feet away from the hut, so this measurement was repeated. Figure 1 gives a comparison of the RFI survey measurements. From this figure we conclude that there may be some RFI produced by the back-end computers within the equipment rack, the most salient features being the peaks closest to 85, 120, and 145 MHz.

[1] There was approximately 3 feet of cable between the FieldFox and SMA connector in wall, then another 6 feet of cable between the connector and antenna

Measurement	Description	Filename	Label
A	FieldFox on table in hut connected to antenna directly (not through cabinet wall). Cabinet door was closed	IN_HUT.csv	Inside-hut
B	FieldFox on table in hut connected to antenna directly (not through cabinet wall). Cabinet door was open	IN_HUT_DR_OPEN.csv	Inside-hut-door-open
C	FieldFox inside equipment rack, cabinet door closed	IN_HUT.csv	In-rak
D	FieldFox outside equipment rack, attached to coax. cable but antenna was disconnected, cabinet door open	NO_ANT.csv	No-ant
E	FieldFox inside equipment rack, 12V power cut to (external) fans, cabinet door closed.	IN_RAK_NO_FAN.csv	In-rak-no-fan
F	FieldFox inside equipment rack, 12V power cut to (external) fans, cabinet door closed.	IN_RAK_NO_FAN_NO_PHN.csv	In-rak-no-fan-phn
G	FieldFox inside equipment rack, 12V power cut to (external) fans, air conditioner turned off, cabinet door closed.	IN_RAK_NO_FAN_NO_PHN_AC.csv	NA
H	FieldFox inside equipment rack, 12V power cut to (external) fans, air conditioner turned off, cabinet door closed.	IN_RAK_NO_FAN_NO_PHN_AC2.csv	In-rak-no-fan-phn-ac
I	FieldFox inside equipment rack, all AC power to hut equipment cut off, cabinet door closed.	IN_RAK_ALL_OFF.csv	In-rak-all-off
J	FieldFox inside equipment rack, backend computers (EDGES-1/2/3) turned off, other rack equipment has power, no (external) fans or air conditioner, cabinet door closed.	IN_RAK_COM_OFF.csv	In-rak-com-off
K	FieldFox inside hut, but not inside rack cabinet, all AC power to hut equipment is off, hut door is open.	OUT_RAK_VNA.csv	Out-rak-vna
L	FieldFox connected directly to antenna, outside hut, cabinet and hut door are closed, all hut equipment powered back on.	OUT_HUT.csv	Out-hut

Table 1: Summary of quick RF survey measurements.

