A-108-S Trip Report

South Pole VLF Beacon and Receiver

Nov. 5 – Dec. 10, 2009

Executive Summary

The first deployment to South Pole for the 2009-2010 field season included maintenance and upgrades to the South Pole beacon and other tasks related to the VLF receivers. In this deployment, the length of the VLF beacon antenna was inspected and found to be in need of repair along the grid north end where there are broken strands at several points. Six of the beacon amplifiers in use were inspected. Five were working normally; the sixth was repaired with new power supply capacitors. A seventh was repaired and installed. New driver boards were installed and modifications made so two amplifiers could start per inverter. Larger connectors were installed on the transmission line; a new transformer was installed and the old one upgraded. A blown surge arrester prompted reinstallation of the upgraded old transformer, which was subsequently damaged severely. Reinstallation of the new transformer was successful pending modifications to amplifier 5, which causes problems when used into the antenna. The PENGUIn low-power VLF receiver and preamp were recovered and shipped to Stanford because of loss of one channel, and sporadic recording of data. The primary VLF receiver, antenna, and preamp were visually inspected and diagrammed. New VLF_DAQ software was trialed, and a program written to return narrowband data to Stanford daily.

Battery Replacement

Replacement of the batteries for the VLF beacon proceeded smoothly. 36 batteries arrived, leaving 4 spares. 32 old batteries, and 3 backups, which were being trickled-charged, will likely be disposed of or recycled.

VLF Receiver Checks

I diagrammed how the VLF receiver was set up as Robb Moore from the University of Florida may need to attach his own equipment to it.

