

UVLBI Memo #031

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To: UVLBI Group
From: G. B. Crew and V. Fish
Subject: SMTO 2012 EHT Observing Campaign Report

Equipment Setup

This memo briefly describes the setup and activities at SMTO during the 2012 EHT observing campaign. The receiver and its connections to the digital back-ends were not changed in any significant way from the previous year(s). (See memos #18 [2010] and #23 [2011] in this series.) One of the connectors to the Up/Down convertor broke, so we took the opportunity to open it and verify that the upper and lower 512-MHz bandwidth-limiting filters were installed. (See [Figure 1](#).)

The receiver and equipment racks are shown in [Figure 2](#). As in previous years, the units not fitting into the rack were piled on a table. (See [Figure 3](#).) This was fortuitous as the Amazon/10GbE daughter card from the recorder on the lower left was faulty and needed to be replaced. There was sufficient slack in the cables that we were able to stack the 3 RDBE-H units atop the other recorder in order to gain access.

The Mark5B and DBE-1 units used in previous years were removed and replaced (this year) by 4 RDBE-H backends and 4 Mark5C recorders. The polyphase filter bank (PFB) used in the RDBE-H personality is similar to the one in the DBE-1 and was tested as described in memos #28 and #29.

It was operationally desirable to operate the 4 DBE-Recorder chains independently. Thus the AZ station was in fact four substations, A1, A2, A3 and A4. The network configuration is as shown in [Figure 4](#). The following polarization/band assignments were driven by cable length:

A1: chB LCP Lower
A2: chB LCP Upper
A3: chA RCP Lower
A4: chA RCP Upper

In this context “Lower” and “Upper” refer to sidebands relative to the 1024 MHz sampler clock (Nyquist zones 2 and 3). The channel A and B inputs to the Up/Down converter were connected to 2 of the 4 receiver channels, viz USB/Hpol for RCP/ChA and USB/Vpol for LCP/ChB. (The LSB channels were not used.)

Two of the RDBE-H units had 3 additional cables installed to allow the regenerated PPS to be passed from the NRAO synthesizer board to the outside so that one RDBE-H unit could supply the PPS to all units. (See [Figure 5](#).) However, it was not clear that the voltage levels of this output (1.6 - 2.0 V) were adequate to drive the PPS inputs (0 - 1.5 V). To be safe, we daisy-chained the four units (“stations” A1, A2, A3 and A4):

```
M(aser) -> A1 -> A3 -> A4 -> A2 -> D(otmon)
```

as shown in [Figure 4](#) and monitored the time separation of the maser tick relative to the DOT monitor output of the final RDBE-H. The maser pulse was rather strong, so 9 dB of attenuation was inserted to reduce it to the specified power voltage level.

This was found to be 260 ns, and during the assembly the per-RDBE-H-delay was approximately 50 ns. (The internal `dbe_fs?` query typically reported a value of about half this for all units.) At the time of the first observation (MJD 56001, day 075) the clock early for the maser was 3.365 us at 2012y075d00h00m00.0000s with 4.35 ps/s drift (since the maser tick precedes gps by an amount that increases with time). Thus the respective *a priori* clock earlies were expected to be:

```
A1: 3.310 us
A3: 3.260 us
A4: 3.210 us
A2: 3.160 us
```

The only drawback to this approach was that it was necessary to start the RDBE-H units in order. (The DOT monitor output is not generated until the unit is fully configured.) In the event, we never needed to restart any of the RDBE-H units, so this was not a problem.

An additional complication with the RDBE-H units is that their synthesizer requires a 5 MHz input (for synthesizing the 1024 MHz sampler clock). At SMTO a buffer was used which was able to provide this at 7 dBm to all units. The input specification for the NRAO synthesizer board was stated as -2.0 to 2.0 dBm; however, we found 2 units which did not lock onto the signal at this level. We ultimately used 7 dBm, and later found that this was consistent with the LMX2531LQ2080E input specification of 0.5-2.0 Vpp into a 50 Ohm load, or -2 dBm to +10 dBm.

The input power on IF1 was specified to be about 33 dBm/512 MHz. We inserted small attenuators (0 - 6 dB) on the inputs and outputs to the Up/Down convertors to equalize the power levels to be approximately correct at the midpoint of the attenuator dials of the Up/Down converter. That is, we wanted the ALC reading to be about 16 on the 4 IFs and the 2 knobs to be about 5.

Back-end Checkout and Monitoring

As usual the maser was monitored for its drift against GPS. It was set to a small value prior to our arrival at SMTO; it was found to have an average drift of 4.382 ps/s during the 2012 campaign. On the two days of observation (MJD 56001 and 56007) it preceded GPS by 3.375 and 5.647 us respectively. (See [Figure 6](#)) The residuals of the fit were found to be between -40 and +60 ns.

In addition, we had a Symmetricom box to monitor the maser relative to an ovenized crystal oscillator. The Allen deviation, phase noise, and relative frequency were monitored continuously. Typical (24-hour) plots are shown in [Figure 7](#).

Once the RDBE-s were set up and running, we found we did not need to restart them. Their internal *dbe_fs?* query always reported a lock to the input 5 MHz signal, PPS generation and a PPS delay of 20-30 ns (5-7 in 4-sample ticks).

From time to time we did try correlating 1000-frame samples from the 4 recorder chains with *vlbi0*. Representative samples are shown in Figure 8 through Figure 13. The upper/lower sideband pairs (Figure 8 and Figure 13) were found to be highly correlated (25%) at the DC edge. This is presumably due to a broader width to the bandwidth filters than one might suppose. (I.e. signals bleeding into the adjacent Nyquist zone.)

The in-band cross-hand pairs (Figure 9 and Figure 12) show a somewhat larger correlation amplitude than was seen last year (2% [LSB] to 25% [USB]). The cause of this is not known.

The out-of-band cross-hand pairs (Figure 10 and Figure 11) were only weakly correlated (at most 4% near the DC edge).

Penultimately, the total power diagnostic from the SMTO analysis suite was monitored with time. Plots for the two days of observation are shown in Figure 14. The “total power” is a voltage which is convertible to receiver temperature (somehow).

Finally, the SMTO provides the observer with an *Xremote* tool that has several pop-up windows. The most useful is the status window that indicates the current observation mode and provides weather information. A screenshot of the window arrangement that was finally used is shown in Figure 15.

In place of the field system, we used the *RM5_CC.py* script which automatically adjusted the analog power levels and bit state thresholds. In practice (while on sky) the ALC never needed adjustment lower than 14 or greater than 18 (a swing of about 3 dB). Across all the SMTO logs, the share in the middle two bit states (should be 67-68%) was 66% in 1.3% of the scans, 67% in 46.0% of the scans, 68% in 51.2% of the scans and 69% in 1.5% of the scans.

Observational Log

The modules used are listed in Table 1.

On the first night of observation (day 075, MJD 56001), the pol15 (March15) schedule was run without incident. However, one of the records (A4) was not operational.

A replacement Amazon card arrived just in time to be swapped in prior to the second night of observing. (See Figure 16)

The second night of observation (day 080, MJD 56006) would have been xray20 (March 20). However, SMTO started the night with the tail end of the blizzard. We got slightly less snow than the lower bound on the prediction, but the timeline of the storm went mostly as predicted by NOAA. The observatory site switched over to generators during one my sleep cycle Saturday and we ran on diesel power through the previous night’s shift. The switch to generators was at the request of the LBT (Large Binocular Telescope) which was concerned about line voltage fluctuations and possible damage to their equipment. This wasn’t an issue for SMT due to the UPS/conditioning systems they have. The LBT wanted to switch back earlier so they could then melt the snow on their roof, but our operators were able to delay that until the expected end of the session. Most of the VLBI/operations equipment is

on UPS systems and they all rode through the switchovers without any noticeable effects. The drive systems take too much power to be on UPS and so they were affected by the switchovers and glitches.

