MIT, HAYSTACK OBSERVATORY
August 28, 2022

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To: EDGES Group
From: J. Barrett, R. Cappallo J. Soohoo
Subject: Devon Island Deployment Log – August 2022

1 August 4, 2022

Today we arrived on Devon Island, coming in two groups. Most of the day was spent establishing camp and unpacking food and other items that were flown in. We verified that all of the EDGES equipment on the packing list was present. J. Soohoo demonstrated the connectivity of the Inmarsat modem. The LiFePo batteries were connected to their cables and charge to between 13.8-13.9 volts. The Bosch laser level was unpacked its functionality was verified.

2 August 5, 2022

After breakfast we started our first preliminary site survey of a location North of the HMP base camp on the Von Braun planitia on foot. The first site that we examined was located appromiately at (75.456560, 89.887960), and is shown in figure 1. As we had forgotten to bring the measuring tape we were only able to make approximate measurements of the ground slope at the site. We set up the laser leveling system next to a small outcrop of rock that would be on the western side of the ground plane if we chose to construct it here. We determined that North-South slope was roughly 1° (sloping down to the South), while the East-West slope was roughly 0.6°.

We later returned with a tape measure and measured the rough North-South slope at Site 1, and it appears to be within the specification at 0.9 degrees (sloping downwards to the south). The approximate East-West slope was 0.6 degrees (sloping downwards to the west). These slopes seem to be fairly consistent over ground plane sized (50x25m) sized area. In this location ground is a mixture of fine clay and dime-to-quarter sized gravel. There are some loose stones that could be fairly easily scraped away or excavated and removed. There doesn't appear to be any major outcrops of bedrock, and there are no large boulders within 100m. No point on the horizon appears to exceed 15 degrees in any direction. We measured the ground conductivity with the METER group probes in a small 3-4 inch deep hole, and obtained readings of (0.038mS/cm and 0.054mS/cm on each probe), which is low but not unexpected. This site is within line-of-site of base camp, about 1.5km away, and is relatively easy to traverse on the ATVs over a fairly smooth path.

Figure 1: Location of the first preliminary site survey on the Von Braun planitia.

In the evening we performed a quick site survey on Drill Hill (Site 2) located at (75.420850, 89.760040). Site 2 has a much lower mean slope. We measured to be 0.3 degrees in roughly the North-South direction. The ground also has higher conductively, measured to be from 0.37mS/cm to 0.47mS/cm. This is probably due to the dirt (breccia) being a fine clay like material which retains more moisture. There are very few rocks, but there is a small amount of vegetation on the surface. However, the ground there is much more bumpy, the surface is covered with cracks and small mounds (about 6 inches to 1 foot in diameter) that undulate about 5-7cm from peak to trough as shown in figure 2. The ground is also prone to cracking into chunks which appears to make the stakes used to the secure the ground plane less stable against much wire tension (if for example it is necessary to tension the wires enough distortion from the undulations). The trail to into the crate to reach the Drill hill location is significantly rougher than Site 1, and might pose a larger risk of vibration damage to the antenna electronics.

Figure 2: The ground condition at Site 2 (Drill Hill), showing the localized mounds and cracking.

3 August 6, 2022

It was decided that Site 1 would be selected to serve as the EDGES3 system deployment location, so after breakfast the wire and pegs were transported to the site. Before starting the construction of the ground plane a more thorough measurement of the slope of the site was performed and the four corners were marked, starting from the South-West corner (as the reference corner). A small sundial was also constructed at the South-West corner to provide a cross check on the GPS indicated North-South direction.

For the solar survey, a 63.5 cm circle drawn about a vertical rod embedded on the ground. Stakes were driven into the ground at the intersection of the shadow of the rod (about 1 cm in width) with circle at 11:00, 12:00, and 13:00 Central Daylight Time (CDT). Since the longitude of the site is 89.8688° West, and approximately 5.991 hours behind UTC, no attempt was made to correct CDT to local noon at the level of minutes/seconds. However, since daylight savings is in effect, 13:00 CDT (local time) is effectively astronomical noon. Surveying string was used to determine that the line passing from the South-West corner to the North-West corner (segment AC in figure 3) of the ground plane was 12.2° to the East of the shadow cast at 12:00 CDT, and was 6.7 degrees to the West of the shadow cast at 13:00 CDT (noon). Alan sent us a message, that for our location, the position of the sun should be (on August 7th) as specified in table 1 below: This indicates that the ground plane is oriented

Time (UTC)	Local time CDT	Local astronomical time	Az	El
16:00	11:00	10:00	145.4	28.52
17:00	12:00	11:00	161.82	30.19
18:00	13:00	12:00	178.53	30.82

Table 1: Sun positions on August 7th vs. time.

approximately 6° to the East of geographic due North.

Once the four corners of the ground plan were marked, diagonal lines were strung between opposite corners using surveying string to mark the center of the ground plane. Then the length of each side was measured, and the change in height relative to the laser level placed at the center (at a height of 3ft 10.5in) was measured. Figure 3 labels the ground plane corners and center, while table 2 shows the measured lengths of each segment and the relative change in height of each segment.