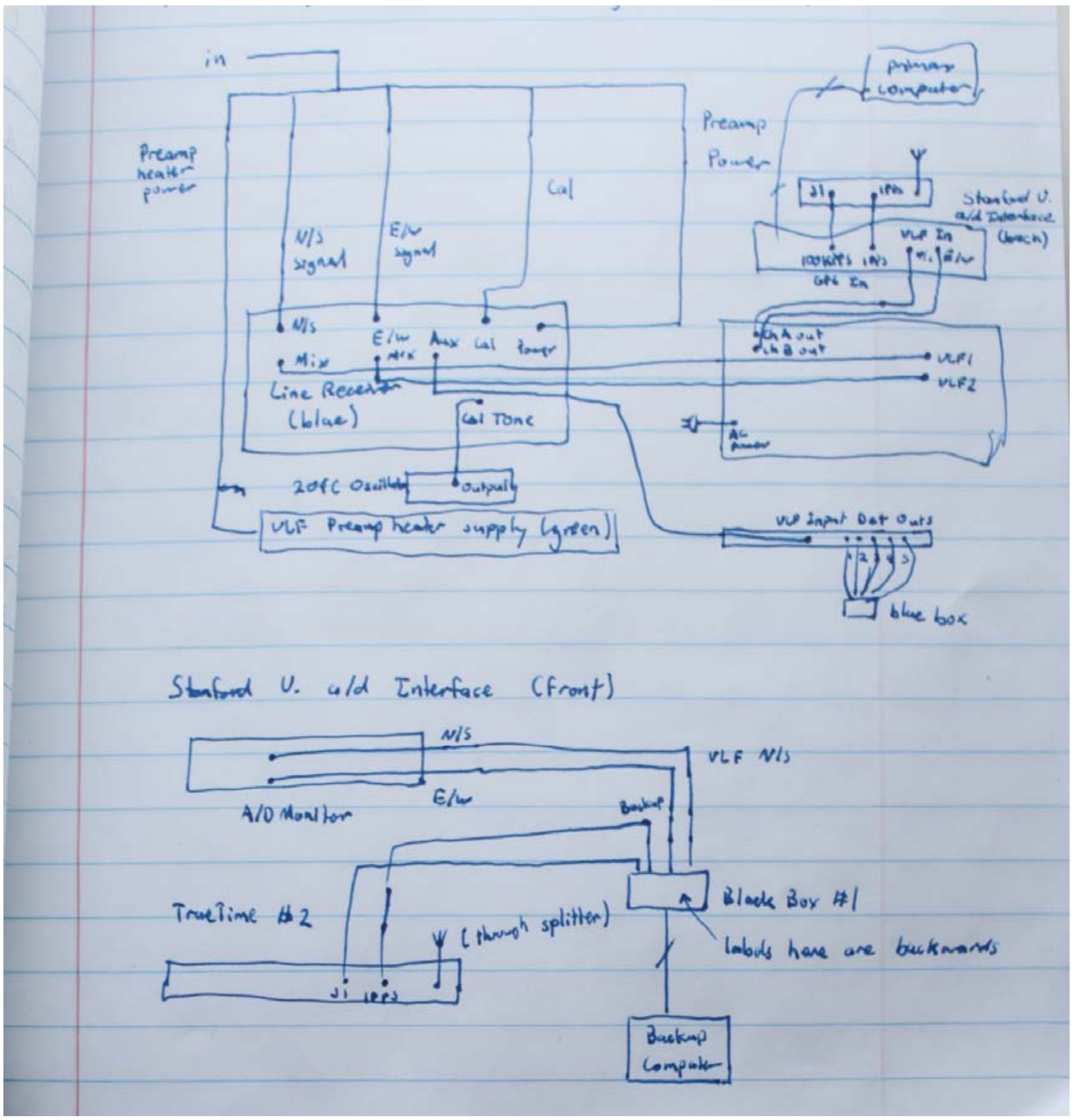

Figure 1: VLF receiver diagram

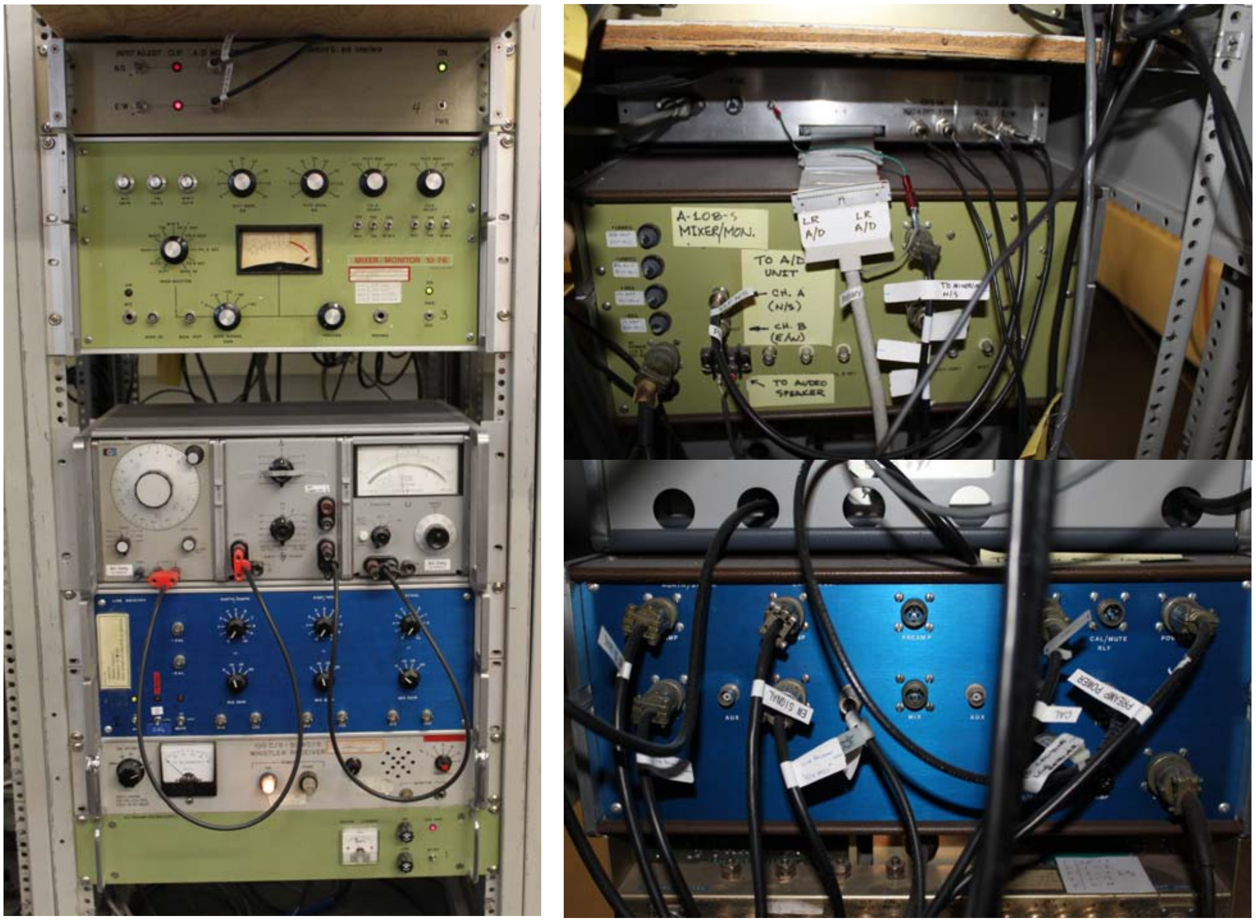

Figure 2: VLF receiver

I also examined the VLF antenna and preamplifier. This was more out of curiosity as there have been no problems with the data.

Figure 3: Clockwise from left: VLF antenna with only a few feet remaining above snow drift. Hatch of shaft was only under an inch of snow. The view from the landing down to the bottom. The preamplifier.