At the start of the VLBI session, tau was very good, but snow was still falling, so Patrick (the operator) was doing hourly assessments of when it would be safe to open. It wasn't until the 080-0800 UT scan that conditions allowed us to start. However, when the drive system was activated, there were immediate faults in the azimuthal drive system.

The more obvious fault was in the part of the system that controls the relative movement of the antenna and the building. (The antenna gets pointed, and the building rotates so that the antenna doesn't hit the building.) This problem has been seen occasionally, and appears to be a warm-up issue (after power-off or line glitches in the Azimuth drive system). The symptom is that the building and antenna cross limits and the drive shuts down, requiring resets/restarts (a pretty complicated dance). Eventually that component warmed up enough that we were only hitting soft limits rather than hard limits, so the azimuth slew would just stop.

At that point it became clear that the Azimuth control had a mind of its own with regard to where the antenna should be pointing—*i.e.* it was slewing elsewhere than its commanded destination. We eventually locked out the computer control and found that manual commanding at the azimuth drive controls took us full speed towards the hard stop. (This system can rotate 1 deg/sec when it wants to.) A servo fault indicator indicated a problem, but not what the problem was, and we were stuck 6 deg from the hard-stop, shut everything down state. I invited the other operator (John) to the party 3 hours before his shift was due to start to get an additional brain on the problem with the drive system. (See [Figure 17](#)) It eventually (by the time of the 080-1100 scan) became very clear that someone (Dave Forbes/Bob Freund) with knowledge of the drive system was required on site to diagnose the fault.

Dave & Bob came up this morning and found that one of the server boards (See [Figure 18](#)) had an overcurrent protection trip, and *fortunately* a spare board of the same type was available on-site. We are now running with the spare board and full functionality appears to have been restored. The antenna has been exercised this this afternoon, and it appears to be able to point to sources as commanded. However, the pointing model appears to be a bit off. (Not enough to be a serious issue, but off nevertheless.) A new pointing model usually requires several days of observations in line mode (*i.e.* not the mode we operate in for VLBI), so it's not fixable tonight. Fortunately Patrick is the operator who builds the pointing model, and he's on duty most of this session, so he should be on top of the situation. (I'll be watching too, of course.)

The third night of observing (day 081, MJD 56007), we ran schedule xray21 with only minor issues. An attempt to access the data from the previous scan during a gap of 4 minutes send `drs` into an unresponsive state. Killing and restarting `drs` and ultimately switching to a 2nd bank solved the problem. (The 2nd module also stalled on a scan, but recovered, so it is not clear if there actually were issues with the modules, or just with `streamstor/drs`.)

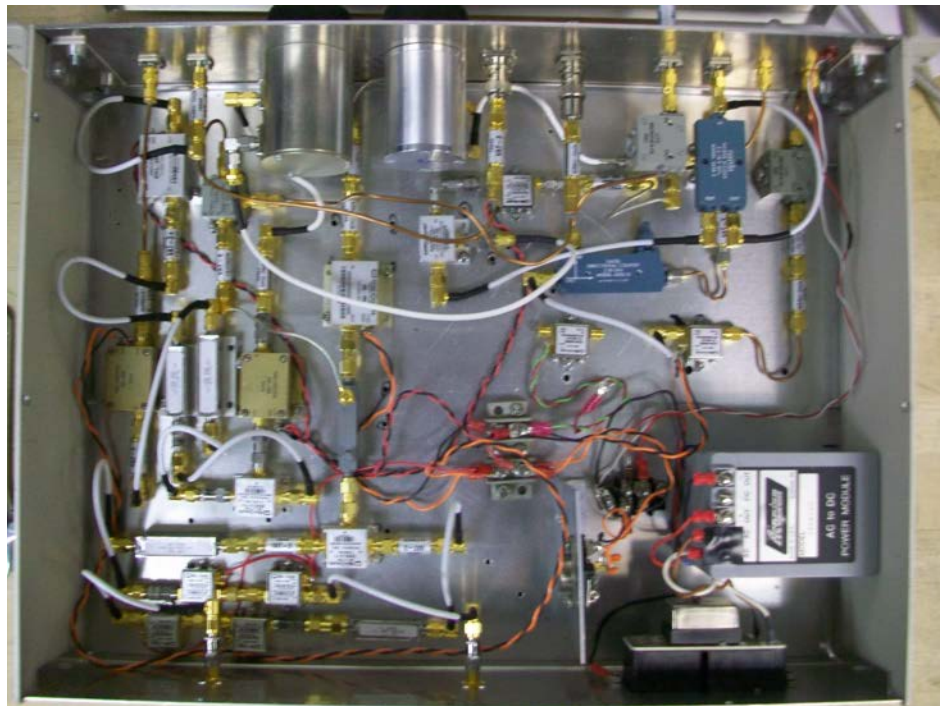
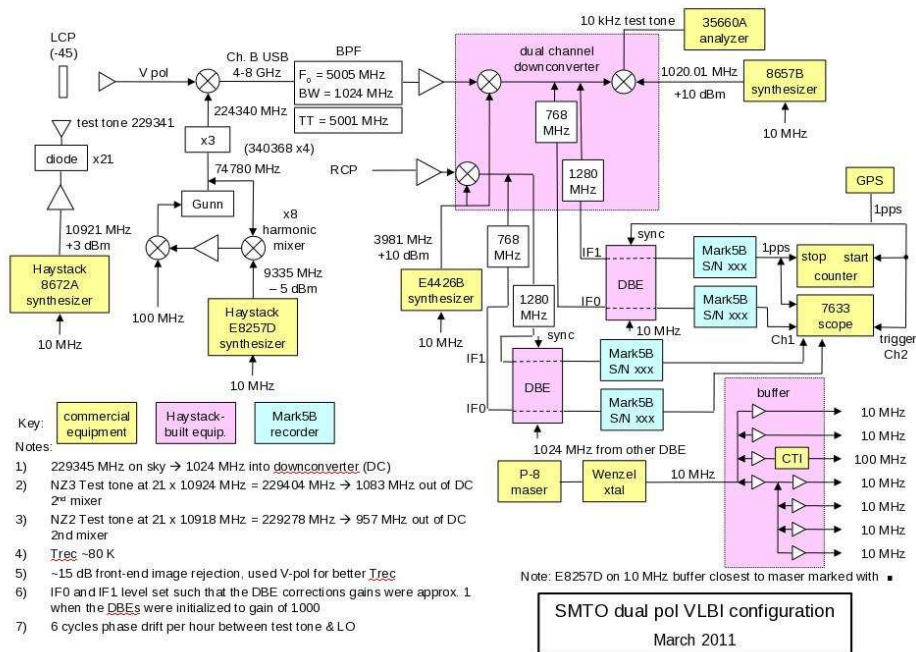


Figure 1: The SMTO Up/Down converter circuit and implementation are shown. The four bandwidth filters are visible in the lower right corner of the photo.



Figure 2: The 230 GHz receiver, support rack, and two VLBI racks are unchanged since previous years except for the insertion of one RDBE-H, two Mark5C recorders, and a digital oscilloscope for DOT monitoring.



