# Starlink South Pole Modifications

Version: 1.0

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This document describes the modifications we implemented to the Starlink antenna in order to improve the viability for general operations at the South Pole. In addition to the modifications we also discuss the results and experience gained from testing the modified antenna.

# 1.0 Deactivate Azimuth and Elevation Motors

During the general Starlink tests we ran into the problem that we are not able to deactivate the primary dish pointing of the antenna in software. The antenna decides based on an internal assessment in what azimuth and elevation position it wants to point and remains most of the time in a fixed position. When the antenna loses the connection to the satellite it goes into search mode, at which it points to zenith. This happens a couple of times a day.

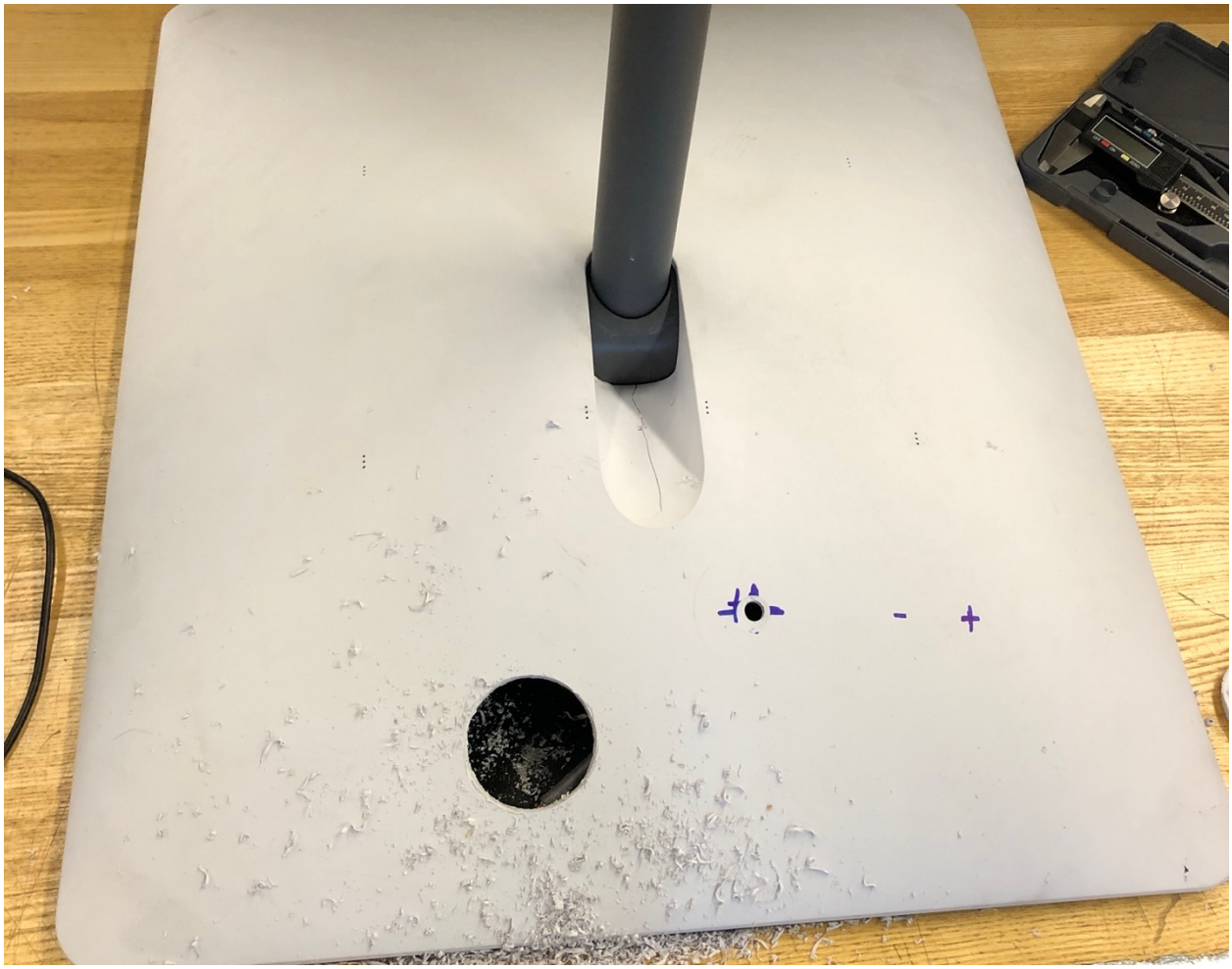
There are two main concerns with this behavior that we are addressing by disabling the motors. The first one is that we do not have control over which direction the antenna points, which is problematic with respect to RFI in the Dark Sector. During our Starlink testes we observed that the antenna always chose to point into the grid North-West direction. When the antenna is placed in the RF Sector or anywhere in the general Elevated Station environment this means that the antenna points towards the Dark Sector. Thereby causing significant RFI. Disabling the motor will give us control over the pointing of the antenna.