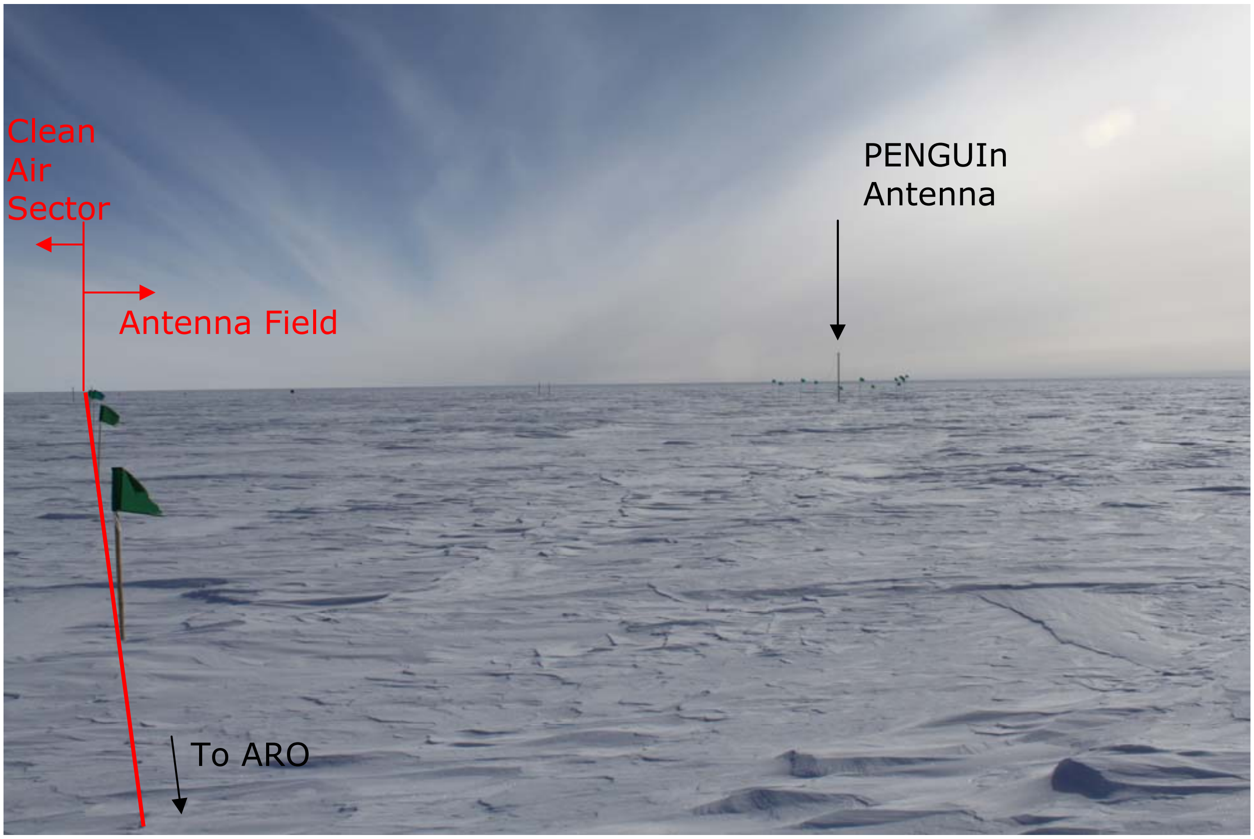

Figure 4: PENGUIn location

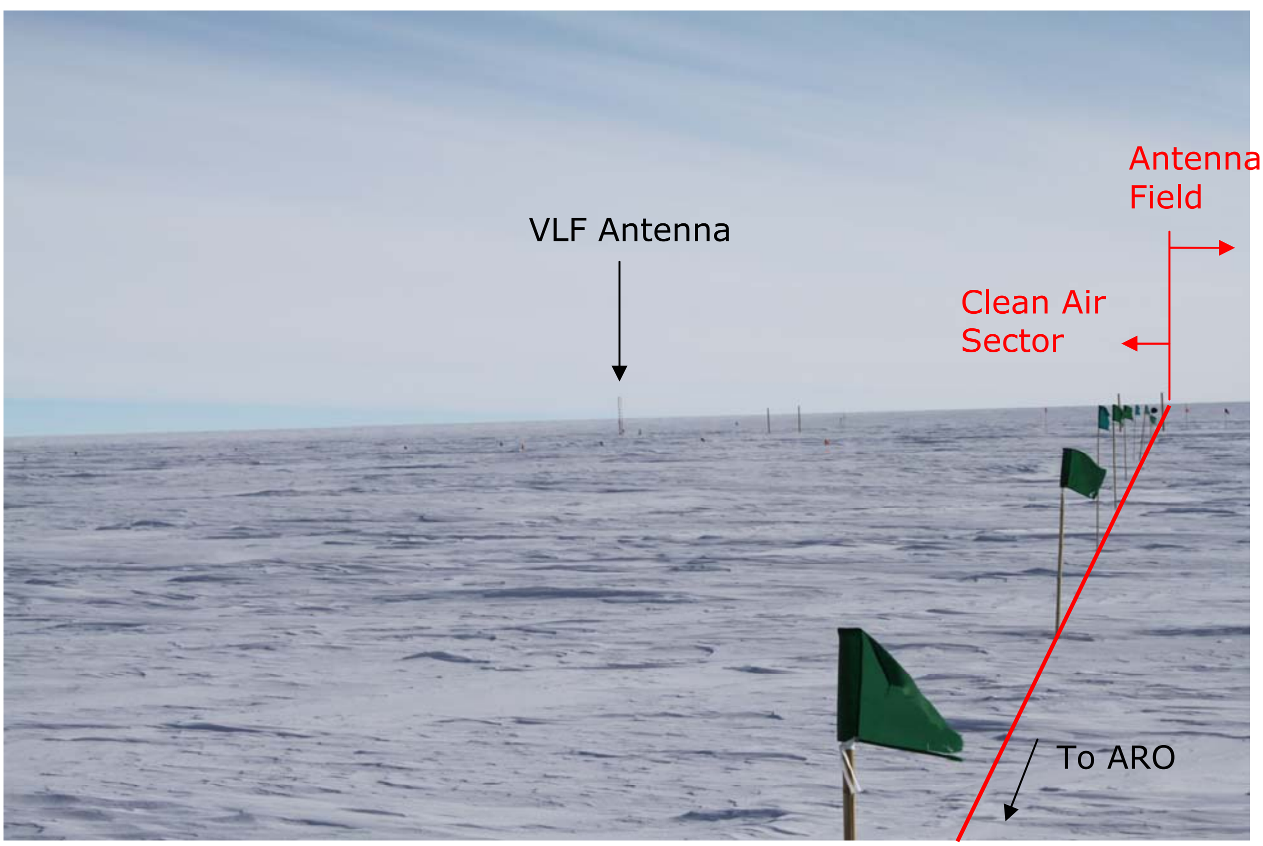

Figure 6: Primary VLF receiver antenna

Amplifier Testing

Ethan helped carry a Tektronix TDS 2014 oscilloscope and a HP 33120A signal generator to the VIPER control room to facilitate testing. There's already a HP 1220A analog oscilloscope in the room for monitoring the transmitter output but it's unwieldy. The beacon was powered off using the remote kill switch and controller front panel. The six running amplifiers were then removed from the rack, and placed on the table and two shipping crates for testing.