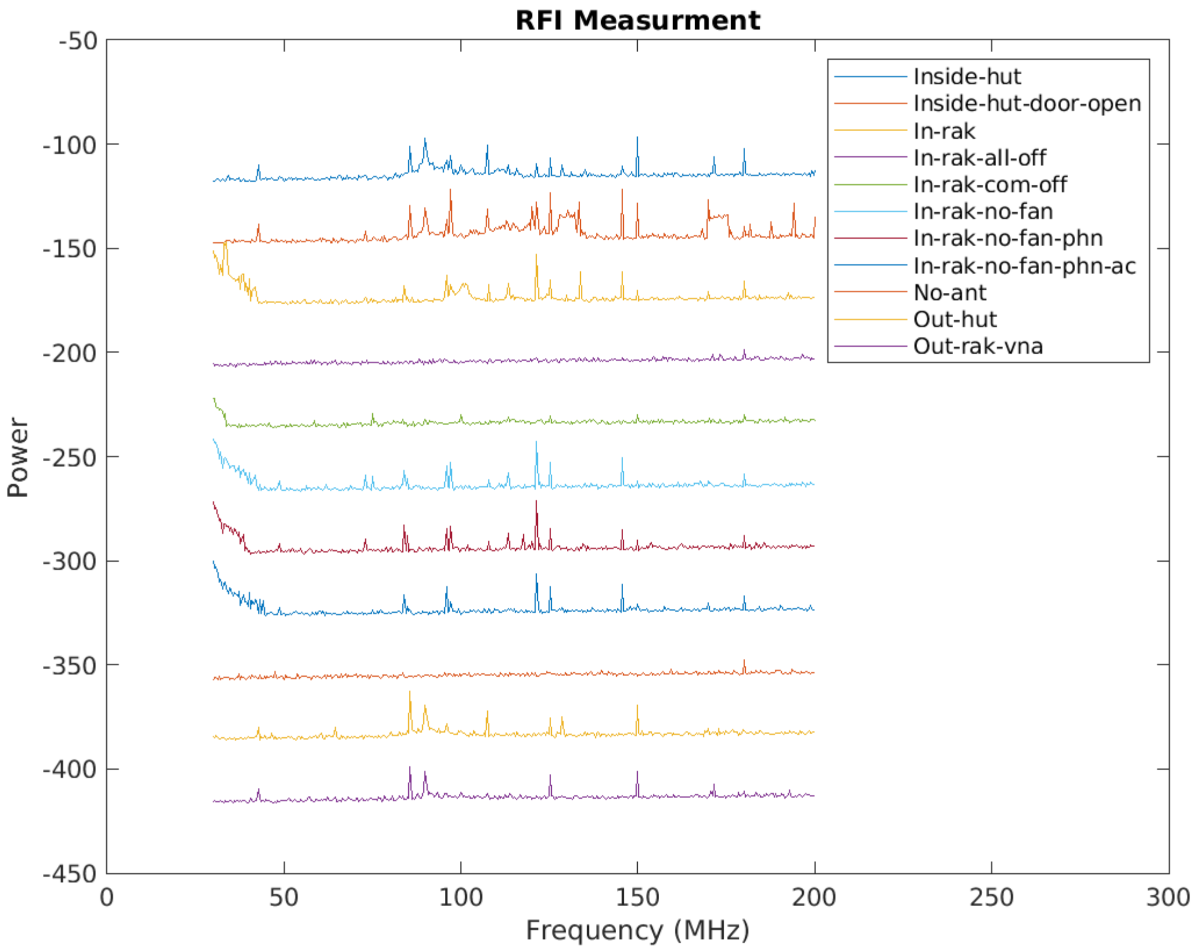


Figure 1: Comparison of RFI survey measurements. The y-axis is relative power in dB, the x-axis is frequency in MHz. The measurement at the top (label: inside-hut) is the associated with the true power scale, whereas each subsequent measurement has offset from the last by -30 dB for clarity.

