Debugging AO-109 – An Update

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Introduction

At the end of our article in the May/June *AMSAT Journal*, we said "By the time you read this, AO-109 may be opened for general amateur use." The opening announcement, in fact, came on July 19, just shortly after the *Journal* was available. Very shortly after that, we started getting reports that some SatNOGS[1] stations had seen telemetry signal from AO-109 as early as May 2021. Chris, G0KLA managed to partially decode one frame from SatNOGS. It was hard work and there were too many errors for our Forward Error Correction algorithm to fix, but by ignoring errors, we could see some data; however we had to guess which data was wrong.

We asked for more people to try to get telemetry, and we were pleased to receive 29 frames over several days from W7KKE, W7FWF, and K8DP. Thanks so much to all of them! Thanks to them we can now say a few more things about the AO-109 situation.

What we have seen and learned from telemetry

First the telemetry we have received confirms what we inferred from our earlier experiments:

- The antenna telemetry shows that they are open (more on that later)
- AO-109 is in transponder mode
- AO-109 does receive commands successfully, especially from a strong command station

In addition, telemetry shows some other anomalies that let us make better hypotheses for other behavior that we have seen:

- First the telemetry IS working, which tends to exonerate the telemetry modulator and software.
- The transmitter is sending telemetry with power output between 6 and 8 mW. You can compare this to our pre-launch testing which showed power output of somewhat over 100mW, as designed.
- The power amplifier current is higher than expected based on pre-launch testing.
- The min/max telemetry shows that the maximum power output since launch was about 440mW implying that the transmitter was likely working immediately after launch. (During the attempted early commissioning period, we tried both transponding, and increasing the telemetry gain, which could explain the relatively high power output.)
- It is even more clear seeing the telemetry downlink on a waterfall that the signal strength varies cyclically. The period seems to be around 25 seconds.

[1] SATellite Networked Open Ground Stations.

After a discussion with Dan W9EQ, one of our transmitter engineers, we believe a reasonable hypothesis for the low power is that one of the dual power amplifier chips has failed shorted. This not only increases the current to the PA, but reduces the power available to the other PA chip. Dan also hypothesizes that running high power into a poorly deployed antenna might cause the blowout, although it is still hard to understand why we initially had no reception at all. Note that even if the 70cm antenna was not fully deployed, it does not cross over itself to make it electrically shorter even when stowed.

Since getting this telemetry, we commanded higher output from the telemetry modulator into the mixer and power amplifier, but saw essentially no change in the output power telemetry. According to W9EQ, this is to be expected with a shorted PA. (It may imply that 8mW is the highest to expect from the transponder as well).

As we hypothesized in the last paper, the cyclic strength of the telemetry beacon could be explained by the antenna being only partly released and blocked by the satellite part of the time as the satellite rotates. Similarly, if the receive antenna were only partly released, it would make commanding difficult for the same reason.

One further hypothesis: Carl, N3MIM proposed that the Nitinol wire used for our antennas was too cold to fully restore to its original shape after it was released. This could explain why both receive and transmit have problems, but does not explain why this satellite in particular should have problems that the other Foxes did not.

Vanderbilt University Experiment Data

As we said in the previous article, one of our goals is to provide data for the Vanderbilt University COTS radiation experiment. This experiment not only funded the AO-109 flight but also will, in the long term, provide great information for satellite builders who can only afford common off-the-shelf parts in their birds. We are happy to say that we have been able to provide some data for Vanderbilt. Of course, more data over a longer period will be that much better, but at least Vanderbilt is getting something.

Where is the data?

The data from AO-109 is on AMSAT server at the same location as all Fox data. You can see the entire dataset by using FoxTelem and downloading Fox-1E (the latest versions of FoxTelem do not require you to download all the other satellites.) You will see that despite having only 29 frames, there are a lot more health records than that in the WOD tab. This is because of AO-109's new capability: Whole Orbit Data[2], which captures a full set of health data every 60 seconds, stores it in memory, and transmits several of these WOD data payloads in each frame. Similarly, Vanderbilt data is stored as WOD, so more science information than you might expect is also available.