All amplifiers were connected to the AC power through the Kill-A-Watt power meter, and most tripped circuit breakers when turned on. Only amplifier 5, which later proved to be defective, and amplifier 4, which output slightly less power did not trip breakers. Both eventually also started tripping breakers. The outlets are clearly labeled and the breaker panel is in the next room. The large breaker panel controls the outlets in the room and is also clearly labeled. Avoid plugging the amplifiers into the same circuits the computer and controller are plugged into (unless they're also shut off). On Ev's suggestion, I resorted to plugging the amplifiers into the inverters, which need to be manually turned on with the controller. This does limit the time available for testing, and after each test, I waited until the batteries were fully charged before attempting more tests.

A basic testing procedure recommended by Ev is as follows:

1. Replace the driver cards
2. Use thick alligator clips to attach the 0V and 138V terminals on the back to the amplifier to one element of the dummy load.
3. Attach the signal generator to the front input. Use a reasonable frequency (or simply 19.4 kHz), and the smallest amplitude.
4. Turn on the amplifier, and check DC voltages.
    a. TP1 and ±60V points on the driver board (clearly marked)
    b. ±45 V on the drain, (usually higher, ~±50V)
5. Monitor the output waveform (source voltage) using the oscilloscope
6. Increase the amplitude on the signal generator until the output waveform starts clipping (~80V peak-to-peak).

Using this procedure, 5 of the 6 amplifiers tested fine. The output clipped at roughly 80V peak-to-peak with an input of ~3.3V peak-to-peak. The power drawn was approximately 2.5 kW, and the AC front panel meter read ~24V.

Amplifier 5 had a drain voltage of only +32V as measured by the multimeter. Closer inspection using the oscilloscope on the output of the AC bridge, revealed very large ripple on the positive output rail indicating a faulty filter capacitor. There were two spares in the room, along with a few more with markings such as "Suspect" and "Beware of Terminals." Replacing one fixed the + supply rail, but it was now slightly unbalanced with the negative rail (+51V vs -49V), so I replaced the other capacitor as well, since it also had a ripple of a few volts. Unfortunately I installed this capacitor backwards, causing the front breaker on the amplifier to trip from that capacitor shorting. Luckily it tested fine upon reinstallation and amplifier 5 performed similarly to the other amplifiers.

When the new gate-drain strips arrived, they were installed into the output modules, populated with new NMOS transistors and installed into amplifier 2, which had been set aside for the year. I also used the newly arrived power supply capacitors to replace the ones in amplifier 4, which was underperforming slightly and showed extra ripple. I could not extract a screw from one the capacitors I replaced and needed to cut it off.

Ethan and I replaced the 7 amplifiers to the rack—they would not turn on. Turning on the inverters with all 7 amplifiers on creates a lot of noise from the inverters and high current draw (60 A according to the meters on the DC panel), but only the amplifier with an inverter to itself turned on. The amplifiers can be turned on one at a time by first turning on the inverters with the amplifiers off, then turning them on one by one, waiting a few seconds in between for the amplifiers to warm up. When tested into the dummy load, the amplifiers were found to work fine with a gain of 1300.

Debugging steps included removing capacitors to reduce spurious oscillations near 4.5 MHz and using a smaller capacitor to reduce the time-constant of the DC null offset circuit. The ultimate solution was to increase the size of the bootstrap capacitor. For testing, I modified two driver boards, installed them in two amplifiers and attempted to turn them on simultaneously with the inverters. The two amplifiers were connected in series to two dummy load elements and fed with the signal generator. Using 33 μF, 47 μF, and 66 μF in parallel with the existing 0.33 μF capacitor was insufficient. Adding a 500 μF (50V) capacitor in parallel with the 47 μF and 0.33 μF capacitors did work, and all the driver boards were modified with the 500 μF capacitor in parallel with the existing 0.33 μF capacitor.