With the corners marked, the locations of the pegs were determined with a measuring tape and were inserted in the ground. It was decided to use the yellow (hammer-in) pegs due to the ground conditions, However the orange (screw-like) pegs were used to indicate the transitions between different wire spacing, as shown in figure 4

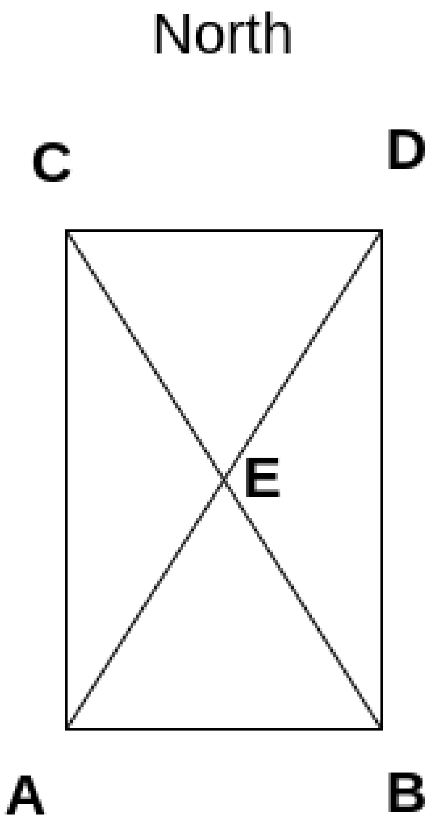


Figure 3: The ground plane layout with corner labels.

Segment	Length	Relative change in height
AB	25 m	NA
BD	163 ft 11 in (49.96m)	NA
AC	164 ft (49.98m)	NA
CD	24 m 97 cm	NA
EC	91 ft 7 in (27.91m)	-2.5 in (-0.0635m)
ED	91 ft 4 in (27.84m)	+18.5 in (+0.4699m))
EB	91 ft 6 in (27.89m)	+8.5 in (+0.2159m)
EA	91 ft 10 in (27.99m)	-19 in (-0.4826m)

Table 2: Ground plane dimensions, taken using a measuring tape laid out on the ground and a laser leveling system.

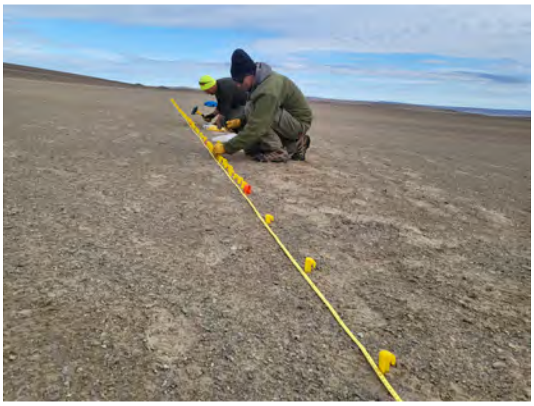


Figure 4: The installation of the ground plane support pegs.

4 August 7, 2022

The ground plane was completed today. It was constructed according to the planning document, using wire spacings of 6.5cm, 12.5cm, and 25cm. We used the coarse spacing (25cm) for the outermost section (±12.5m, ±6m), then 12.5cm spacing from (±6m,±2) and finally, we used the fine (6.5cm) spacing for the inner-most ±2m portion.

Due to the 500 ft lengths of wire many connections were needed (usually occurring mid-way between pegs). Initially we started making these connections with butt-style crimp connectors. However, we found that any appreciable amount of tension caused these connections to fail, so we transitioned to using a generator powered soldering iron to join the wires. The soldering was much stronger and progress moved quickly, and we completed the ground plane by the mid-afternoon. The antenna frame was retrieved from camp and assembled on site. The antenna and receiver crates were then transported to the site and tarped in preparation for installation the next morning.

GPS measurements of the ground plane were also taken at the corner locations, and are listed in table 3.

Location	GPS coordinates
A1	N 75°26.9038' W 089°52.1326'
A5	N 75°26.9318' W 089°52.1382'
C5	N 75°26.9318' W 089°52.0837'
C1	N 75°26.9045' W 089°52.0786'

Table 3: GPS coordinates of the ground plane corners.

Following the completion of the ground plane a series of height measurements were taking on a grid over the ground plane. This was done using the laser leveling system. Figure 5, shows the grid, and the alpha-numerical location labels, while table 4 lists height of the laser plane above the ground at each grid point. Note that a larger height indicates that the ground is lower in that location. To get the relative height of each point in the grid subtract it from the height of the laser itself (point B3 – 1.060m). The East-West/North-South distances between each pair of adjacent grid points are 12.5m.

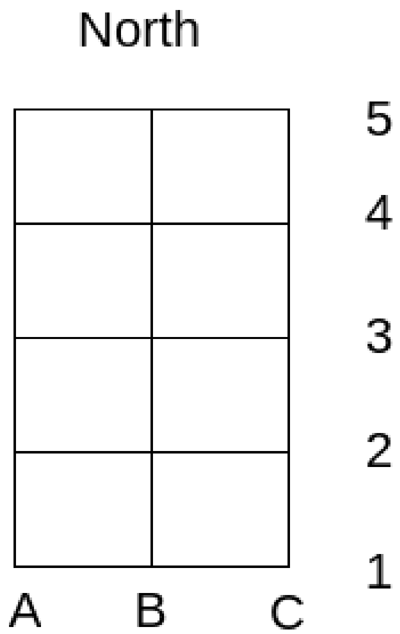


Figure 5: Grid points of height measurements on ground plane. Grid spacing is 12.5 m.

Soil conductivity measurements were also taken at each corner of the ground plane, using both of the provided probes. These measurements are listed in table 5. There is some systematic difference in the conductivity read by each probe, it is not known if one probe should be preferred to the other.