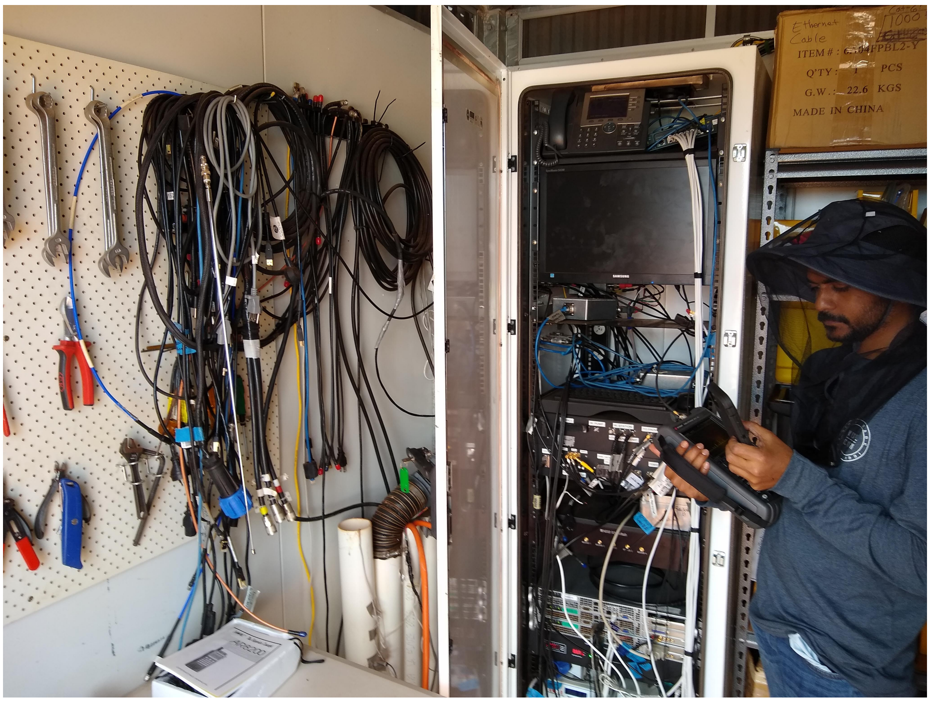


Figure 2: Position of antenna with respect to equipment cabinet during quick RFI survey. Antenna is visible in front of the collection of cables hanging on the hut wall.

3 February 19, 2020

Work during the day was constrained to be inside the hut because of rain and the presence of lightning in the area. The interior cabling for the low-2 and mid-band receivers (to be installed) was reconfigured according to the diagram in figure 3. Some small metal break-out boxes for the receiver control wires (over ethernet cable) were machined to replace the small plastic boxes currently in use.