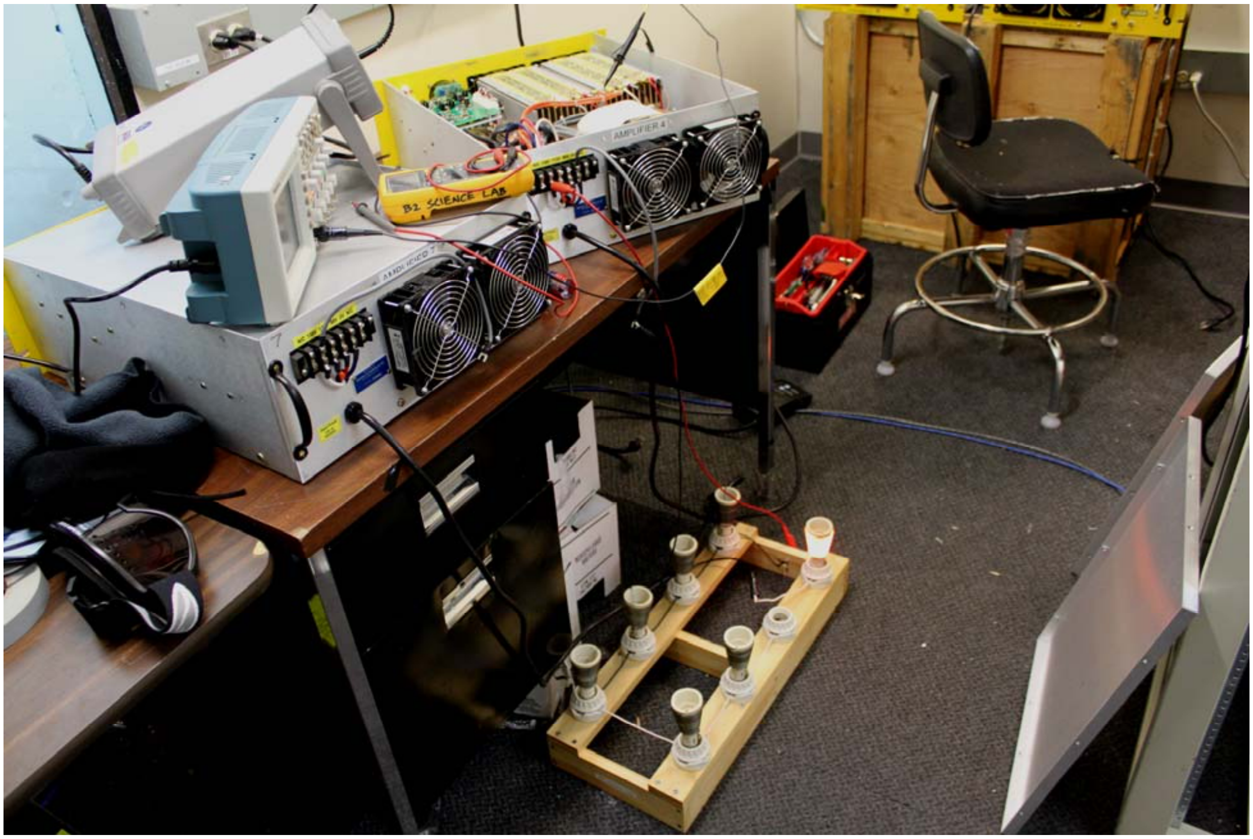

Figure 7: Amplifier test setup

One final problem involved spurious oscillations near 4.5 MHz that are worse in some of the amplifiers than others. In all cases, they become insignificant near full power, but may be responsible for evidence of arcing when amplifier 5 is used with the antenna, although it does not cause problems into the dummy load.

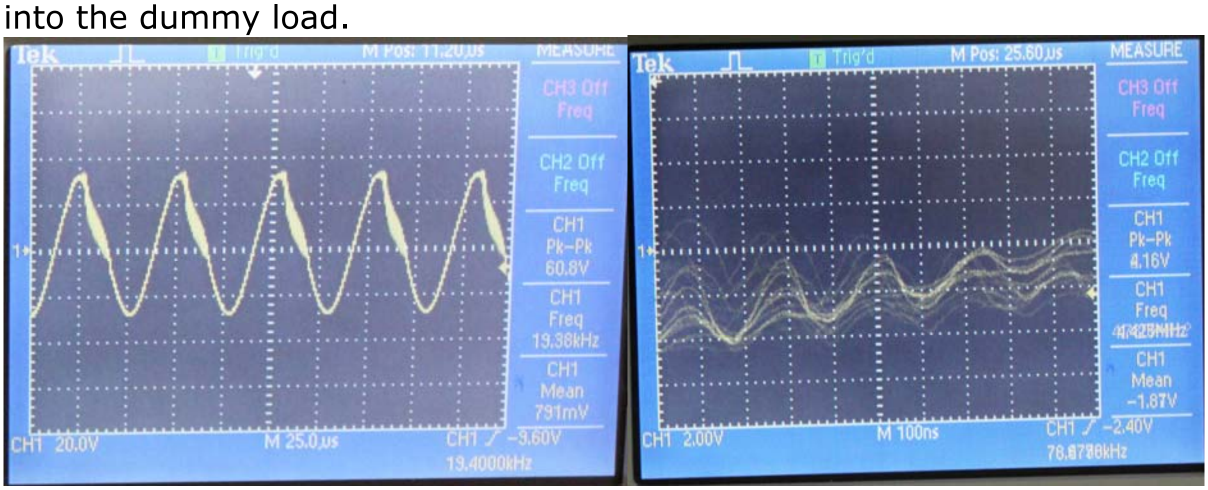

Figure 8: Spurious oscillations deform the output of amplifer 5 (left). Triggering on spurious oscillations (right)

Figure 9: Testing 7 amplifiers into the dummy load

Software Updates

The following software was updated on the VLF beacon computer:

- Windows XP SP2 -> SP3
- Office XP SP2 -> SP3 (and numerous security fixes)
- Apache 2.2.13 -> 2.2.14
- Python 2.5.2 -> 2.6.4
- Internet Explorer 7 -> Internet Explorer 8 (breaks USAP login script)
- Firefox 3.0.9 -> 3.5.5
- Updated nova password for FTP of diagnostics

I also made minor error handling tweaks to the ArchiveData Python script, which saves diagnostic files to various places. Also the lines in the Beacon Monitor MATLAB script that generates yesterday's plots for the webpage were uncommented. The system was reconfigured to run this script at startup using the task scheduler as opposed to the Startup folder. This prevents the script from running twice, but has the disadvantage of not running for an hour after running at startup. Since reboots are relatively rare, this isn't an issue.

PENGUIn recovery

The PENGUIn low power receiver was located in the antenna field near the boundary with the clean air sector. The receiver was located near the antenna, marked with green flags, and a wooden post with the event number (A112) and a GPS antenna. The receiver was found buried under at least 6 feet of snow, protected by a piece of plywood. When recovered, the unit continued to record files until the unit was disconnected, although channel 1 did not appear connected after Apr 21, 2009 around 0705 UT, and files were only recorded sporadically after May. The batteries seemed to have power remaining. The voltage was measured at 6.96 V when cold (within hours of extraction), and 7.15 V the next morning.