Location	Height (ft, in)	Height (m)	Relative Height (m)
A1	5 ft 0.75 in	1.543	-0.483
B1	4 ft 6.75 in	1.391	-0.331
C1	4 ft 3 in	1.295	-0.235
A2	4 ft 5.75	1.365	-0.305
B2	3 ft 10.5 in	1.181	-0.121
C2	3 ft 8 in	1.118	-0.058
A3	4 ft 2 in	1.27	-0.210
B3	3 ft 5.75 in	1.060 (laser)	0.0
C3	3 ft 0.5 in	0.927	0.133
A4	3 ft 11 in	1.194	-0.134
B4	3 ft 2 in	0.965	0.095
C4	2 ft 7.25 in	0.794	0.266
A5	3 ft 9.5 in	1.149	-0.089
B5	2 ft 10.5 in	0.876	0.184
C5	2 ft 1 in	0.635	0.425

Table 4: Ground plane grid height measurements.

Location	ZSC09675	ZSC27727
A1	0.028 mS/cm	0.043 mS/cm
A5	0.072 mS/cm	0.044 mS/cm
C5	0.074 mS/cm	0.055 mS/cm
C1	0.029 mS/cm	0.041 mS/cm

Table 5: Soil conductivity measurements. Note, no rain had been observed at the site since the time of our arrival at this point.

5 August 8, 2022

The antenna frame was carried out to the center of the ground plane (marked with a peg placed at the intersection of the diagonals), and the frame was oriented such that each corner leg was approximately equidistant with the nearest diagonal (marked with surveyor string) as shown in figure 6. Next, the antenna panels were carried out and mounted on the frame. The spacing of the panels was adjusted until the central distance between the two panels was approximately 1.3in, as shown in figure 7. The FieldFox VNA was connected, and the fiber and DC power cables were passed through the tuning pipes, which were then attached to the antenna panels.

Figure 6: The location of the antenna support frame.

The DC power cables was zip tied to the center marking peg below the antenna and strung out to the East over the top of the ground plane (at a 90 degree angle to the ground plane wires). The battery was connected to the DC power cable, and the fiber was connected to the media converter. Some quick tests were done to confirm that the back-end PC was reachable, and that thermal controller was function. A couple of quick scripts were run to confirm that the VNA was able to acquire S11 measurements and fastspec was able to acquire data from the antenna and each of the calibration targets.

Following verification that the electronics were functional, the antenna panel covers were fasten down with screws through the conductive elastomer gasket. The thermal control was set up to keep the front-end electronics

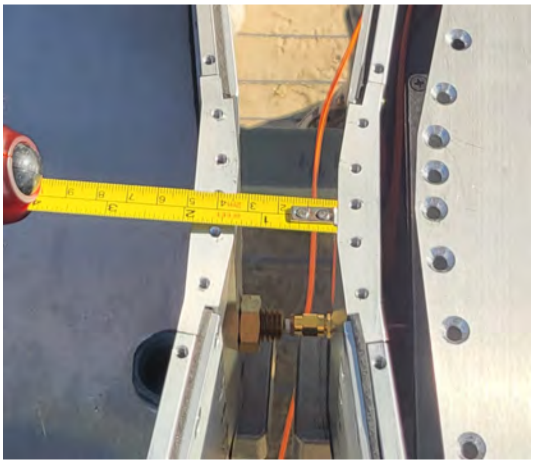


Figure 7: The spacing of the antenna panels.

box at 30C and a script to perform the VNA calibration measurements was launched. At 9:00PM (CDT) a fresh battery was brought out and the spectrum calibration measurement script was launched to run overnight. In addition, the plastic rain cover (from juice bottle) was attached with caulk to protect the central connector from direct precipitation as shown in figure 8.

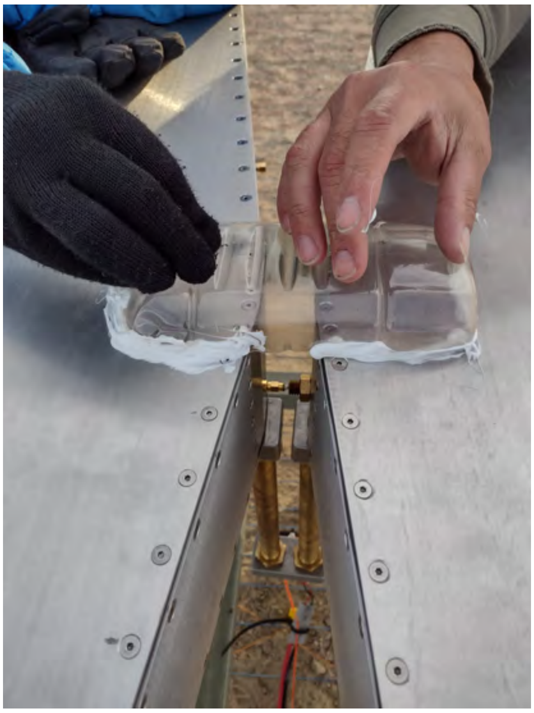


Figure 8: Rain cover attachment.

6 August 9, 2022

At 9:00AM we returned to swap in a fresh battery, and launch a script to acquire sky data until 9:00PM. At this point the front-end box was still configured to run at 30C. However, in consultation with Alan (upon viewing the spec-cal data), it was discovered that the system was having difficulty maintaining a temperature of 30C, often dipping as low as 27C. This was determined from the large residuals on the open/shorted cable fit, as shown in figure 9.