Figure 3: The equipment that could not be placed in the rack was assembled on an adjoining table.

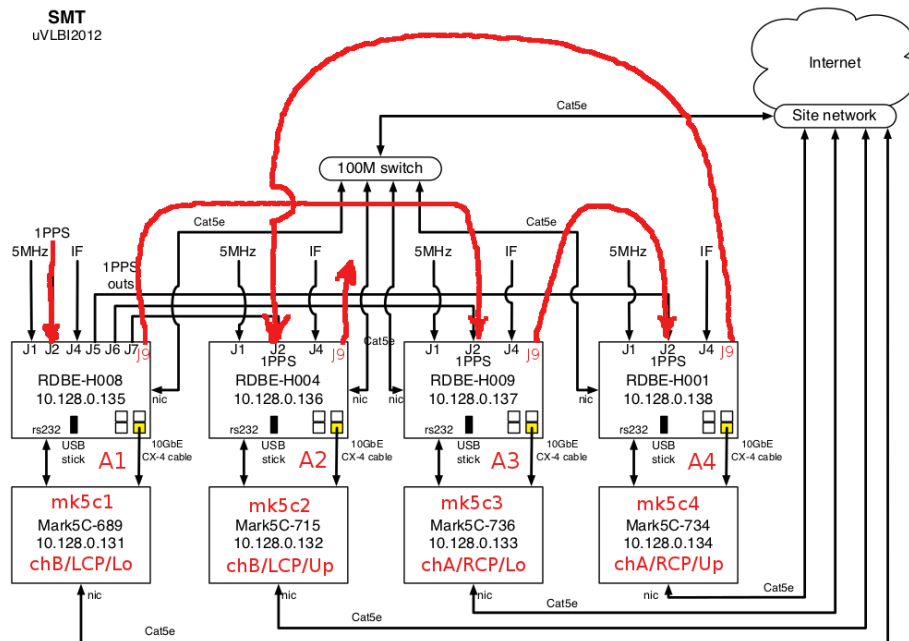


Figure 4: The network configuration at SMT of the 4 recording chains is shown. The analysis host (*smtast*) is not shown. The daisy-chain of the PPS signal is shown in red.

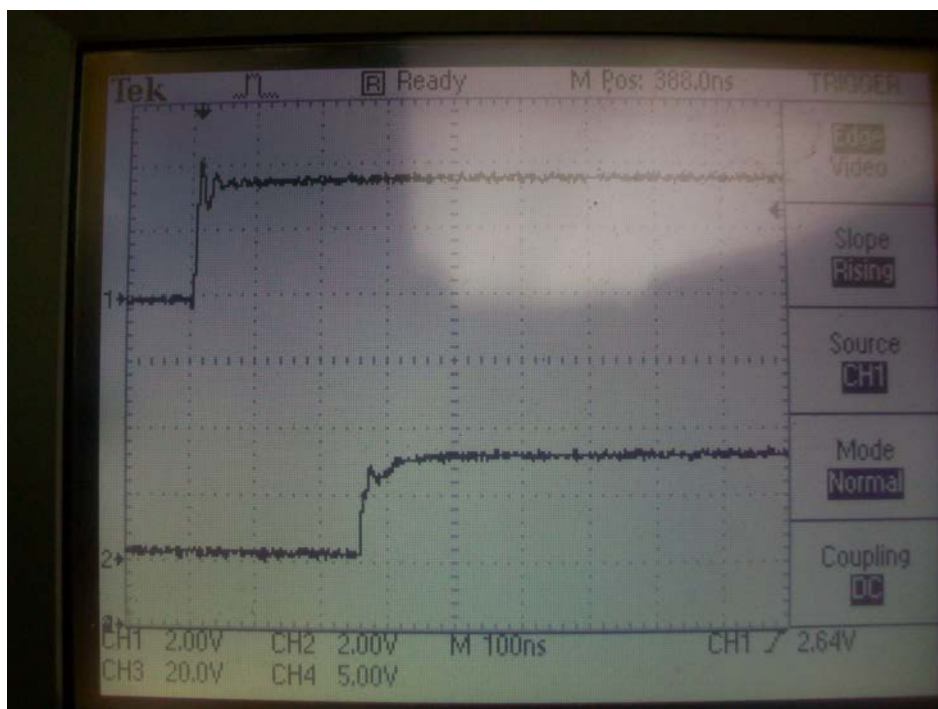
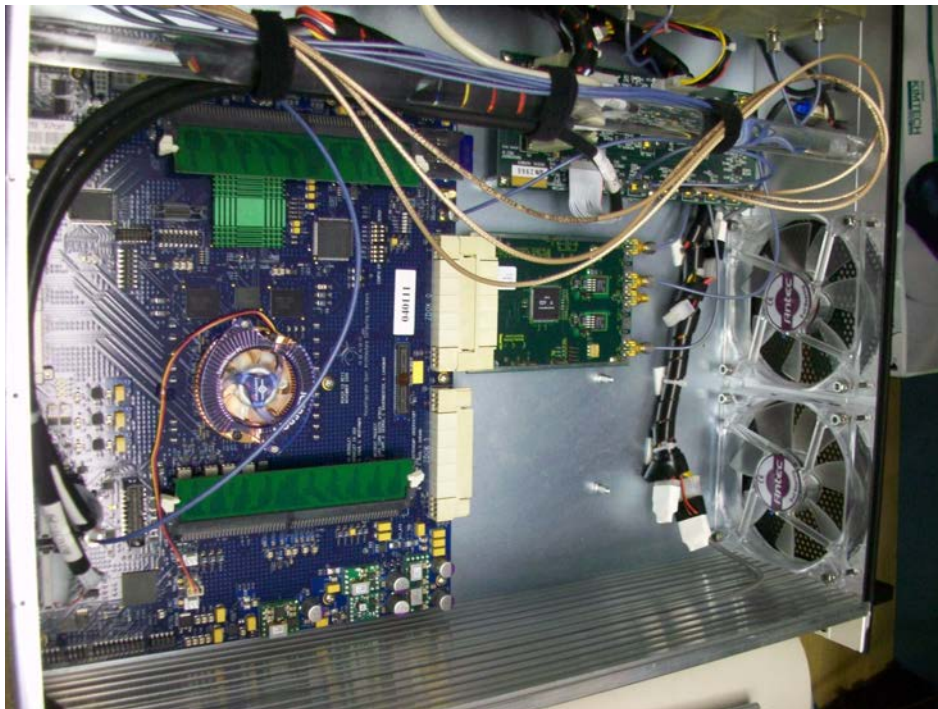


Figure 5: The inside of one RDBE-H with 3 extra PPS cables (copper-colored) from the NRAO synthesizer board is shown. In the event, the 4 units were daisy-chained and the maser tick and dotmon output of the final unit were monitored by scope to be less than 260 ns.