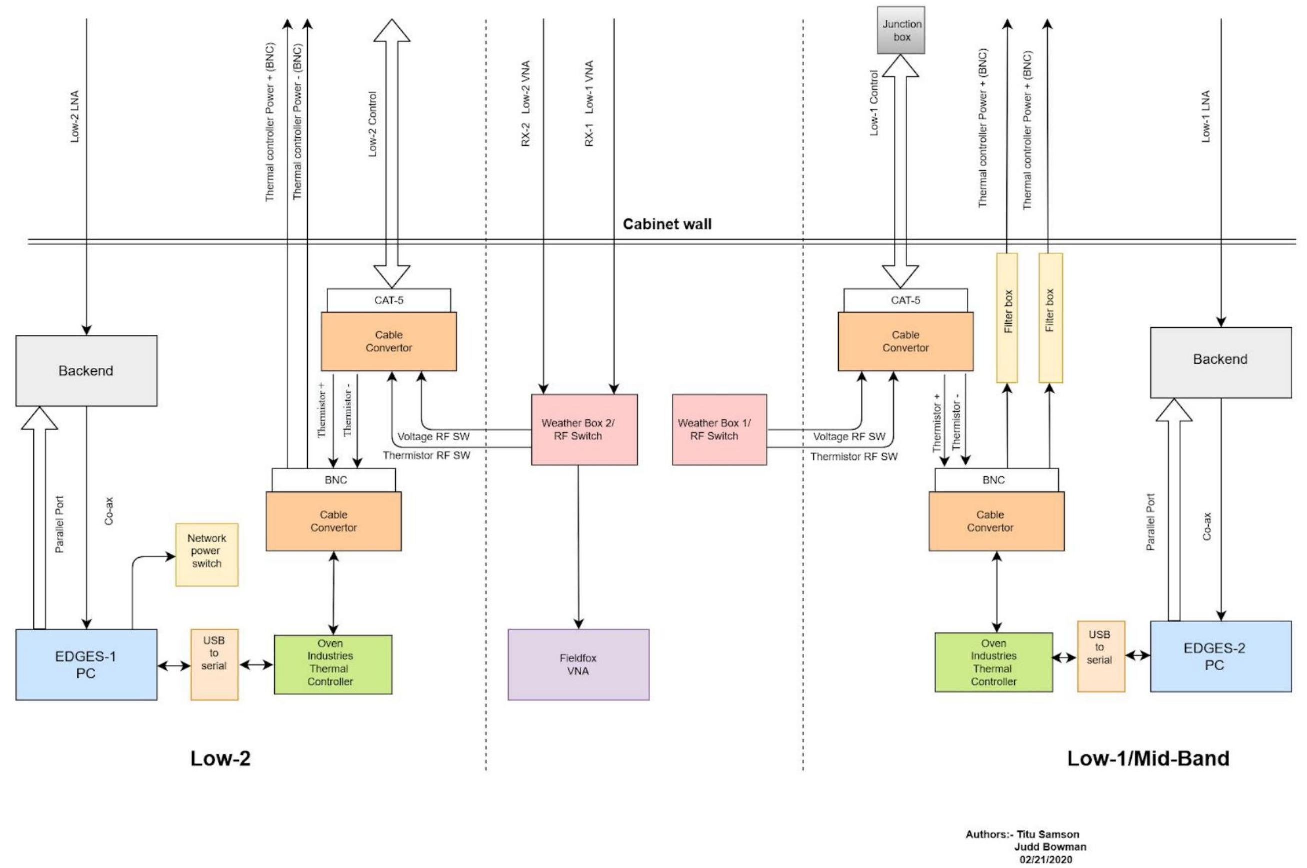


Figure 3: Wiring scheme of the equipment cabinet wiring scheme for low-2 and mid-band receivers, from T. Samson and J. Bowman.

4 February 20, 2020

Since it was raining again this morning, we decided to move ahead with work on the PVC conduit pressure test by constructing a (90mm PVC) cap with Schrader valve and press-fit port for an air gauge at the MRO control building. J. Morris located a gauge with a 0-6 kPa (0-0.87 PSI) range so this should be sensitive enough to detect slow leaks, though we will have to keep the pressure in the pipe to a relatively low level during the test. See figure 4 for pictures of the air-pressure test cap and gauge.

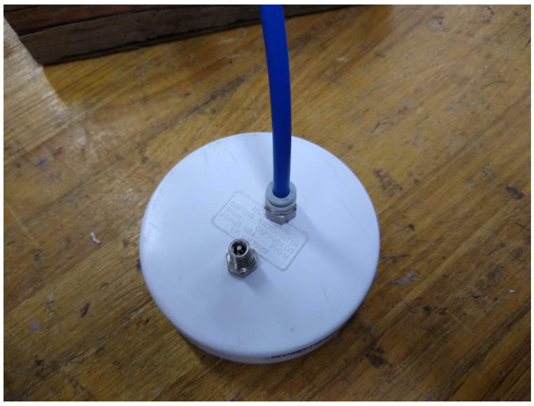
To test the air-tightness of the PVC conduit the far end in the pit was wrapped with one layer of duct tape (to provide a slightly larger diameter) and the black ABS 3d-printed cap was press fit over the opening. On the end of the pipe inside of the hut, the test cap was press fit over the end using a hand-cut rubber gasket. See figure 5 for the test configuration.

During the first test, the cap failed with an air leak from the hole through which the Schrader valve was fit, this may have been due to a crack which formed during free-hand drilling. On the second attempt, a new cap was drilled using a drill press and a drill bit with a hollowed out cutting edge[2], this resulted in a tighter seal and no cracks in the PVC cap. However there was still some leakage though the valve stem threads so teflon tape was applied, which improved the seal and seems to have resulted in no leaks from the valve/gauge ports.

We realized upon further testing that to better isolate the source of any leak we first need to ensure that the end caps can be fit on the conduit with no leaks. In order to check this, we chose a short two feet section of pipe with no seams as a test chamber. Upon mounting the black ABS cap and then PVC cap it was determined that

[2]Small 1mm pilot holes were drilled first as a guide.