At 9:00PM we returned to swap in a fresh battery. We reconfigured the system thermal control to keep the front-end electronics box at 20C. We then configured an overnight script to run the VNA-cal process and then spec-cal process.

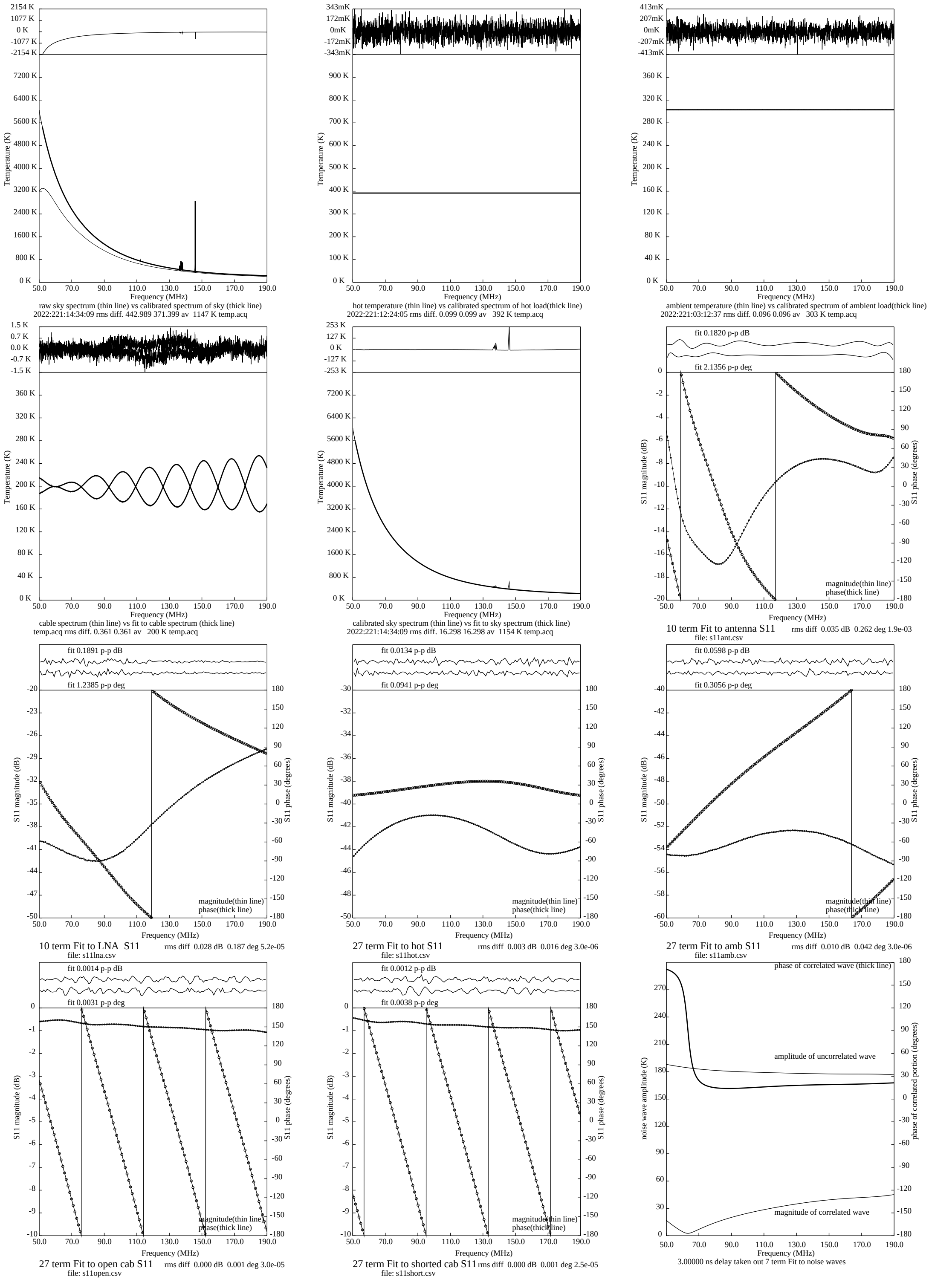


Figure 9: The initial calibrated spectrum (poorly maintained 30C front-end temperature, with 15 minutes of sky-data). Note the large residuals in the plot of the cable spectrum (left, 2nd from top).

However, unfortunately a typo (missing apostrophe) in the script prevented both VNA and spec cal from running overnight.

We did look at 12 hours of sky-data (from the unstable 30C front-end) for RFI and it looked fairly clean, with only a minor amount of meteor scatter in the EDGES observing band. A waterfall plot from 50 to 190 MHz is shown in figure 10. The signals near 137 and 145 MHz appear to be satellites.