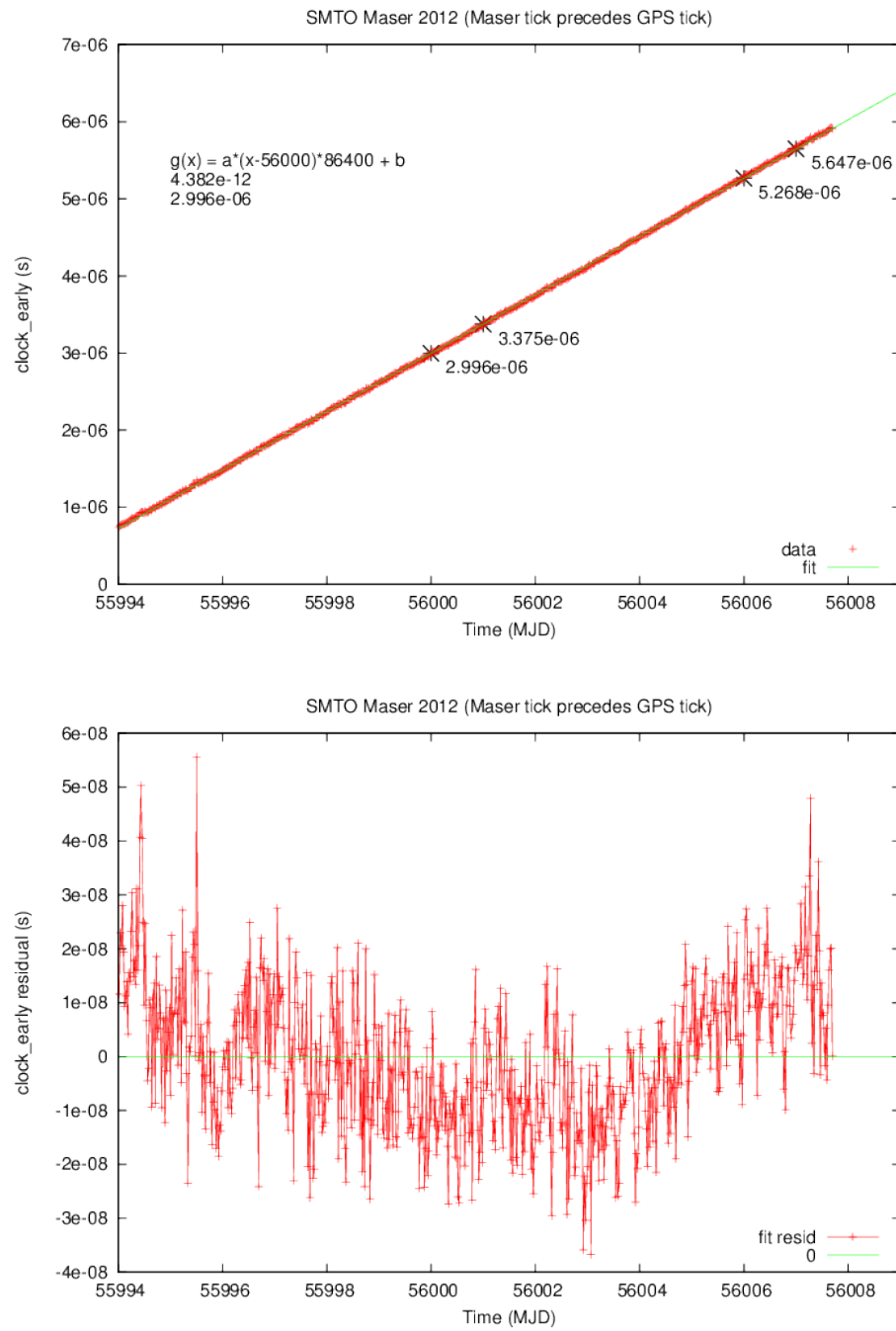


Figure 6: The maser drift relative to GPS was monitored from setup through the final day of observation (MJD56007).

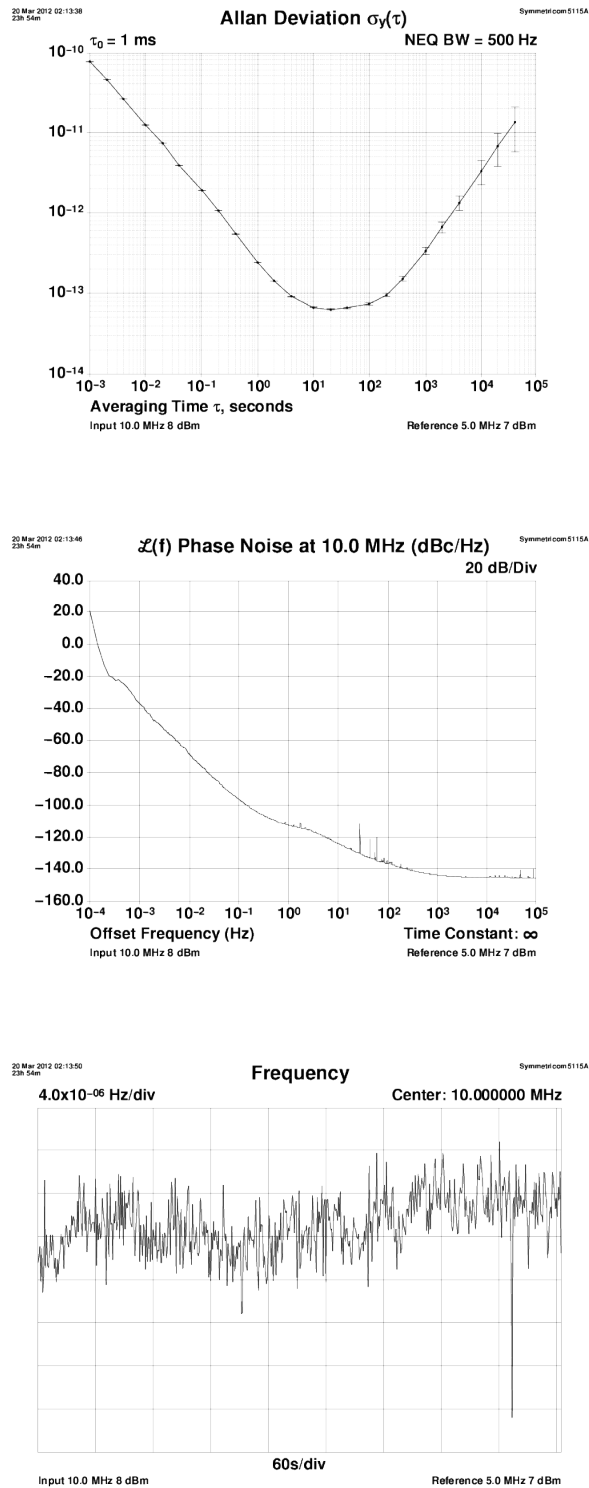


Figure 7: The ovenized oscillator was compared to the maser-derived 5 MHz input to the RDBE-H units.