The second concern is that any mechanical movement during wintertime could break the motor assembly and leave the antenna inoperable in a non-defined position. This could leave the antenna unusable for communications.

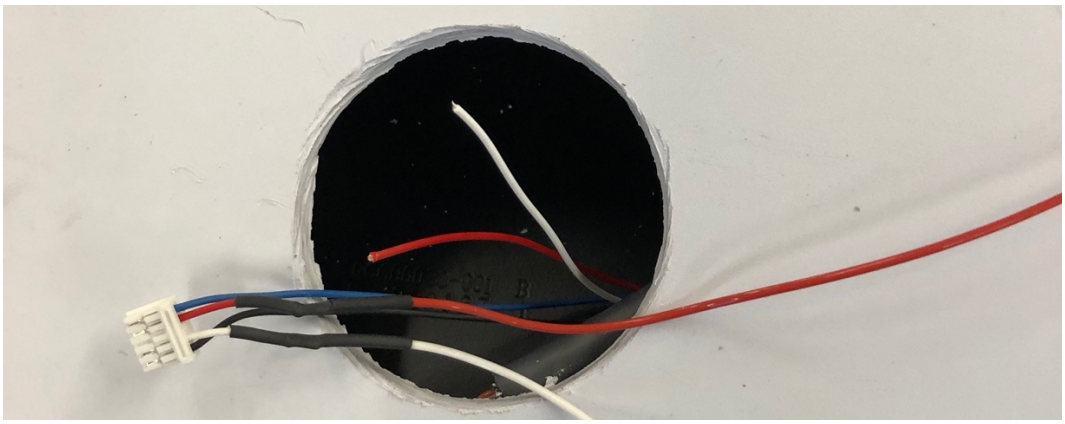
In the following section we describe the modifications to the antenna and results of operating the antenna with the motors disabled.

## 1.1 Deactivation of the Starlink antenna motors

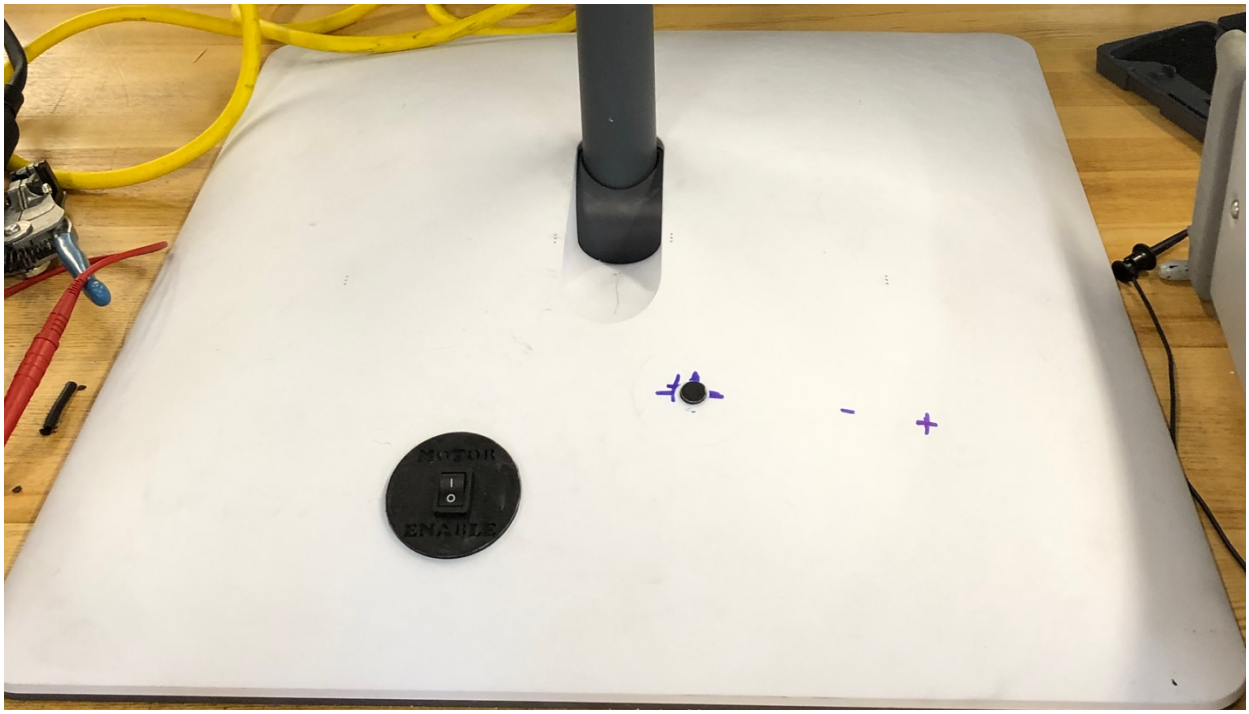
Based on information provided by IceCube and the Internet we knew that the Starlink antenna has a motor connector on its primary PCB. The manuals which were available on the internet however were all for the private antenna version, which is smaller compared to the comerical version we have. Therefore, we decided to drill a pilot hole and use an endoscope to locate the connector. The picture below shows the antenna with after we located the connector and drilled the primary hole.