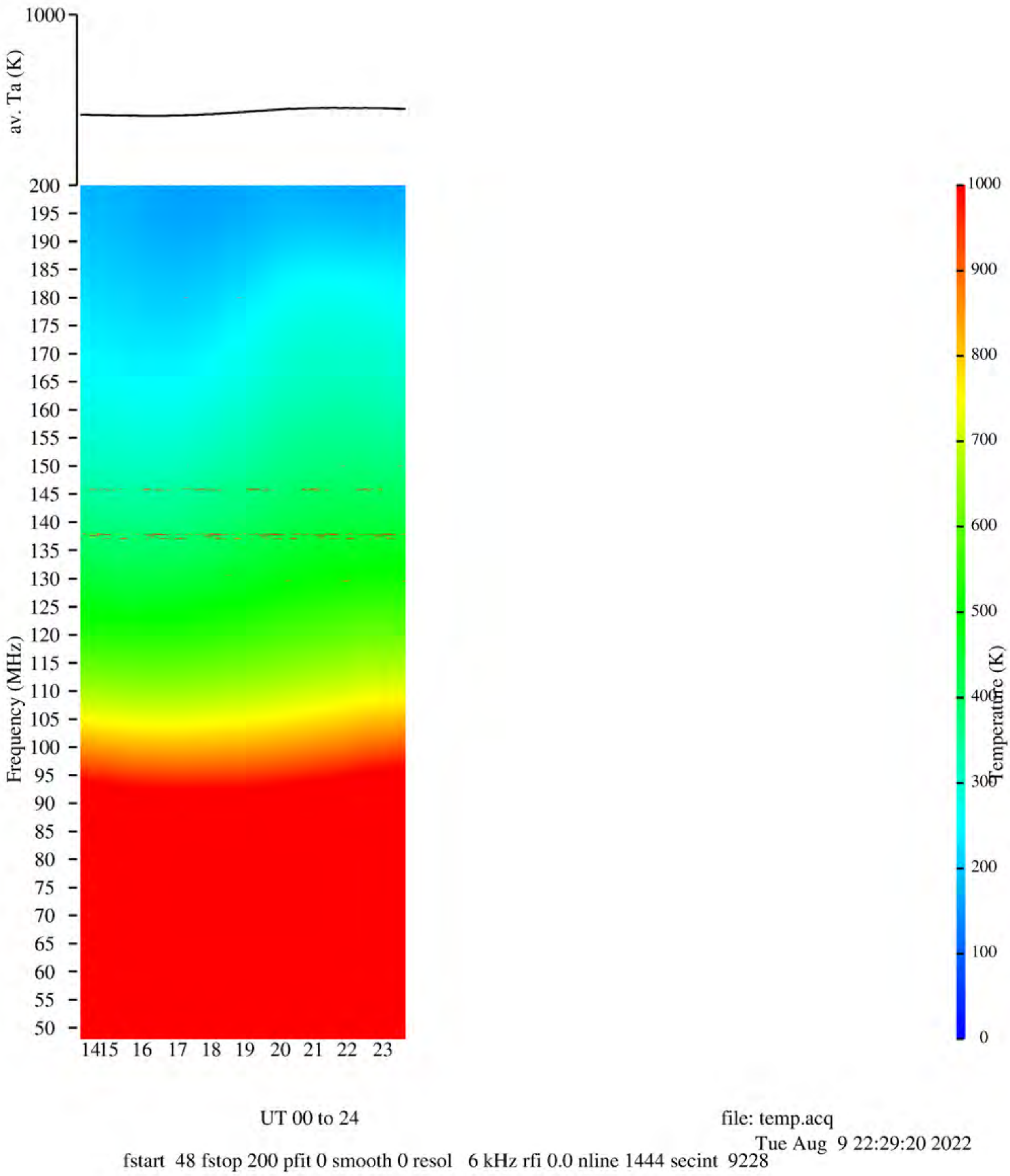


Figure 10: Water-fall plot of roughly 12 hours of spectrum observed by the EDGES instrument.

7 August 10, 2022

We returned at 9:00AM, and unfortunately discovered a typo in the data acquisition script prevented both the VNA and spec. cal processes from running. Furthermore, temperature data was not logged. We inserted a fresh battery and then corrected the VNA and spec-cal acquisition scripts and tested that they would run properly. We also started a separate temperature logging process to keep track of the front-end box temperature, as well as the ambient load, inner box, and pr59 current draw.

It started raining shortly after returning to base camp, around 10am and continued until about 2:00pm. We returned at 12:00PM to collect the VNA calibration data, and to start the spec-cal script. A quick examination of the temperature log for the morning run, showed that 20C was maintained stably (during the day, with thick cloud cover, and approximately 12C outside temperature). The temperature for the first ~ 3 hours is shown in figure 11. We noticed two breaks in the ground plane wires (at a soldered joint), these were were repaired by loosening wires slightly at the pegs and twisting the broken connection tightly back together.

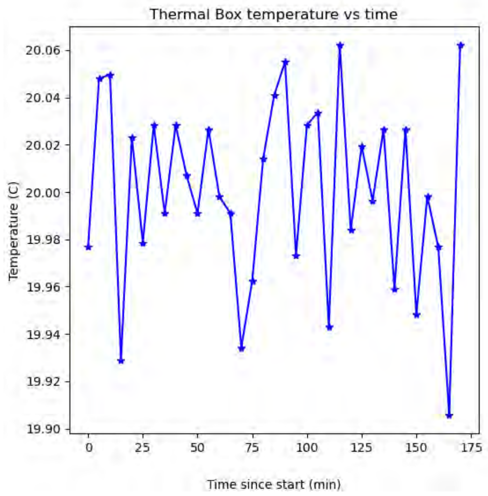


Figure 11: The temperature of the front-end box, short interval.

We went out to refresh the battery at 9:00PM CDT, and collected some data from the VNA calibration, and some of the (incomplete) spectrum calibration. A quick look at the thermal state of the system during the date showed that it appears to be stable at 20C for relatively long periods (see figure 12a).