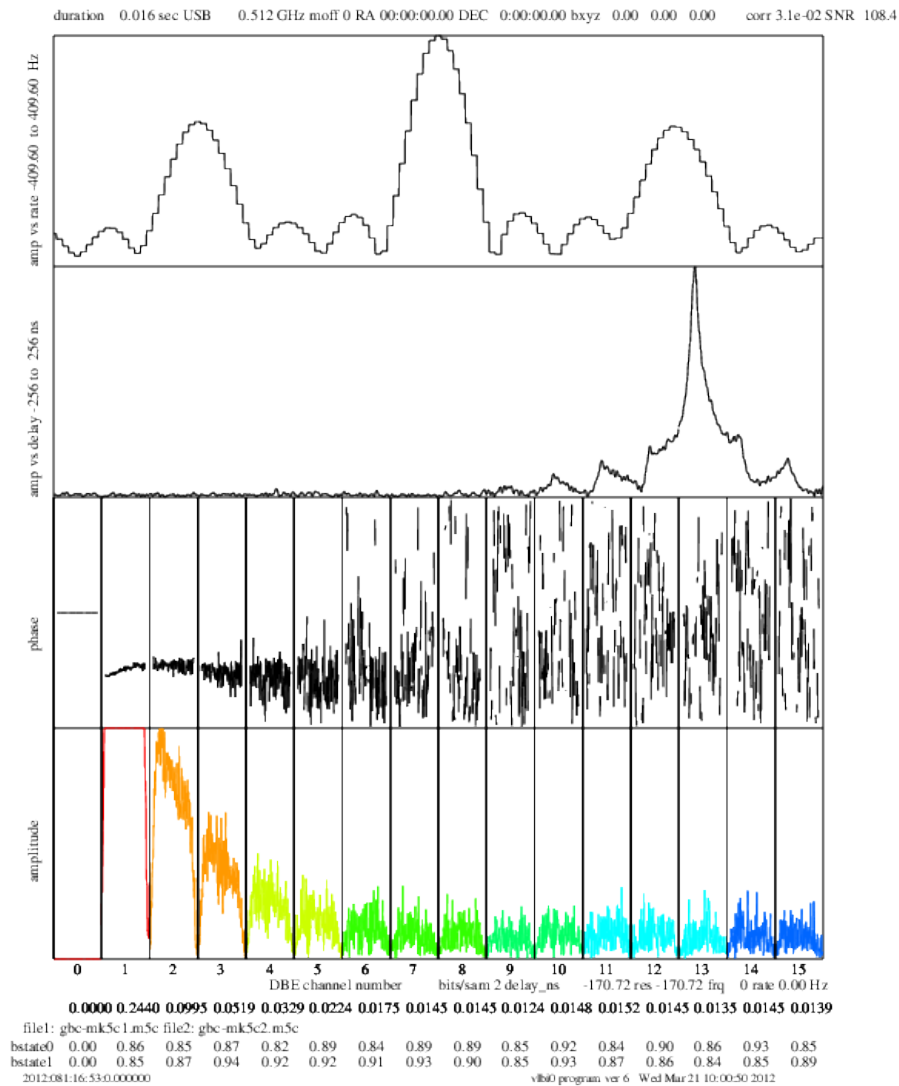


Figure 8: Sample correlation of A1 (LCP Lower) with A2 (LCP Upper).

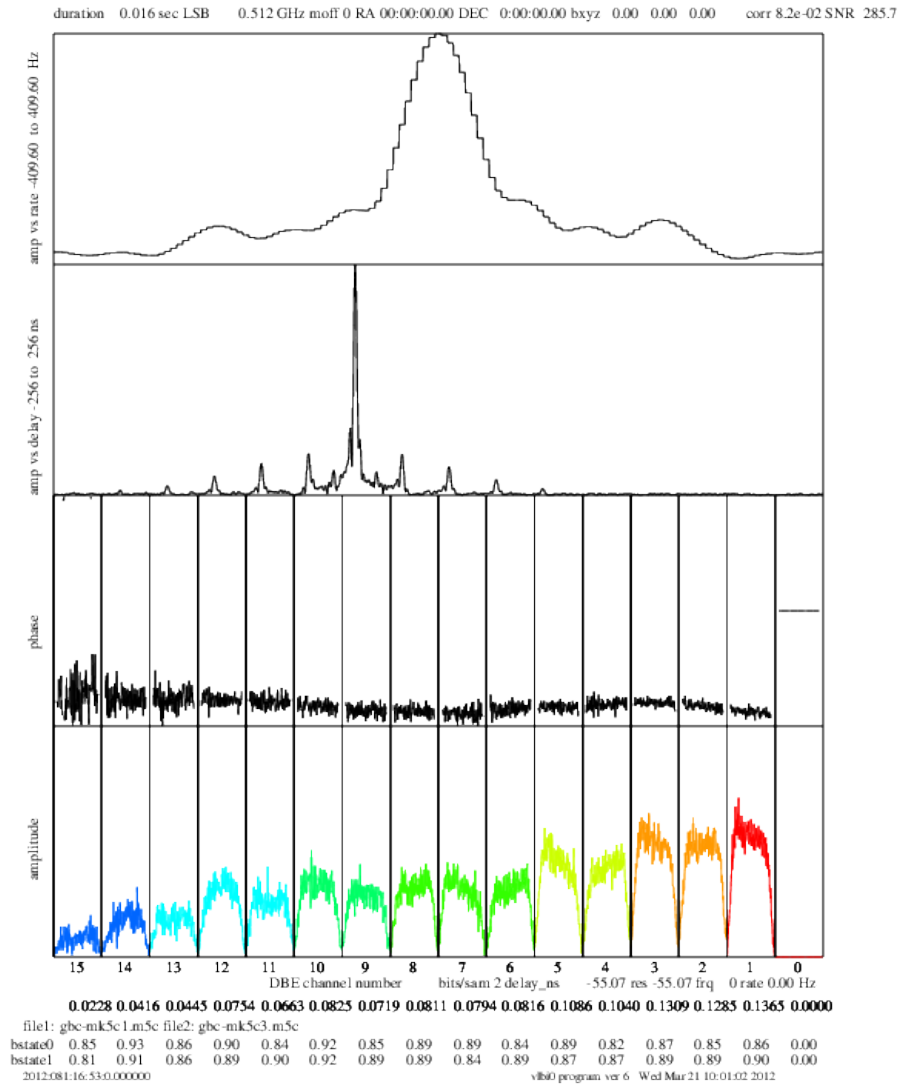


Figure 9: Sample correlation of A1 (LCP Lower) with A3 (RCP Lower).