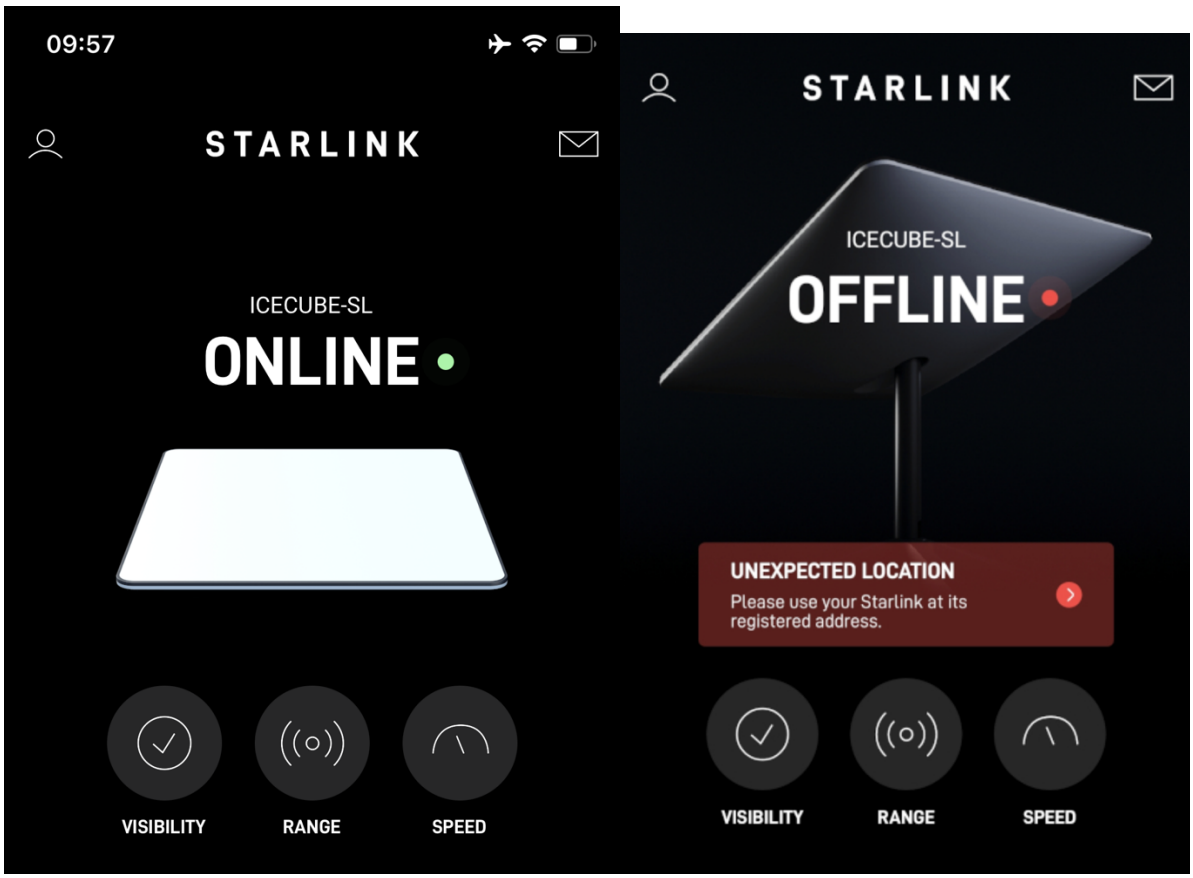

After successfully locating the motor connector and disconnecting it from the PCB we measured the resistance of the four wires to confirm which pair of wires belong to a motor. The result of this measurement is that **blue** and **red** are one pair and **white** and **black** are the other pair. The resistance we measured for each motor was 9 Ohm. To finally confirm that these are only DC motors we also powered up each motor with a bench power supply. This confirmed that we just need to disconnect one wire for each motor to deactivate them.