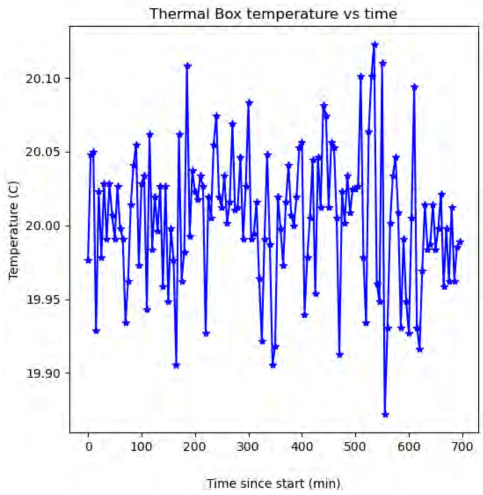
8 August 11, 2022

At 9:14AM – Swapped battery 3 (11.2 V) with battery 1 (13.5 V). Discovered that battery 3 had drained beyond its capacity to power EDGES3 approximately 45 minutes before our arrival, causing fastspec to cease running (operating system appeared unstable), along with the temperature control unit (TCU). After connecting the fresh battery, the TCU still was non-functional, drawing no current when queried with pr59 -reg 152. In an effort to fix this issue, we reset the nuvo, but the problem persisted. We eventually opted to start running fastspec with no functioning TCU and returned to base for further debugging. Additionally two of the inner (blue) wires in the ground plane had come apart at soldered joints, and we twisted them together by hand.

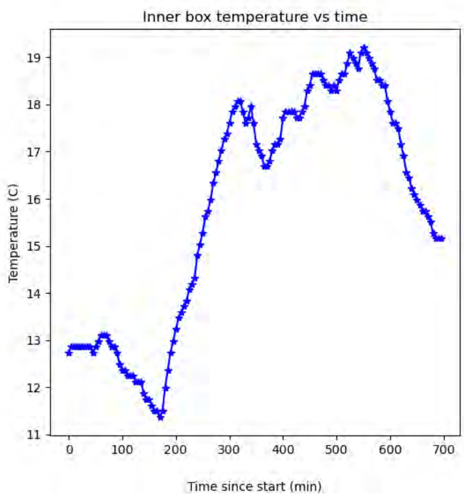
At 11:12AM – We returned to the site to debug the temperature control issue and discovered it had been resolved of its own accord. Fastspec was continuing to run and the inner temperature had returned to 20 C. Due to the two breaks in the wire found in the morning, the tent pegs were loosened by hammering sideways on each one towards the antenna, creating room for movement to allow for slight changes in the wire tension due to varying environmental temperatures.

15:13 – Battery 1 (13.1 V) was replaced by battery 2 (13.4 V). pr59 -reg 152 reported a current draw of 1.02 A, and the inner box temperature remained steady at 20$\pm$0.1 C throughout the early afternoon. Visual inspection of the wires showed no new breaks since the loosening of the tent pegs. Rain remained steady accompanied by ~ 20 MPH winds. We left the site at 15:21.

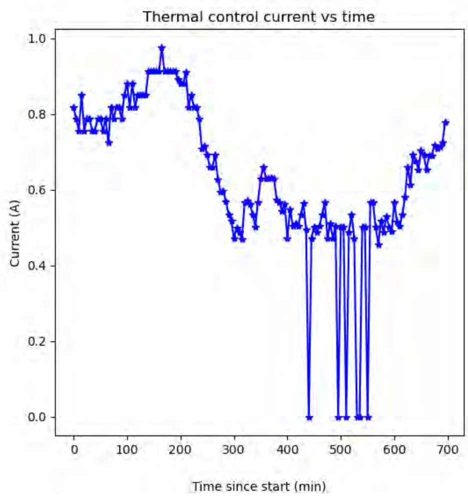
At 23:00 – We left to swap in battery 1 (13.4 V), and returned with battery 2 (at 12.9V).



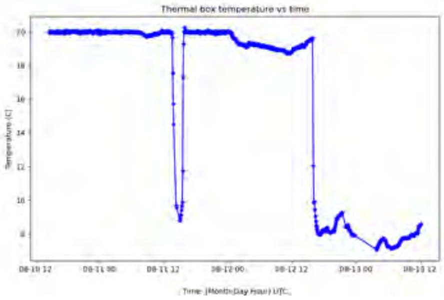
(a) The temperature of the thermal (front-end) box, long interval.



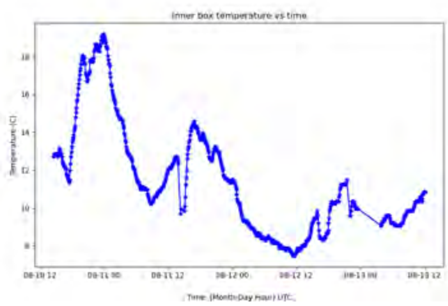
(b) The temperature of the inner (back-end electronics) box.



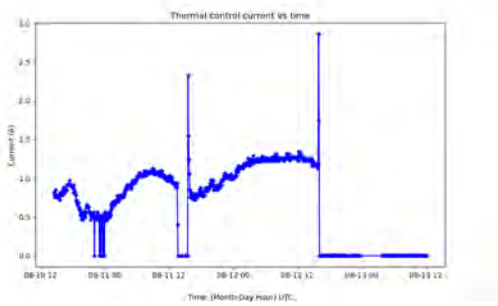
(c) The current draw on the thermal control system.



(a) The temperature of the thermal (front-end) box.