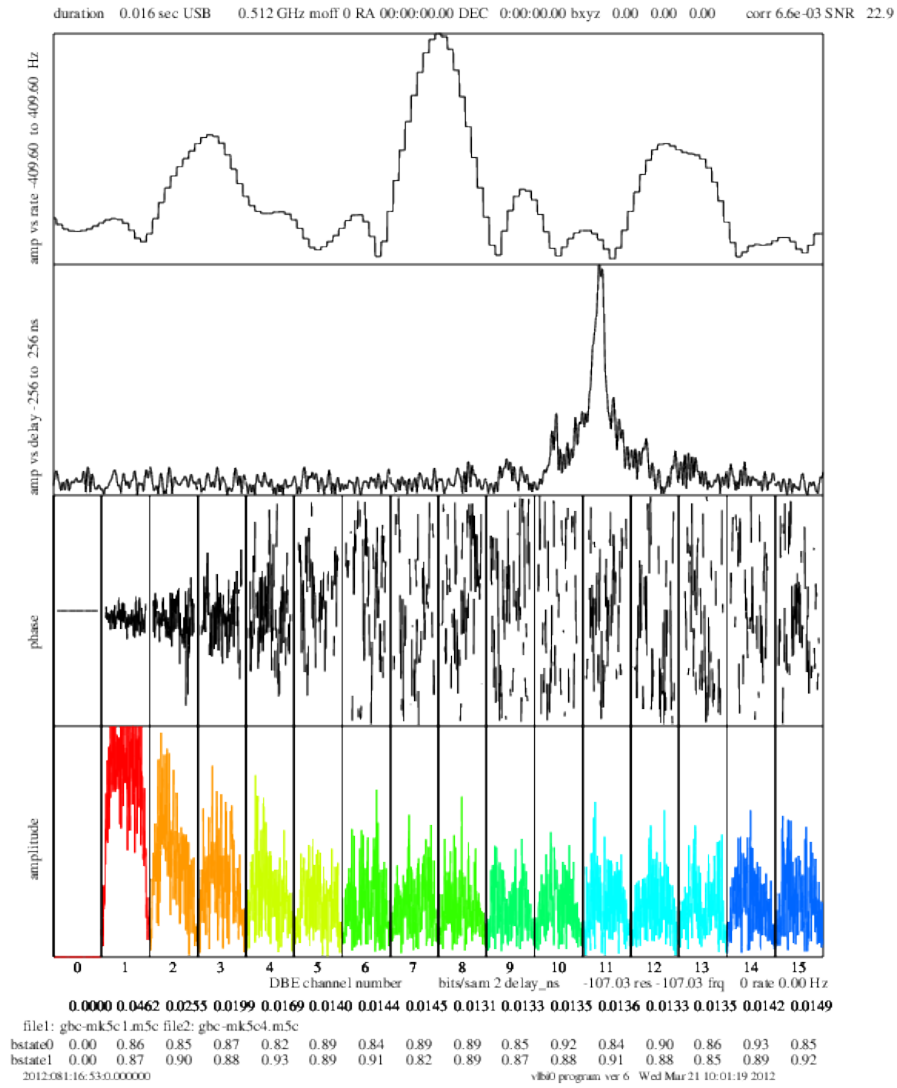


Figure 10: Sample correlation of A1 (LCP Lower) with A4 (RCP Upper).

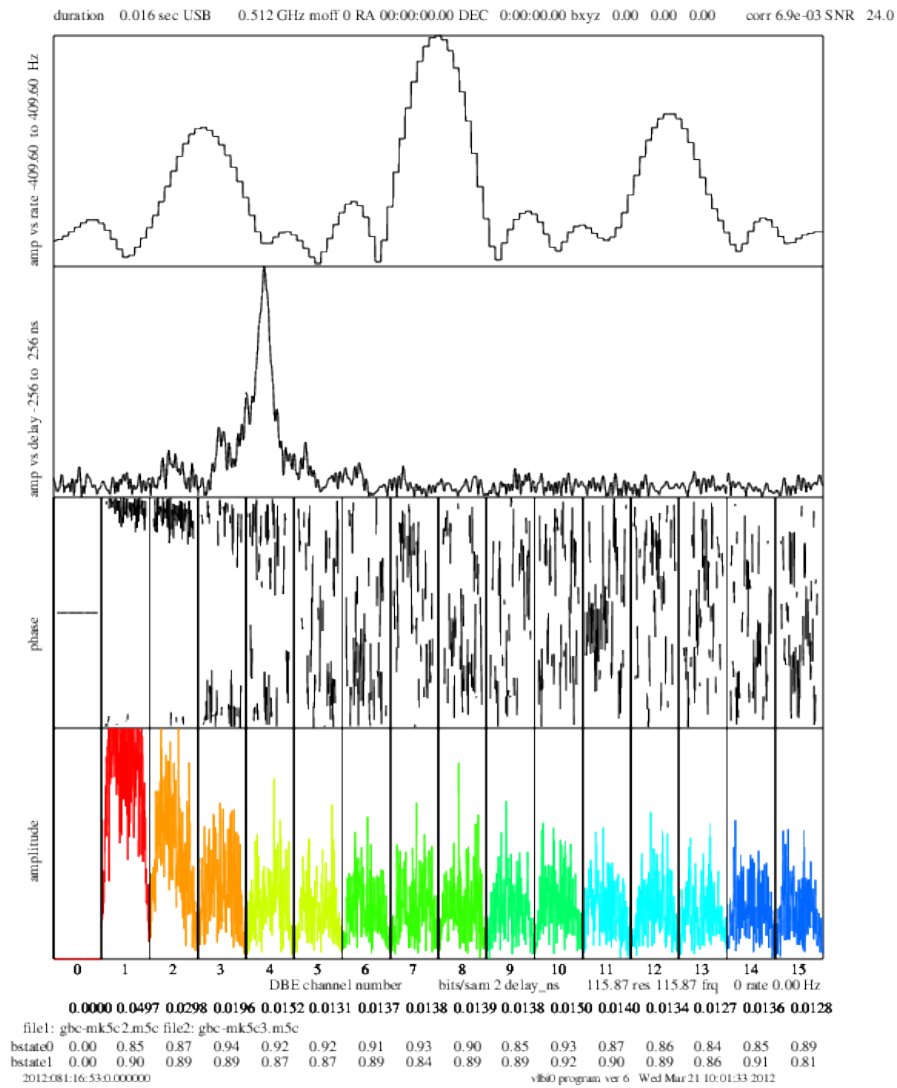


Figure 11: Sample correlation of A2 (LCP Upper) with A3 (RCP Lower).

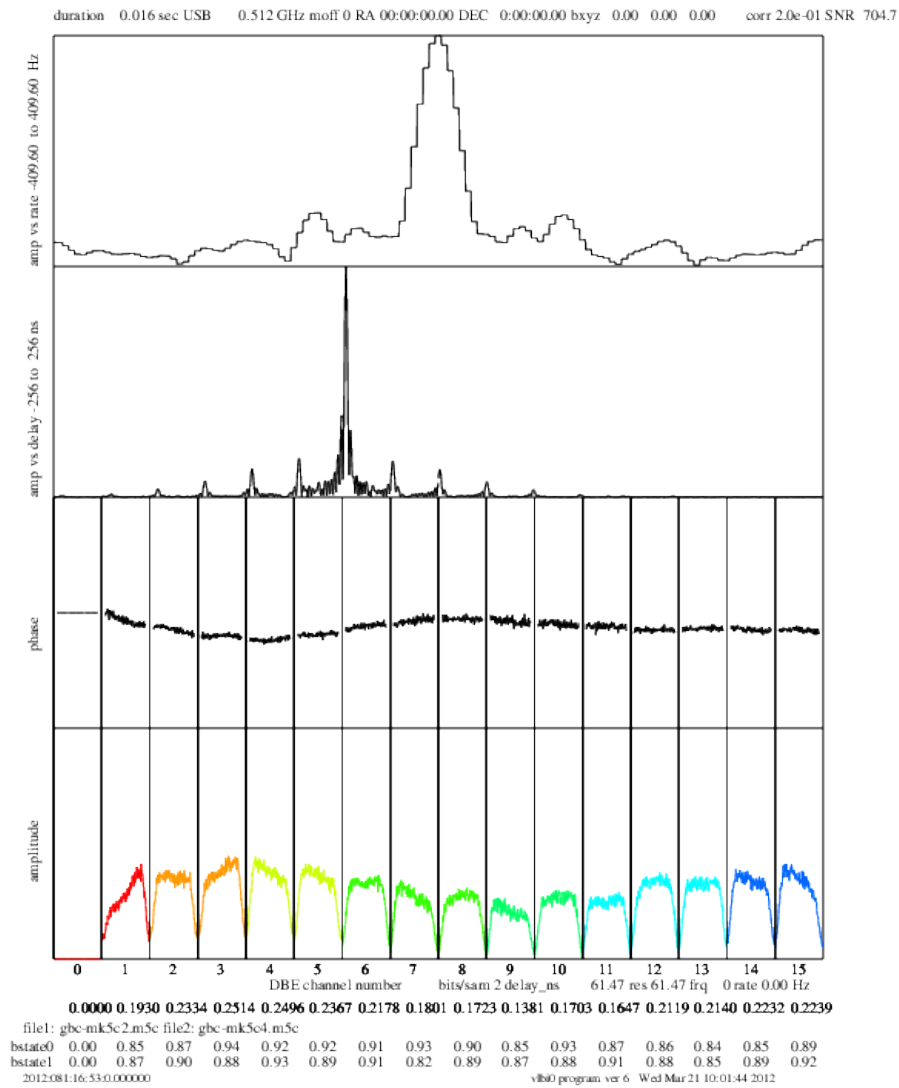


Figure 12: Sample correlation of A2 (LCP Upper) with A4 (RCP Upper).