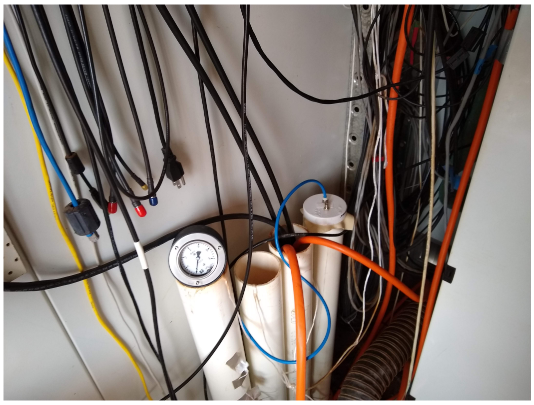
(a) The 6kPa pressure gauge.



(b) The 90mm PVC pipe cap with Schrader valve and press-fit coupling used to charge the line

Figure 4: Air pressure test attachments.

(a) Black ABS cap fitted to far end of conduit in pit.



(b) PVC cap fitted to conduit in hut, sealed with rubber gasket material.

Figure 5: Air pressure test configuration.

the primary leak was due to a poor seal between the ABS cap and the PVC pipe. However, the rubber gasket material used to seal the end with the valved cap appears to fit tightly with no leaks. Tomorrow we plan to seal both ends with 90mm caps equipped with rubber gaskets (as shown in 5b).

In addition to the conduit air pressure testing, we began the process of drilling out the top holes of each antenna pad base plate. This is to allow the bolts to pass through the top plate freely so that the base plate sheet metal can be tightened down into better contact with the frame and ground plane mesh.

5 February 21, 2020

Overnight it rained about 20mm so the roads were a little soft this morning and pad-3 pit had some water, but we otherwise had fairly clear skies today. Upon arrival at the site we first tested the air-tightness of the caps we devised the day before on a short section of pipe, as shown in figure 6. This scheme held about 6 kPa of pressure for several minutes with no signs of leaks, giving us a fair degree of confidence that the end-caps should be able to hold enough pressure to check the conduit for leaks.

Once the end-caps were tested for a good seal, we then proceeded to test the first conduit pipe. Inside the hut, this is the 2nd pipe from the entrance, while inside the pit this pipe is the one closest to the road. After capping both ends we charged this pipe with 6 kPa of pressure, however, there was a large enough leak in the line that the pressure dissipated completely within 30 seconds. Following this, we then tested the next pipe, from inside the hut this is the furthest one from the door, while in the pit it is the furthest from the road. After capping both ends of this pipe, we again charged it to 6 kPa, and waited for the air pressure to dissipate. The seal on this conduit was better than the last and took about 1:30 for the pressure to drop from 5 kPa down to 1 kPa, and over 2:30 to drain completely. In conclusion, it does not appear that these PVC pipes are completely air-tight along the entire 50 meter length, this may pose some challenge towards using them in a closed circuit air cooling loop if we wish to keep all moisture out. One additional thing to note is that there is some amount of dust and debris already in the pipes that may not be ideal for a cooling system and may prove difficult to remove.

Figure 6: Test chamber used to test end-cap seal before testing the conduit.

After testing the conduits, we proceeded with the installation of the DC power cable and optical fiber for EDGES-3. The fiber and DC cable were pulled through the central conduit containing the other cables routed to pad-4. The free ends of the optical fiber were fed into a leak-proof box to keep the connectors from being damaged. Connectivity of the fiber cable (on fibers #1 and #2) was verified by establishing a connection from a laptop in the pit to the CSIRO network, using the following static IP configuration in table 2.

Parameter	Value
IPv4 Address	202.9.9.168
Subnet mask	255.255.255.240
Gateway	202.9.9.161
DNS	8.8.8.8

Table 2: Static IP configuration for spare EDGES computer/port in hut.

It should be noted that in order to do this it was necessary to provide external +12V power to the media converters, as neither the network switch or laptop were configured to provide power-over-ethernet. The +12V supply was fed to the pit via the main EDGES-3 DC power supply cable from the low-2 fan power circuit. Future provisions (i.e. a 1U chassis and power supply) should be made for installing the media converter(s) in the rack.