(b) The temperature of the inner (back-end electronics) box.



(c) The current draw on the thermal control system.

9 August 12, 2022

We replaced the battery between 7:00 and 7:20 (inserting battery 3 at 13.4V, and returning 13.0V). We returned at 10:35 to replace battery 3 (at 13.2V) with battery 2 (at 13.6V), and set the system thermal control to 10C (as the system did not appear to be stable at 20C overnight). We returned at 15:00 to check on the system and inserted battery 3 (at 13.5V). However, we discovered that the system thermal control was not functioning (there was no current being sent from the pr59 controller, as reported in register #152).

At this point we tried several things to debug the system. We rebooted the pr59, and also restarted the system after a complete shutdown and battery disconnect. We ensured that `pr59 -mode 2` was run to make sure the system was in PID mode, and check several register values. There was an error code issued by the system which was: `0002 C001 C0A1`. We then dumped all the register values to text for debugging. We left the system in sky-data acquisition mode (without thermal control running) the rest of the day. The final battery change was done at 22:30.

10 August 13, 2022

The batteries were swapped at 7:00, returning battery 1 (at 13.1V) and bringing out battery 2 (13.9V).

After consulting with Alan and sending him the pr59 register values he noticed that the low temperature alarm value (register 72) was set to 10C, which is much too high for this environment. After the fog cleared, we returned to the system and modified pr59 to allow us to set the value of register 72. We changed it from 10 to -40, and the system immediately cleared the low temperature alarm and began regulating the system to the set-point of 10C. We re-started sky-data acquisition and plan to repeat the VNA cal in 36 hours, and will re-do the spec-cal on Aug 15th after verifying the system is stable at 10C.

The batteries were swapped again at 12:50 inserting battery 3, and returning battery 2.

At 14:00 we returned briefly (10 minutes or so) on two ATVs to grab the battery we forgot to bring back.

A temperature logs up until this morning are shown in 13a.

11 August 14-23, 2022

Starting from August 14th, for the remainder of the the deployment, we have documented the site-access times (primarily for changing batteries and collecting data) in an excel spreadsheet. Hardware changes to the antenna or the ground plane with any additional information will still be documented here.

12 August 17, 2022

Today around 7:30PM we added an additional ferrite on the DC input line at the base of the antenna, as shown in figure 14.

Figure 14: Additional ferrite at DC input.

13 August 18, 2022

Today at 3:00PM after consulting with Alan we opened up the antenna in order to add an additional ferrite to the DC input line at the pipe opening as shown in figure 15. We added an additional ferrite on the DC input line just after the terminal block as well for good measure.

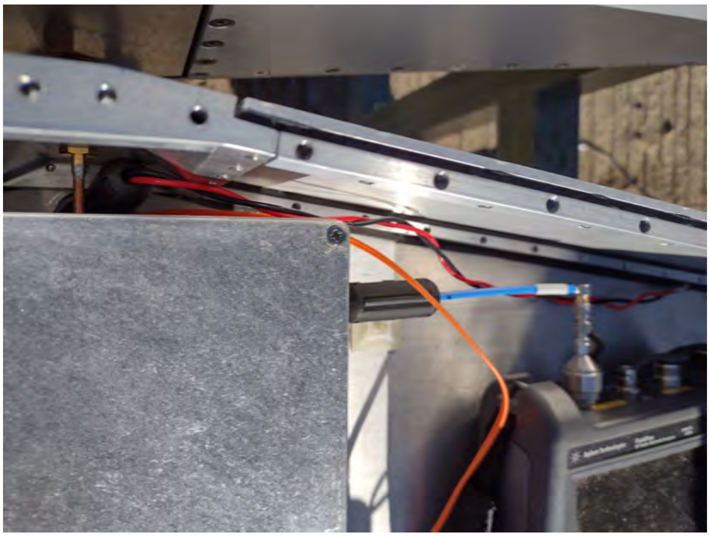


Figure 15: Internal ferrite at the DC input inside of the antenna.

14 August 20, 2022

In order to rule out the LiFePo batteries as a possible unexpected source of noise today we borrowed a standard Lead-Acid (50AH) battery from the HMP staff and charged it to 12.8V. This battery was connected around 9:35AM in place of the normal LiFePo battery in the external battery box, and normal data acquisition was conducted while it was attached. We returned around 2:35PM to disconnect this battery and insert the standard LiFePo battery. The data acquisition files associated with the external Lead-Acid battery are as follows:

1. 232_14_59_23_ant.acq
2. 232_17_55_35_ant.acq

A quick analysis of these files did not expose any significant difference in the data from that taken with the standard batteries. The remainder of the day was run using LiFePo batteries.

15 August 21, 2022

Today, starting around 11:40AM we conducted a test to rule out the external power system and DC power line as a possible source of noise using a set of 4 gel-cell 6V VRLA batteries borrowed from the HMP staff. A harness to connect these batteries two pairs in-series, in-parallel was put together and the antenna was opened up to insert these batteries as shown in figure 16. . The DC power line was disconnected and completely removed from the ground plane, while the remaining short connection below the antenna was tucked up into the pipes/box underneath the antenna, with the panel partly closed, as much as the connector would allow, as shown in figure 17. Once the batteries were connected, the antenna panel was screwed down and data acquisition was started.