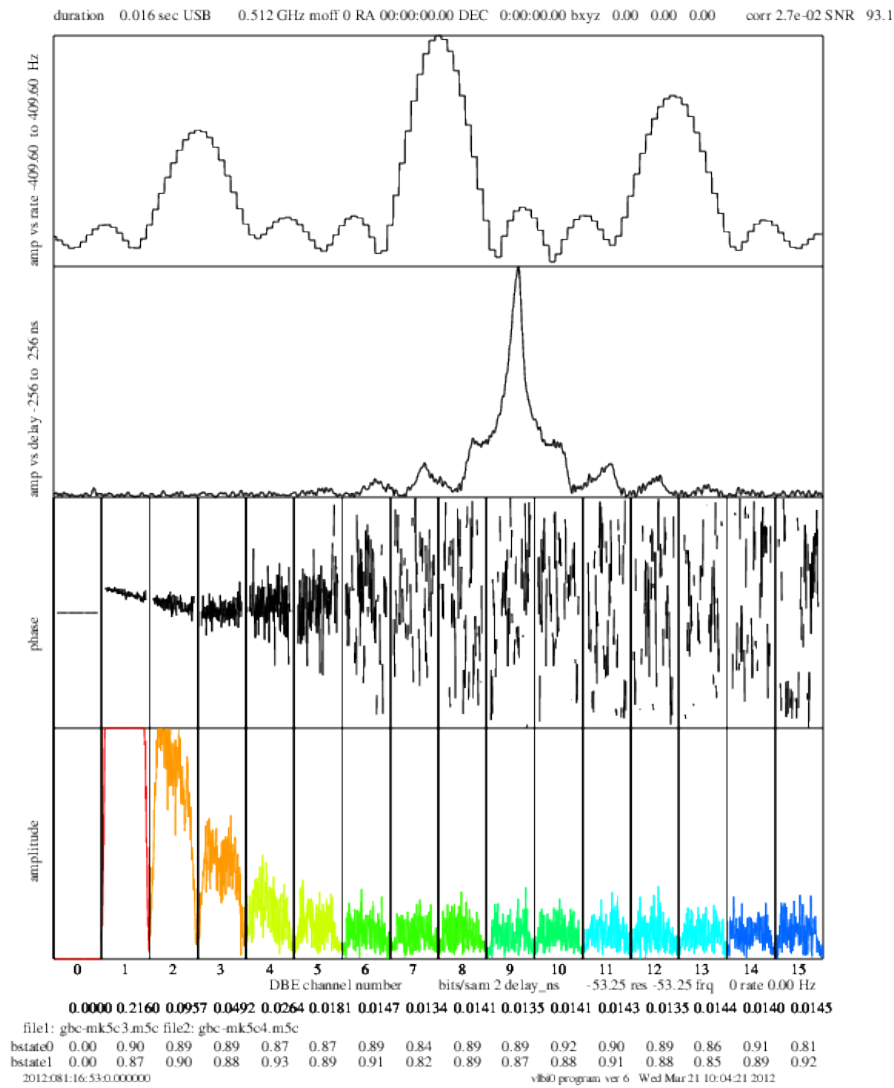


Figure 13: Sample correlation of A3 (RCP Lower) with A4 (RCP Upper).

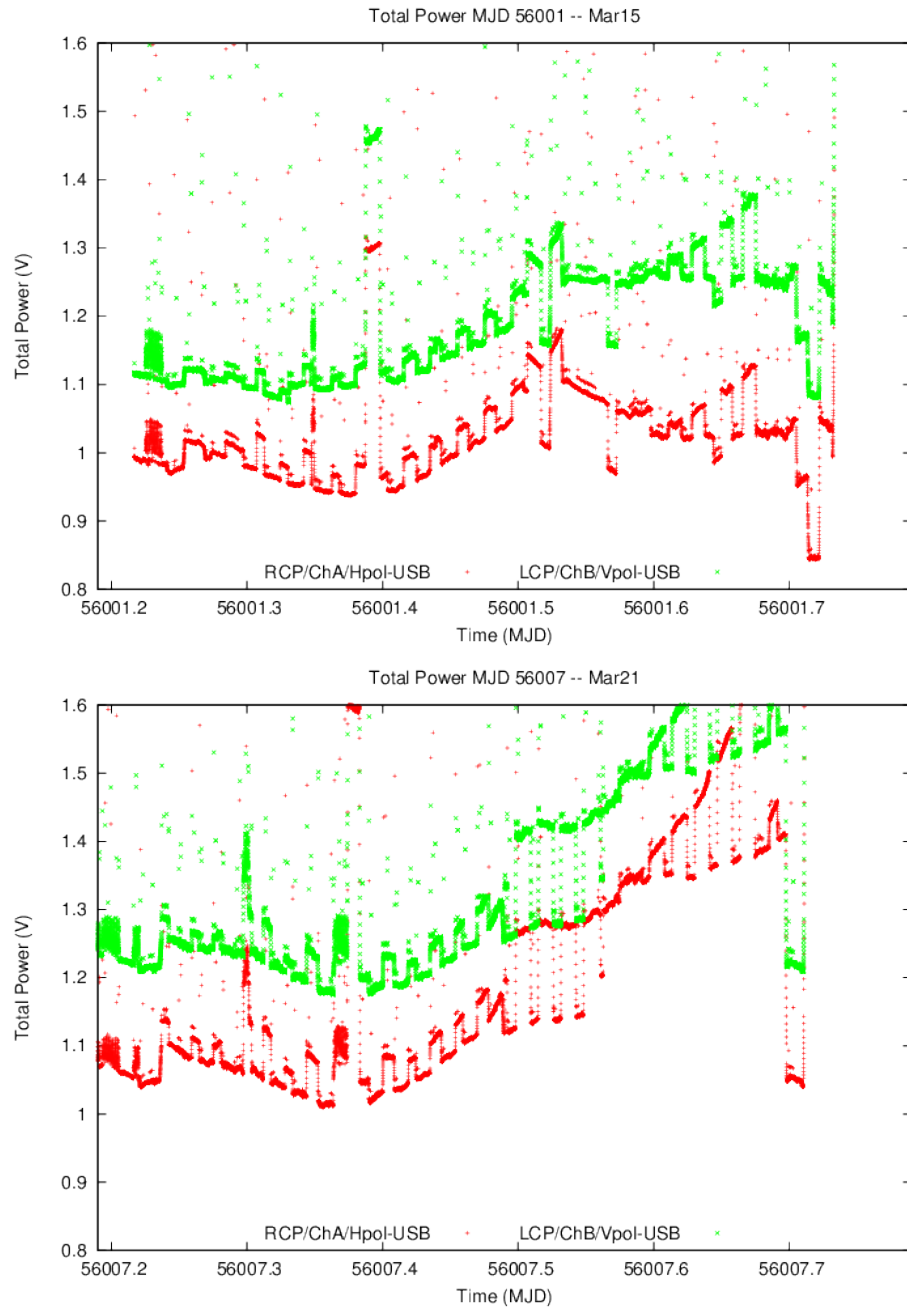


Figure 14: Total power diagnostic for the two receiver channels recorded for VLBI.

