Report on Tianlai tests at Xinglong Station, December 21, 2012.

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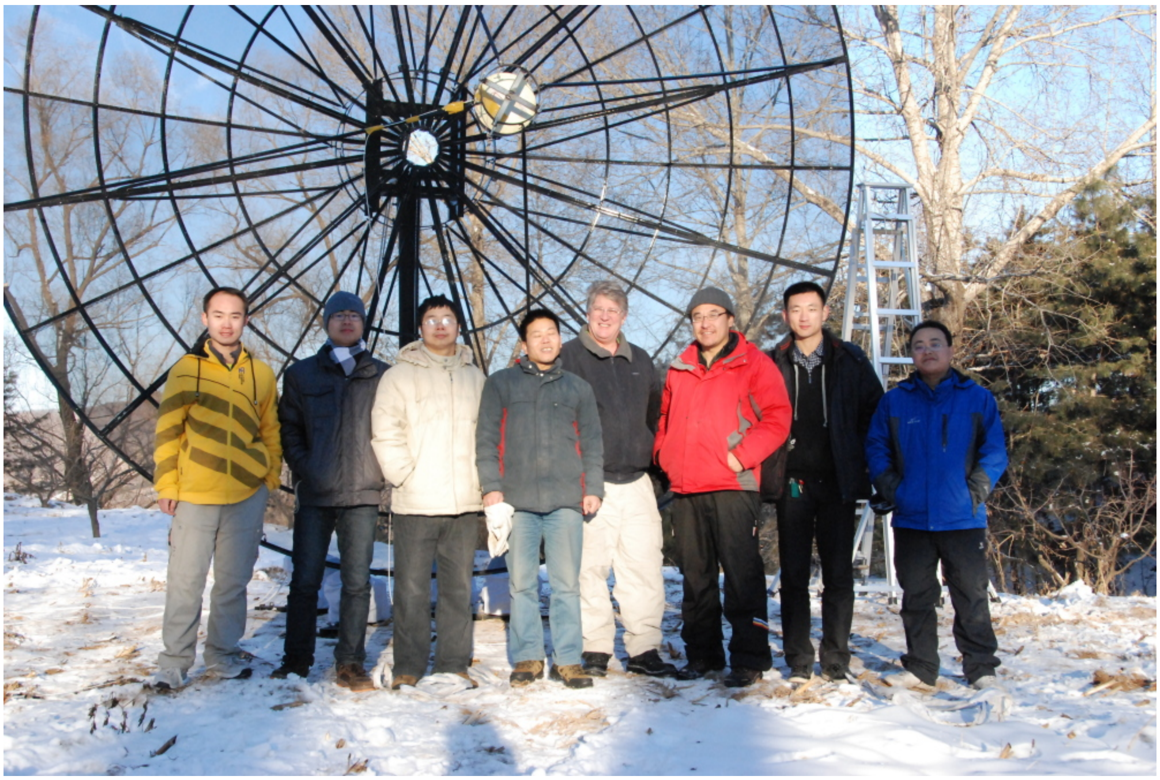
The test team with East dish.

Separate reports on the feed, dish, LNA, Receiver, and Correlator are posted to the Tianlai WIKI.

We set up three 5-meter dishes with the Inst. 54 feed and LNA, and tested the Inst 54 receiver system and the Inst. of Automation FPGA correlator. We placed the dishes in an approximate E-W line about 45 m long with the East and Center dishes separated by 15m.

Assembly.
A team of about four assembled and erected the dishes at ambient temperatures ranging from -5 to -19 C. Assembly/erection time was about 6 hours each. The speed of assembly was limited by the tools on hand: only two open end wrenches of the right size were available on-site. The work would go much faster using nut drivers and box end wrenches or better still, a cordless drill to tighten nuts. Also useful would be several drift punches that could be used to align holes between panels. Using the right tools, an experienced team, working in good weather, could probably assemble a dish in two-three hours.

RFI and filter passbands.

For most of the following tests we used the I-54 feed and LNA.

The site has a strong mobile phone signals at frequencies near 950 MHz, so we were forced to use a filter between the feed and LNA. Most of the time we used a minicircuits filter with a bandpass centered on 780 MHz (+- 60) MHz. This attenuated the mobile phone signal enough to allow the LNA to operate linearly, 90% of the time. We still had occasional overloads.