In parallel to the fiber test, the mid-band receiver was installed in the pad-2 pit and reconnected to the back-end system. It was verified that signal is being received by the digitizer, but further tests are needed to confirm full functionality.

6 February 23, 2020

During the morning the fiber optics termination box in the pit of pad-3 was mounted against the pit wall to prevent it from becoming immersed if there is heavy rainfall. In addition, the plastic control electronics junction box for pad-2 (mid-band) was replaced with a metal box and the wiring within was re-done. The thermistor for conduit-1 (east) was replaced, leaving one spare remaining. Currently there is only one spare humidity sensor, so for the immediate future a choice must be made as to whether to use it to replace the weather station humidity sensor or the conduit humidity sensor. Some brief testing of the mid-band receiver (installed in pad-2) was done. The temperature control of the receiver appears to be working, and the spectrum exhibits some expected features (out-of-band noise source, Orbcomm satellite). However the signal from the antenna during a switch cycle saturates the ADC (min/max value of ± 0.500 was reported by fastspec) so more debugging is needed before it will be able to be brought into operation.

7 February 24, 2020

We decided early on to rotate the low-band antenna on pad-4 by 45 degrees. To do this we removed the antenna and then marked the new locations for the flanged nuts according to table 3, and then drilled and re-mounted the nuts. Figure 7 shows the type of nut used to attached the threaded nylon rods. Note that each nut has had 3 through-holes added around its perimeter to permit size M4 screws to pass through to the base-plate, and the nylon lock-washer present inside the nut has been tapped-out to allow the 3/4"-10 threaded rod to pass through. The approximate diameter of the outer flange is about 1.3". For EDGES-3 we may want to consider a mounting scheme along these lines since it is much easier to deal with than mounting through the base-plate.

Figure 7: The modified flanged nuts use to attach the threaded nylon rods (withing the fiberglass support legs) to the base-plate.

We also cut a notch in the side of balun-tube hole in the base plate in order to permit mounting of the balun-tube without removing the base plate in its entirety. A new hole for the rotated balun tube was also punched out at the (X,Y) position of (1021, 1077).

Upon leaving the site we decoupled the mid-band receiver from the antenna (while leaving a ground connection) between the balun tube and the reciever case. This was done in order to determine if ground loops could be playing a part in the ADC saturation events that we had noticed earlier. The low-2 receiver was left connected to the antenna, and both back-ends were left running overnight.

8 February 25, 2020

Today the camera box window was repaired and re-sealed. We checked the over-night data and found that with few exceptions (there were couple events at 8:30 and 10:30 PM) most ADC saturation events stopped occurring

X position (mm)	Y position (mm)
80	939
619	1478
699	1558
883	136
1422	674
1502	755
2041	1294
1238	2097

Table 3: (X,Y distances were measured from the southwest corner of the base-plane (corner closest to the road and ASKAP antenna), with X being the East-West coordinate, and Y being the North-South coordinate.

after 6:30 PM (local), but re-started after 8:00 AM. Only a single event was noticed on the mid-band receiver (which for the duration of this test was decoupled from the antenna.

Afterwards we surveyed the low-2 and mid-band antennas. The orientation (directed along the long edge of the antenna panels) of the low-2 antenna on pad-4 was measured with a compass and was found to be roughly 42° to the East of due (magnetic) North. Figure 8 shows the antenna postion relative to the base plate. We also measured the degree to which the low and mid-band antennas were out of level. For the low-band antenna, we measured the gap between the two dipole halves was 1.85 inches, and the height of the top-cap above the antenna was 0.65 inches. Figure 9 shows the relative positioning of the low-2 antenna panels. For the mid-band antenna (which was not moved or otherwise modified on this trip) we measured the gap to be 50mm (1.96"). However, we did not remove the plastic cap to measure the top-cap height. The original dimensions (measured Nov. 25, 2017) of the mid-band antenna were $\sim$ 1.9" for the gap spacing and $\sim$ 0.75" for the top-cap height above panels.