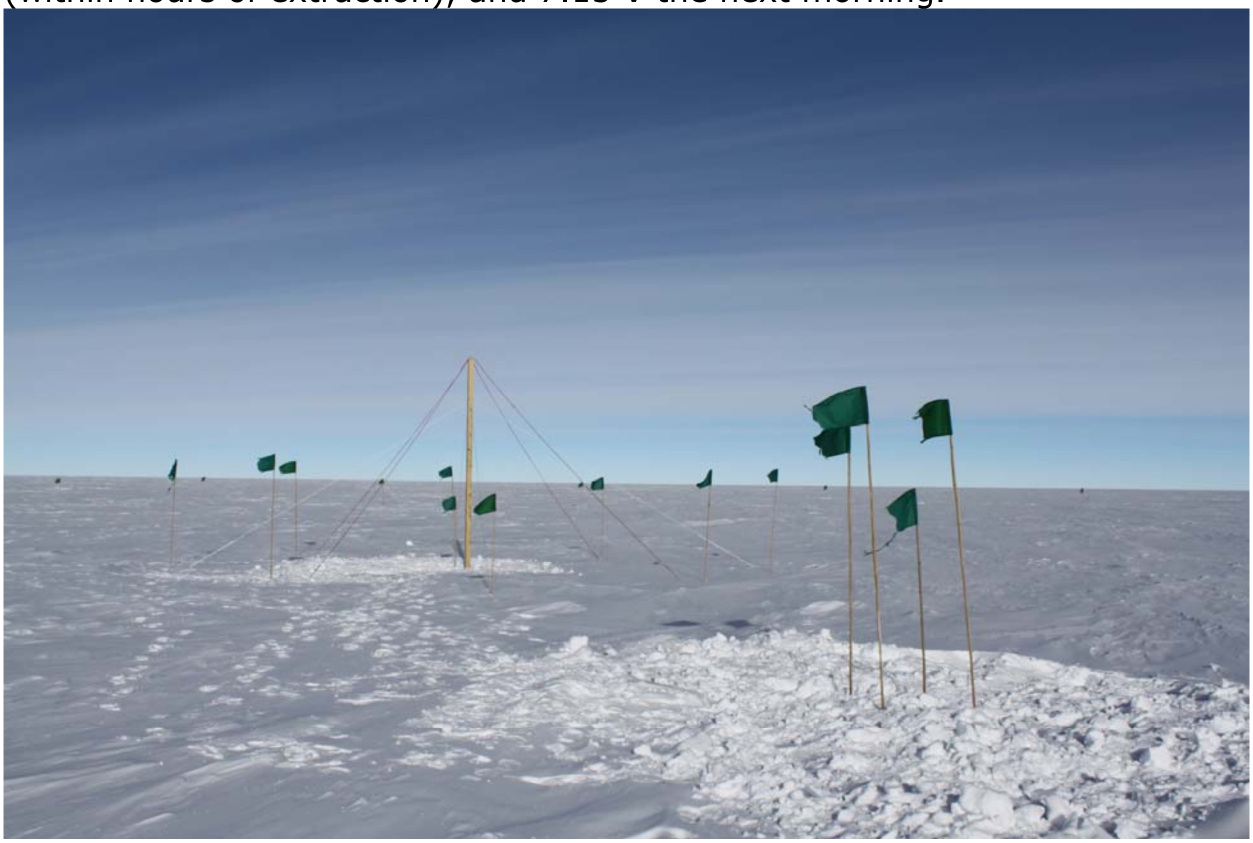

Figure 10: PENGUIn antenna and excavation site for the preamp on the left, and the excavation point for the PENGUIn receiver on the right

Transmission Line and Antenna Transformer

The connectors on the LMR-900 transmission line at each of 8 junctions were changed from male N connectors joined by F-F barrels to male and female 7/16 DIN connectors, rated for higher power. The old connectors are sitting in the closet next to the VIPER control room. The N connectors and barrel adapters can be removed and used. The back nut should be the same for the N and 7/16 DIN connectors though it might be more difficult to remove from the cable.

The male connector connected to the transformer was also replaced with its 7/16 DIN counterpart. Ethan and I then changed the transformer with the Mark II version, featuring surge arrestors and Litz wire. I also upgraded the old transformer with the surge arrestors a 7/16 DIN connector and new feed-through bushings to replace the cracked ones.

The DC resistance as measured from the cable in the VIPER control room should be 6 ohms and this is what we measured. After transmitting the beacon into the antenna and getting strange results (low current out of phase with the voltage), we also checked the line with the TDR, which also showed the line to be good. The station actually has at least 3 TDRs:

- Tektronix 1502C in CUSP Lab: only works to 2000 feet
- Tektronix 1503C in the Comms shop: works past 10000 feet but inexplicably doesn’t tell you the impedance where the cursor is (the 1502C does)
- Agilent N1610B Service Advisor Tablet with N1627A TDR module in the Comms shop: Runs Windows CE, has a touchscreen, is portable (or would be if the battery worked), and has solitaire. It’s slow and the software is clunky though.

Figure 11: Ethan tightens some cable clamps at one of the transmission line junctions

The surge protector attached to the grid south feed line was burnt when we arrived to take a closer look. It was replaced with the rebuilt transformer and the grid south end of the antenna was checked. No breaks were found. There were signs of arcing with gains above 700 and impedance mismatch at lower gains near 520. The new transformer was tested in the VIPER control room with the dummy load connected to the output with the good surge arrestor. The setup oscillates strongly near 400 kHz with no input, but otherwise works with no arcing when the gain was increased to 1200. Finally the new transformer was swapped in again, using the still functional surge arresters from the old transformer. I probably lost the good surge arrester on the new transformer at this point. We also checked the grid north end of the antenna and found it to be free from breaks also. There were still signs of arcing at a gain near 200, but the impedance seemed correct at lower gains. We made an inspection of junction 4 on the transmission line, which the TDR indicated had slightly higher capacitance than the other junctions. The new transformer looked fine after a quick visual inspection. The same could not be said for the old transformer which had scorch marks on the side facing the input. Peeling back the tape revealed chunks of the ferrite core between the input ends of primary to be flaking off.