The bandpass filter has in-band insertion loss ~2db, which adds to the LNA noise figure of 0.4 to 0.5 db for a total of about 2.5 db NF. In addition, there would be a ground spill noise contribution of about 50 K, if the noise figure were lower. We adopt 200 K as an estimate of Tsys.

On the last day at the site we also tried a minicircuits 1200 MHz highpass filter instead of the bandpass. This did better at attenuating the 950 MHZ RFI, but this passband is above the design range for the feed. We still had occasional strong RFI in this configuration.

Dish/Feed/LNA Results.

We pointed at the Sun and carried out a "deflection test" by measuring the ratio of power levels at the output of the LNA. We compared the power pointed on-the-sun versus about 20 degrees off-the-sun. Numbers below are given in db and the measurements were done at 743 MHz.

We built an adjustable support for the feed and scanned the focus over about a 25 cm range, testing sun-deflection at four settings using the I54 feed. Here are the results showing the distance F, which is measured from the vertex of the reflecting surface of the dish to the metal disk on the feed, and the sun-deflection. We used the West dish for these tests.

Focus Position F (cm)	Sun Deflection (db)
177 +- 5	2 +- 0.5
185 +- 5	7 +- 0.5
193 +- 5	7.5 +- 0.5
202 +- 1	7.5 +- 0.5

On The Center dish we did not have the focus adjuster and the fixed feed position was F=218 cm. On this dish the deflection was 8 db.

Leaving the focus at 202 cm on the West dish we carefully adjusted elevation and azimuth and achieved deflection 9.8 +- 0.5 db. This is in excellent agreement with the expected deflection given the estimated system temperature of 200 +- 100 K. The calculation of the expected deflection is presented in a separate note.

We then measured the beam width, 7 +- 1 degree FWHM. This is in a plane at 45 degrees to both the E and H plane. Assuming 3 db illumination at 3 meters aperture, lambda/d = 7.6 degrees, so this checks as well.

Because of the RFI we were not able to try the CMU sleeve-dipole-cone feed with it's built-in active-balun/LNA system, but we did get a chance to test the feed by itself, connected via the highpass filter to the I-54 LNA (with no balun). We achieved 7.5 db deflection at 1200 MHz in this mismatched configuration.

Inst. 54 receiver.

We tested the receiver units and found them to work well and have more than enough gain. They also have digitally switched attenuators with enough range to reduce the signal size to the proper level. The IF filter used in the receiver is centered on 250 MHz and is 100 MHz wide at 3 db points. Unfortunately, 250 MHz is currently the sampling frequency. So either the sampling frequency or the filter (or both) must change. Also the RF filter was not placed in a socket. This filter must be in a socket since we need to change this filter several times over the course of the experiment.

Inst. of Automation Correaltor.

This Inst. of Auto. team spent many long days and nights fixing thermal problems and hardware failures. We succeeded using the correaltor to sample signals from the receiver at 250 Ms/s (10 bit). We displayed sample stream plots. Specifically, we fed identical band-limited noise siulataneously into multiple inputs and checked that the sample streams agreed. We did this for signal sizes that nearly clipped at the +- 1 V input limit of the ADC and for smaller signal sizes that produced 5 adu rms amplitude noise. This part of the hardware and software seems to work properly.

Unfortunately, with the same band limited noise (60 MHz +- 20 MHz) waveform applied to two inputs, the correlator code did not give the same auto-power spectra. Oops. The correlator code did sometimes seem to show power in the correct part of the spectrum, so the code works at some level. However, the code did not work well enough to acquire fringes.

Conclusions.

The 5 m dishes are easily assembled and pass all tests. They work well.
The I 54 feed works well.
The CMU feed is a useful backup.

The LNA works well but should be modified to drive RG-6.
The receivers work but need changes to the filters.
The correlator hardware works but the software has fatal errors at this point.

Next Steps.

Fix the correlator and test it in the lab with correlated noise fed into multiple inputs.
Add cable delay to one input to create fringes in the lab.
Return to Xinglong and measure fringes on the Sun.
Record fringes on Cas A and Cyg A.
Use the S/N of these fringes to forecast the sensitivity of a dish-based Tianlai.

Move to a site quiet enough that the filter can be removed. (Bai Qi?)
Measure sun deflection and estimate Tsys without the filter.
Carefully account for any differences between on-sky measured T_sys and T_LNA.
Using a 300K eccosorb load over the feed, confirm the Tsys estimate.
Record fringes on Cyg A and repeat the estimate of Tianlai sensitivity.
Record data continuously for several months to determine reliability of all components.