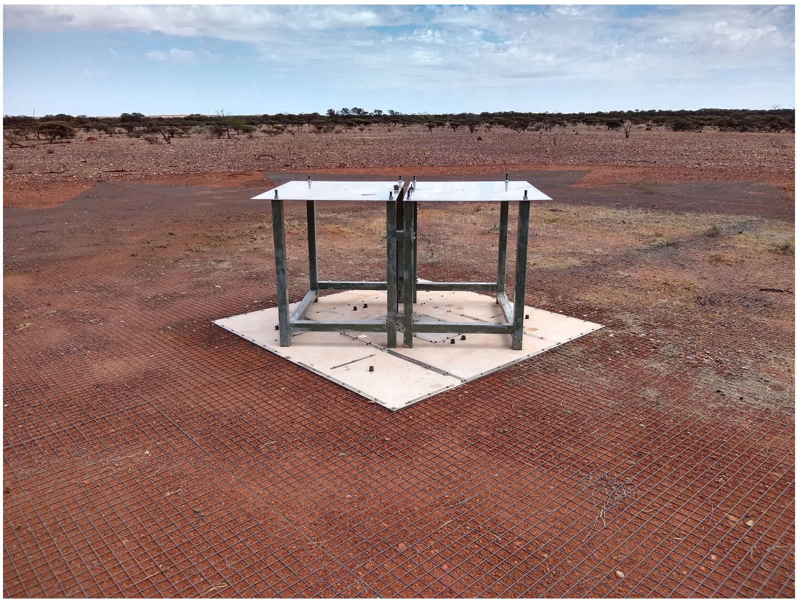


Figure 8: The low-2 antenna rotated roughly $\sim 45°$ relative to the base plane.

Figure 10 shows the relative positioning of the mid-band antenna panels. The orientation of the mid-band antenna was found to be 82° to the East of due (magnetic) North. Note that the low-2 receiver was connected to back-end D (in the rack) while the mid-band receiver was connected to back-end B.

Once the antennas were surveyed we quickly did an S11 measurement to determine if any tuning was needed, but concluded that they were probably fine as is. The receivers were then both reconnected to their respective antennas and the pit access doors were screwed closed.

Next, DC feed-throughs for EDGES-3 were made in the equipment cabinet wall by drilling holes and inserting Schaffner #FN7562-16-M4 filters. These were then crimped to the pad-3 10mm power cable.

9 February 25, 2020

This morning we finished cleaning out the hut to meet some minimal degree of sanitation, and the optical fiber for EDGES-3 was fed into the equipment cabinet.

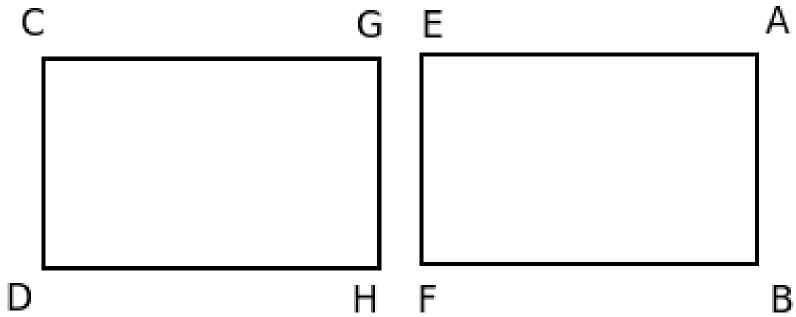


Figure 9: Rough survey of low-2 antenna panels, view from top down. Side CD is the South-West side, while side AB is the North-East side. Using a level we measured side GH to be 8mm lower than the outside edge CD, while side AB is 3mm lower than EF. In the perpendicular direction, side CG is 5mm lower than DH, while side AE is 4mm lower then BF.