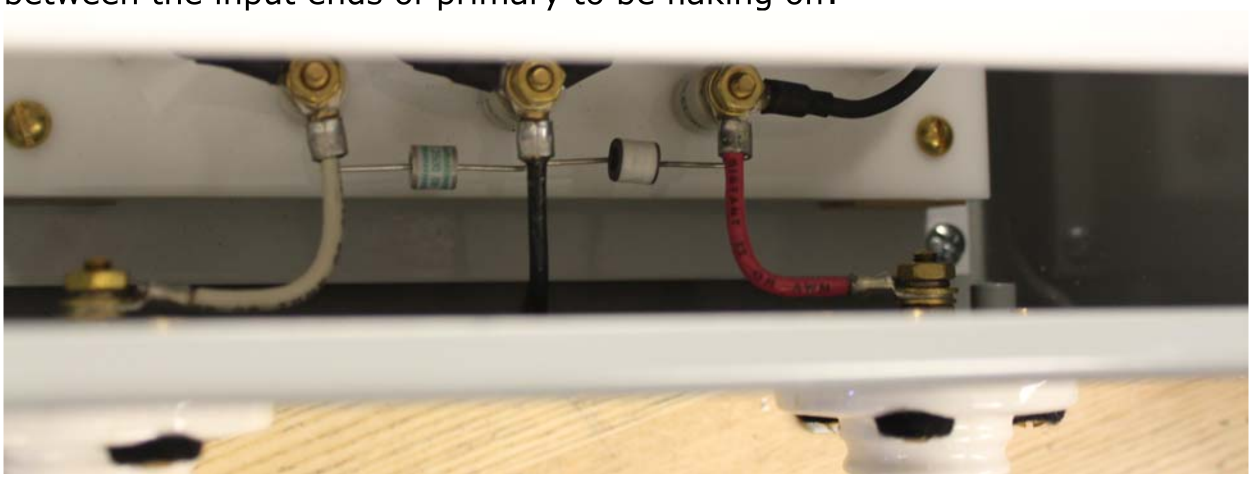

Figure 12: Failed surge arrester (right) versus what it should look like (left)