In addition, you can see the AMSAT web page for AO-109 health at https://www.amsat.org/tlm/health.php?id=5&port=

[2] See Fisher WB1Fj, Fox-1E Telemetry, AMSAT Journal, March/April 2018

Telemetry Reception

Unfortunately, it seems that it requires a fairly "hefty" station to receive AO-109 telemetry. A normal end-mounted M2 LEO Pack, for example, is not enough. Everyone we have seen who has been successful has had a longer yagi, a preamp, and short coax. One person felt that the ability to reverse circular polarity also helped. Several SatNOGS stations have received a signal, but so far we have not been able to cleanly decode any of them. (See Figure 1.)

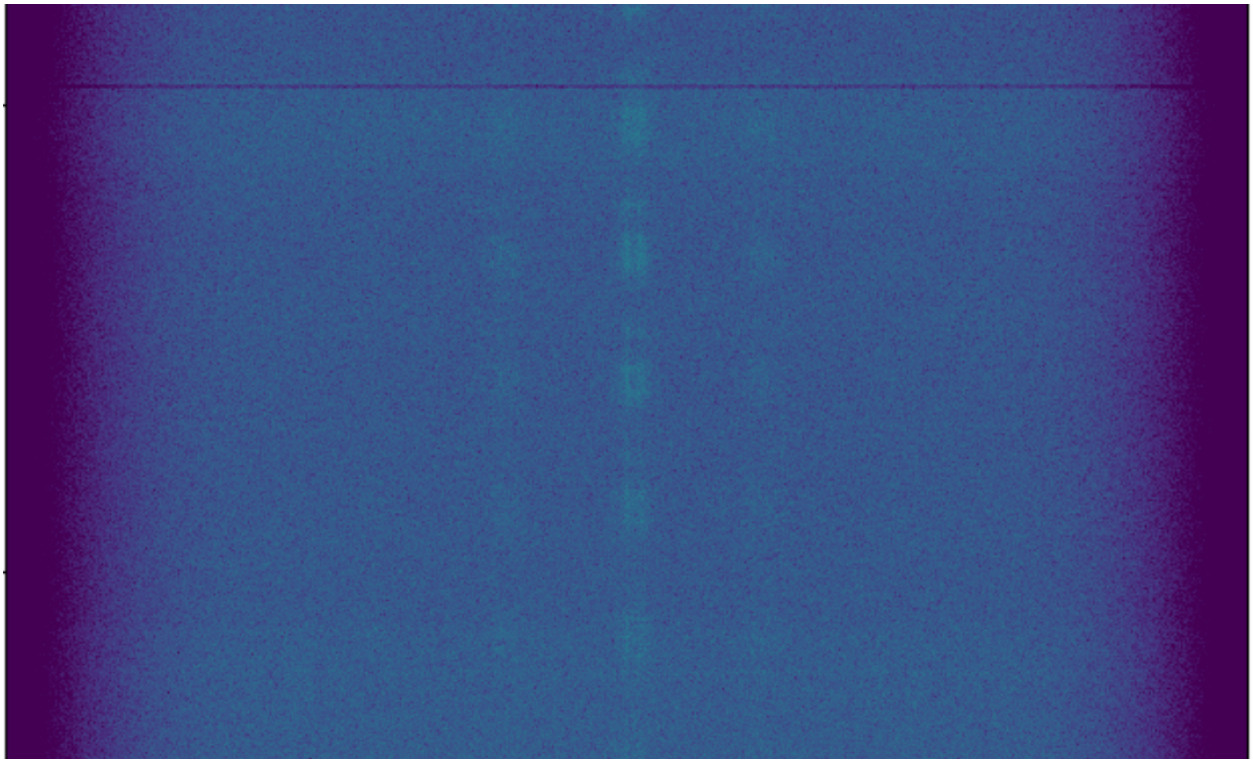

Figure 1: SatNOGS Station 488 (W7KKE) Reception of AO-109

Both for Vanderbilt University and for our own engineering testing, we would really appreciate even a few frames of telemetry that any stations can receive. One way to do this is to use FoxTelem directly via a Fun Cube Dongle Pro Plus (FCDPP) and an antenna as mentioned above. Another way that we know works is to record the IF or AF from an ICOM 9700 that is being doppler corrected during an AO-109 pass. The best chance for useful frames may be to record IQ using SDR# or HDSDR with something like an FCDPP or Airspy SDR Dongle, and then playing it back into FoxTLM.

We continue to thank all of our supporters and data collectors around the world! Please keep trying!