The picture above shows the motor connector with the red and white wire disconnected. In order to be able to still use the motors when required, we installed a switch that allows us to enable both motors. To mount the switch we 3D printed an adapter plate to mount the switch in the hole. See picture below.




We then tested the antenna out at SPRESSO again to see if the software allows operation with the motors diactivated. When connecting to the antenna with the Starlink app we noticed that the picture of the antena changed. Previously the antenna picture showed a mast below the antenna and now after deactivating the motors it only shows the dish surface without any mount below. See picture below for the comparison. The left-hand picture shows the app dashboard after deactivating the motors and the right-hand side shows the app dashboard before deactivation.




We also could confrm that the antenna connects to the sattelites and operates normaly. This is a significant result and brings us one step closer to understand the capabilities of the Starlink system and its viability to be used at the South Pole.

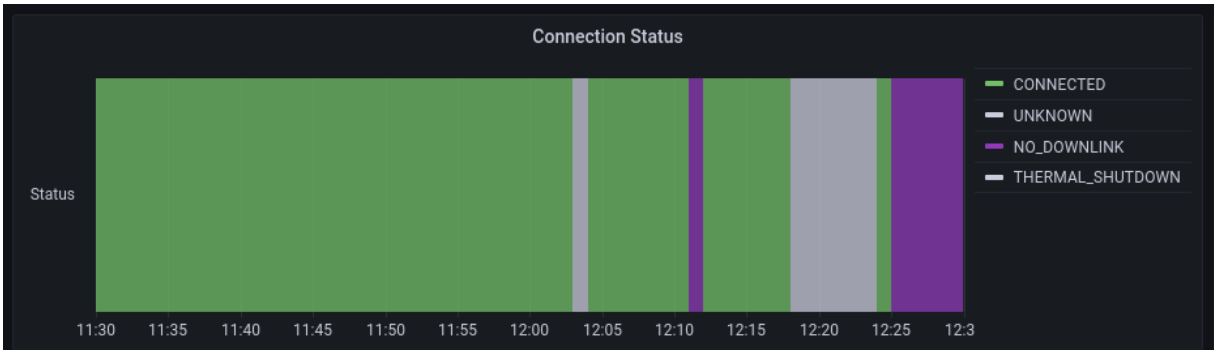
## 2.0 Thermal Insulation

Winter temperatures at the south pole are typically around -80 deg F and peak as sol as -100 deg F. Most devices will not be able to operate at such low temperatures, hence the need for thermal insulation. Based on the experience from station personnel we embedded the Starlink antenna in 1.5-inch-thick Styrofoam, see picture below. Similar insulations are added to the Vessel link antennas.

When we installed the antenna at SPRESSO with the thermal insulation we wanted to test if the Styrofoam causes any problems with the connectivity of the satellite link. As far as we can tell in a 2 hour test period, we had about 100 percent connectivity.

After about 2 hours of operation, we saw in Grafana that the antenna shut down due to overheating. Note, that the heaters have not been activated during this time. This result shows that if we want to thermally insulate the antenna for winter operation, we will need to adjust the amount of insulation. (reduce thickness or only cover certain parts of the antenna)

It is also worth noting that the antenna has three heater settings. The first one is off. The second one only heats the antenna if it thinks it is obstructed e.g. it thinks that it is covered by snow. The third setting preheats the antenna and keeps it warm continuously. We currently run the antenna in the second setting. To change the setting one needs to login with the IceCube Starlink account.




## 2.0 Conclusion

Deactivating the motors by installing a switch that disconnects the wire to the motors was successful. Even with the motors disabled the antenna was still operational and did not show any faults. In fact, based on the change seen in the Starlink app we believe that operating the antenna in the deactivated motor configuration is fine.

We could verify that the antenna is able to connect to satellites when covered by Styrofoam and we do not see any significant performance hit. We also saw that only minimal insulation is required to keep the antenna warm, too much insulation will lead to overheating. And finally, the heater setting could be changed to account for colder winter temperatures provided thermal insulation is not sufficient.