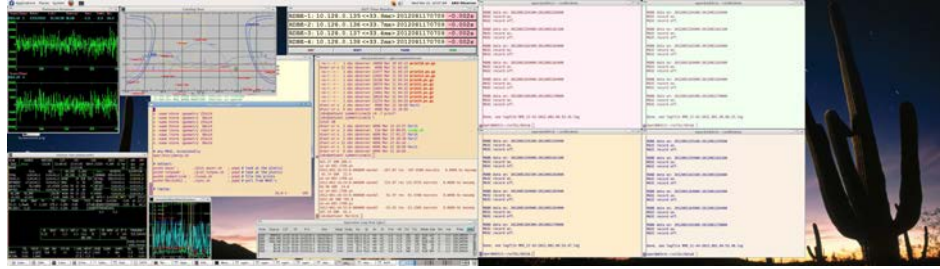


Figure 15: Observer windows used at SMT0 for the campaign. The display offered an additional 3 virtual desktops which were useful for following the detailed logs and some occasional commanding. The *Xremote* windows were placed “Always on Top” on the left side, leaving windows for the recorder on the right side in the 4 virtual desktops. The main *RM5_CC.py* script outputs for the 4 recorders are shown. Color was a useful organizing principal among the windows.

Stn	Script	seconds	size	comments
A1	UVLBI+75.20120314.script	36129.4	6000	Mar15/pol15
A1	UVLBI+64.20120307.script	21561.2	6000	A:Mar21/xray21
A1	UVLBI+77.20120302.script	35706.3	6000	B:Mar21/xray21
A2	UVLBI+59.20120312.script	22833.2	6000	Mar15/pol15
A2	UVLBI+67 cond on A1(+61)	35730.4	6000	A:Mar21/xray21 [+]
A2	UVLBI+80.20120302.script	36294.4	6000	B:Mar21/xray21 [+]
A3	UVLBI+65.20120312.script	21429.1	6000	Mar15/pol15
A3	UVLBI+78.20120306.script	18336.1	6000	A:Mar21/xray21
A3	UVLBI+74.20120302.script	20751.1	6000	B:Mar21/xray21
A4	UVLBI+58.20120314.script	21252.2	6000	A:Mar21/xray21
A4	UVLBI+79.20120312.script	35727.4	6000	B:Mar21/xray21
–	UVLBI+68.20120306.script	00000.0	6000	bad
–	UVLBI+84.20120306.script	20541.2	6000	misbehaved in A2
–	UVLBI+70.20120307.script	35778.1	6000	unused
–	UVLBI+71.20120307.script	35718.4	6000	unused
–	UVLBI+B4.20120307.script	33240.4	8000	unused

Table 1: Eleven modules were used to record data in 2012. Of the 16 that were shipped, two were immediately found to have issues. Two more developed problems while recording that were transient while recording. Three were unused. The modules marked [+] had minor issues (missed a scan) during recordings.



Figure 16: The faulty amazon card (still cabled) and the replacement (uncabled) are shown. The IDE cables were swapped from the old to the new card and operability was restored.



Figure 17: The Azimuth drive electronics exhibited a fault that was beyond our immediate ability to repair.

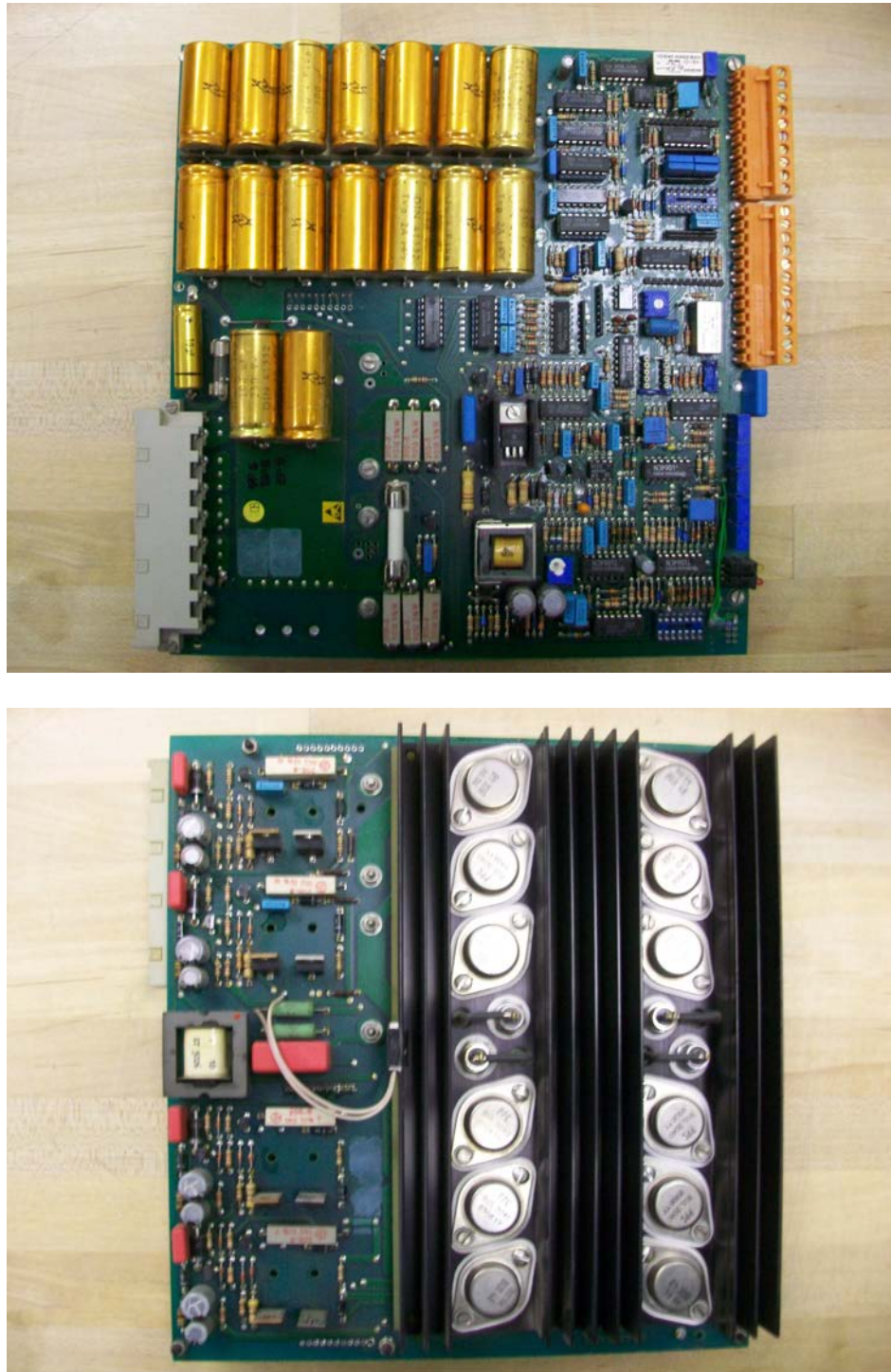


Figure 18: Ultimately the fault was traced to this servo board, and operations were restored after a suitable spare was located and installed.