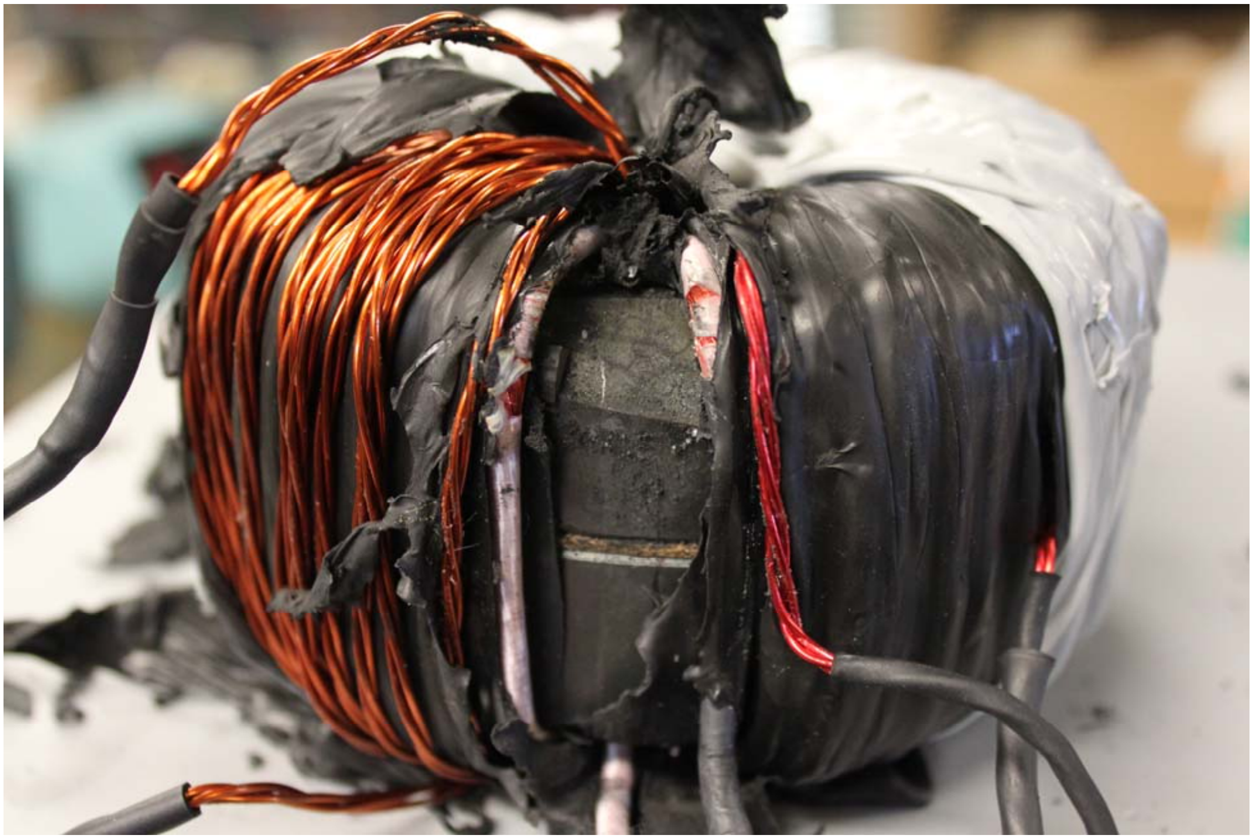

Figure 13: Extensive damage to the old antenna transformer

Appendix A: Timeline

All dates and times NZDT (UTC +13) unless otherwise noted

Nov 5 1620 (PST): AA 2246 departs SFO
Nov 5 1750 (PST): AA 2246 arrives LAX
Nov 5 2230 (PST): AA 7364/QF 12 departs LAX
Nov 7 0930: AA 7364/QF 12 arrives SYD
Nov 7 1110: AA 7345/QF 45 departs SYD
Nov 7 1410: AA 7345/QF 45 arrives CHC
Nov 8 1300: CDC Issue
Nov 9 0700: CHC-MCM report time
Nov 9 0820: Flight briefing
Nov 9 1000: Flight departs CHC
Nov 9 1540: Flight arrives MCM
Nov 9 1900: Bag Drag for P012
Nov 10 0730: Report time for P012
Nov 10 0823: P012 departs MCM
Nov 10 1130: P012 arrives NPX
Nov 10 1400: Meeting with Al Baker, Ethan Goode, and Jack Corbin
Nov 11: VLF receiver diagrammed
Nov 11 1330: Snowmobile training with Dave Carson

Nov 11: Batteries for VLF Beacon delivered inside MAPO
Nov 13 0800: Pisten Bully training with Al Baker and inspection of grid south end of beacon antenna
Nov 14 0600: Inspection of grid north end of beacon antenna
Nov 14 1030: Science meeting
Nov 15 1200: Batteries for VLF Beacon replaced
Nov 16 1200: PENGUIn recovered
Nov 18 0900: Amplifiers removed for testing
Nov 20 0630-1030: PENGUIn preamplifier recovered; site secured
Nov 21 1300: Brief visit to PENGUIn antenna, main VLF receiver antenna and preamplifier.
Nov 21: DVDs (9108-0002) and antenna repair sleeves (9108-0003, 9108-0004) arrive
Nov 23: Software updates on beacon computer
Nov 24: Antenna transformer, new gate drain strips, transmission line connectors, extra parts (9108-0006) arrives
Nov 28: Thanksgiving dinner
Dec 1: Driver cards modified with larger bootstrap capacitor
Dec 2 0715-1215: Transmission line connectors and antenna transformer replaced
Dec 2: Modified driver cards installed and tested
Dec 2: Old antenna transformer rebuilt
Dec 3: Amplifiers returned to racks, tested into dummy load
Dec 3 1336 (Dec 3 0036 UT): Beacon transmits with gain of 1450 and severe distortion
Dec 3 1351 (Dec 3 0051 UT): Beacon transmits with gain of 1000—surge arrestor likely fails
Dec 3: subsequent tests indicate impedance mismatch
Dec 4: Transmission line checks with TDR passed
Dec 4: New transformer swapped with rebuilt old transformer and check of grid south end of antenna
Dec 5: Tests show signs of arcing at low gains and impedance mismatch
Dec 5: New transformer tested with dummy load
Dec 7 0730: Old transformer swapped for new transformer and check of grid north end of antenna.
Dec 7: Tests continue to show signs of arcing
Dec 7 1520: Transmission line junction 4 and new transformer inspected
Dec 8 0851 (Dec 7 1951 UT): Beacon transmits at gain of 1350 without amplifier 5
Dec 8 1323 (Dec 8 0023 UT): Beacon goes off for testing
Dec 8 1851 (Dec 8 0551 UT): Beacon goes on for one-time test
Dec 9 1336 (Dec 9 0036 UT): Beacon goes on at gain of 1350
Dec 9: Retro cargo prepared for pickup by cargo.
Dec 9 1900: Bag drag

Dec 10 0830: Retro cargo picked up
Dec 10 1400: P073 departs NPX
Dec 10 2000: Bag drag for ACH033
Dec 11 1200: Report time for ACH033
Dec 11 1500: ACH033 departs MCM
Dec 12 1110: NZ 510 departs CHC
Dec 12 1235: NZ 510 arrives AKL
Dec 12 1545: AA 7315 (QF 25) departs AKL
Dec 12 0635 (PST): AA 7315 (QF 25) arrives LAX
Dec 12 1115 (PST): AA 1928 departs LAX
Dec 12 1245 (PST): AA 1928 arrives SFO

Appendix B: Glossary

Antenna Field: Area housing the VLF receiver antenna (also Operations Sector)
ARO: Atmospheric Research Observatory. Sits at the apex of the clean air sector and is a good waypoint for finding the PENGUIn and VLF Receiver antennas.
Bag drag: when checked luggage is taken and you're weighed with your carry-on.
CDC: Clothing Distribution Center in Christchurch, also housing the Antarctic passenger terminal.
Clean Air Sector: The sector containing the PENGUIn antenna. No vehicles or overflights below 2000 feet.
CUSP Lab: Science lab in the elevated station where I spend most of the day.
Dark Sector: The sector containing the VLF Beacon antenna
Grid North: "North" on maps of the South Pole—points from the pole northwards along the Prime Meridian.
MAPO: Martin A. Pomerantz Observatory: building the VIPER control room is attached to, though with no direct access.
Pisten Bully: tracked vehicle with lots of room, heated interior, and good height.
VIPER: former radio telescope; its control room now houses the VLF Beacon transmitter
Operations Sector: Antenna field

Appendix C: Retro cargo

Box 1: PENGUIn receiver enclosure and battery module
Box 2: PENGUIn electronics box
Box 3: PENGUIn preamp
Box 4: VLF Beacon antenna transformer