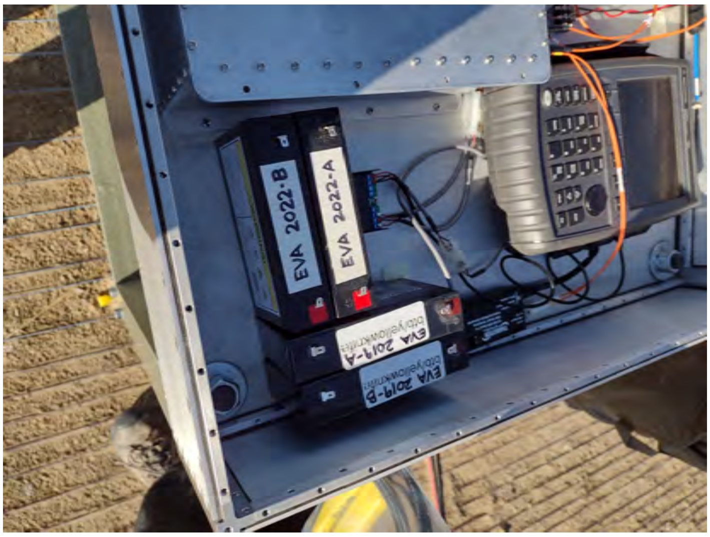


Figure 16: The internal 6V VRLA batteries used for the internal battery test.

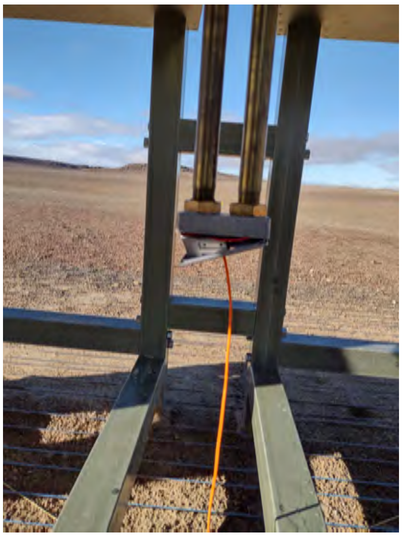


Figure 17: DC power cable disconnected and short remaining wire tucked into pipes/box.

We returned around 3:10 PM to find that the system had shut down due to low power, as the VRLA batteries had drained sufficiently that they could no long support the power needed by the system. The the data files associated with this internal battery test are listed below:

1. 2022_233_13_48_59_ant.acq
2. 2022_233_16_55_36_ant.acq

16 August 22, 2022

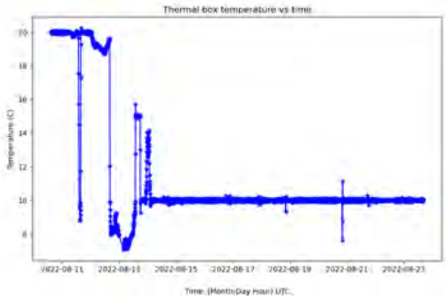
Today after talking with Alan, we returned to check the ground plane electrical continuity. While the ground plane was examined to physically continuous, we discovered that there were several electrical breaks in western most 5 meter section of the ground plane. These disconnects were due to poor electrical connections formed by the crimp-style butt connectors used in this (earliest assembled) section, as shown in figure 18. The locations (wire, as numbered from west, starting with #1) of the disconnects are listed below, the distance specified is the length measured from the south side of the ground plane, all discontinuities discovered were in the outermost 25cm spaced section. These breaks were repaired, and the resistance between the South-East corner of the ground plan and opposite North-West corner was measured to be 176 Ohms, while the resistance between the South-East Corner to the approximate mid-point was 90 Ohms.

1. Wire #3, @ 3.65m
2. Wire #6, @ 42.5m
3. Wire #9, @ 12m
4. Wire #12, @ 33.6m
5. Wire #15, @ 16.45m
6. Wire #18, @ 33.15m
7. Wire #21, @ 17.3m

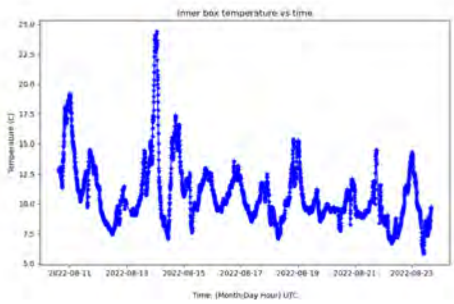
Figure 18: The bad crimp style butt connectors (avoid in future deployments).

17 August 23, 2022

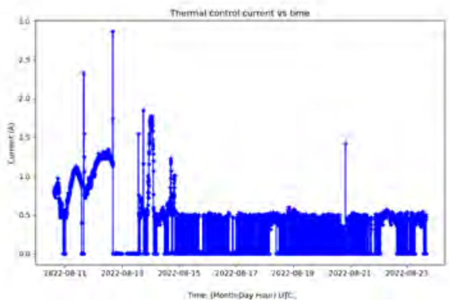
Today, the system was dismantled with the ground plane being left in place. Before disassembly, the VNA-calibration script was run to perform the antenna S11 measurement for the last time. The prefix for these VNA measurements is 2022_235_14. One final soil conductivity measurement was taken, which showed that the soil conductivity had no appreciable changes and was still in the range of 0.02-0.04mS/cm. The complete temperature logs were also copied and show the system was stable once the pr59 issues were resolved as shown in figure 19a.



(a) The temperature of the thermal (front-end) box.



(b) The temperature of the inner (back-end electronics) box.



(c) The current draw on the thermal control system.