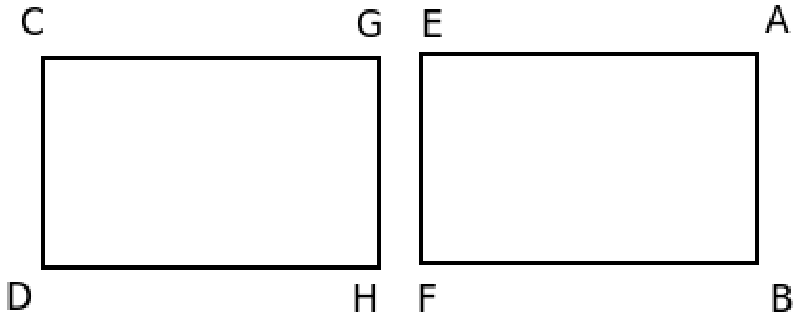


Figure 10: Rough survey of mid-band antenna panels, view from top down. Side CD is the West side, while side AB is the East side. Using a level we measured side AB to be 5mm lower than the central edge EF, while side GH is 6mm lower than CD. In the perpendicular direction, side CG is 7mm lower than DH, while side AE is 5mm lower then BF.

Some investigation was done on the source of the ADC saturation seen over the past few days. One possible source of this that was considered was the positioning drive of ASKAP antenna 34 (the closest to EDGES), however this did not appear to induce any saturation events when activated around 2PM. Another possibility to consider is nearby (100s of km) lightning, but this does not seem to be well correlated with the timing of events. The weather is expected to be clear tonight, so this might possibly be able to be ruled out if we do observe this issue again. It should be noted that the VNA has been on during a period of time today that we did not observed any noise events.

In the afternoon we used Sikasil-800 to re-attached the plastic bottle half over the top-cap of the low-2 antenna. We also did another brief RFI survey of the EMI that may be coming from the cabinet electronics. The AR8200 had a corroded battery so we resorted to the FieldFox with the same $\sim$ 2 ft monopole antenna for spectrum measurement. Base on our previous measurements we identified a noise spike near 121.375MHz as signal indicative of noise from the rack. With the cabinet door open and the antenna held vertically a few feet away we measured a peak signal strength at this frequency of approximately -90dB. With the rack door closed, but the antenna held vertically close to the door-seal crack we measured a signal strength of around -92dB, however the signal was much weaker when then antenna was held horizontally. Away from the equipment rack (near the hut entry) the signal strength dropped off quickly to around -120dB and beyond this point was not detectable by the FieldFox. Additional measurements near the mid-band antenna on pad-2 could not detect this noise spike above the noise floor at all. A cursory look at the spectrum data recorded by the low-2 antenna showed a large noise spike at 131.5 MHz in the aircraft safety band (Meekatharra airport transmitter?), but we were not able to determine if this signal is the culprit for the ADC-saturation events.

10 February 27, 2020

We drove back to Geraldton today and had a brief meeting with representatives from Albrolhos Steel (Philip Martin) and Geraldton Sheetmetal and Roofing (Anthony McAuliffe) who are providing a bid for the ground plane wire mesh and welding crew. They mentioned several things which we may want to consider as options in the design of the base plate, these are:

1. Using aluminum sheet metal plates on top of a steel frame for the base plate may induce galvanic corrosion, which may not be ideal for a good electrical connection.
2. One alternative, if steel plates were used they could be welded to the frame (with the exception of the central plate, which needs to be removable) instead of bolted. Then the entire assembly could be hot-dip galvanized for corrosion protection.
3. The hot-dip galvanization process induces some thermal stress so it may cause some slight distortion or buckling of the plate surface which may be undesirable.
4. Another alternative (using steel plates instead of aluminum) would be for them to be individually galvanized and then welded to the frame.
5. Finally, as an alternative to welding, the sheets could be attached with hex-head self-drilling tapping sheet metal screws instead of drilling/tapping individual bolt holes.