Novel design features of the Submillimeter Array atmospheric phase monitor

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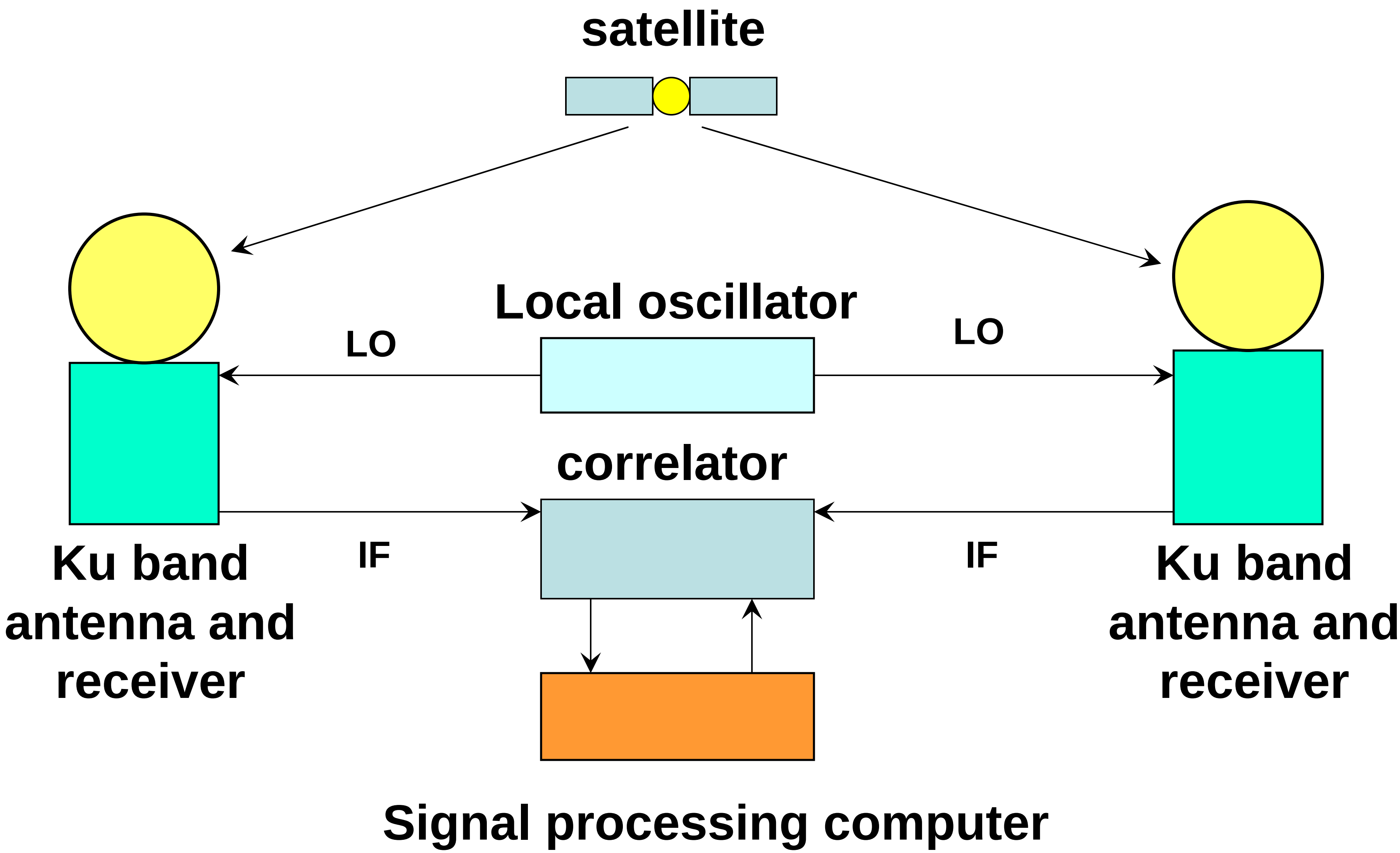
Single baseline atmospheric phase monitor



To extrapolate the measured phase noise at 12.5 GHz to 600 GHz the noise floor of the phase monitor must be low

Bob Wilson has given us a function to estimate the minimum rms phase noise floor of the phase monitor in radians Φ_{rms}

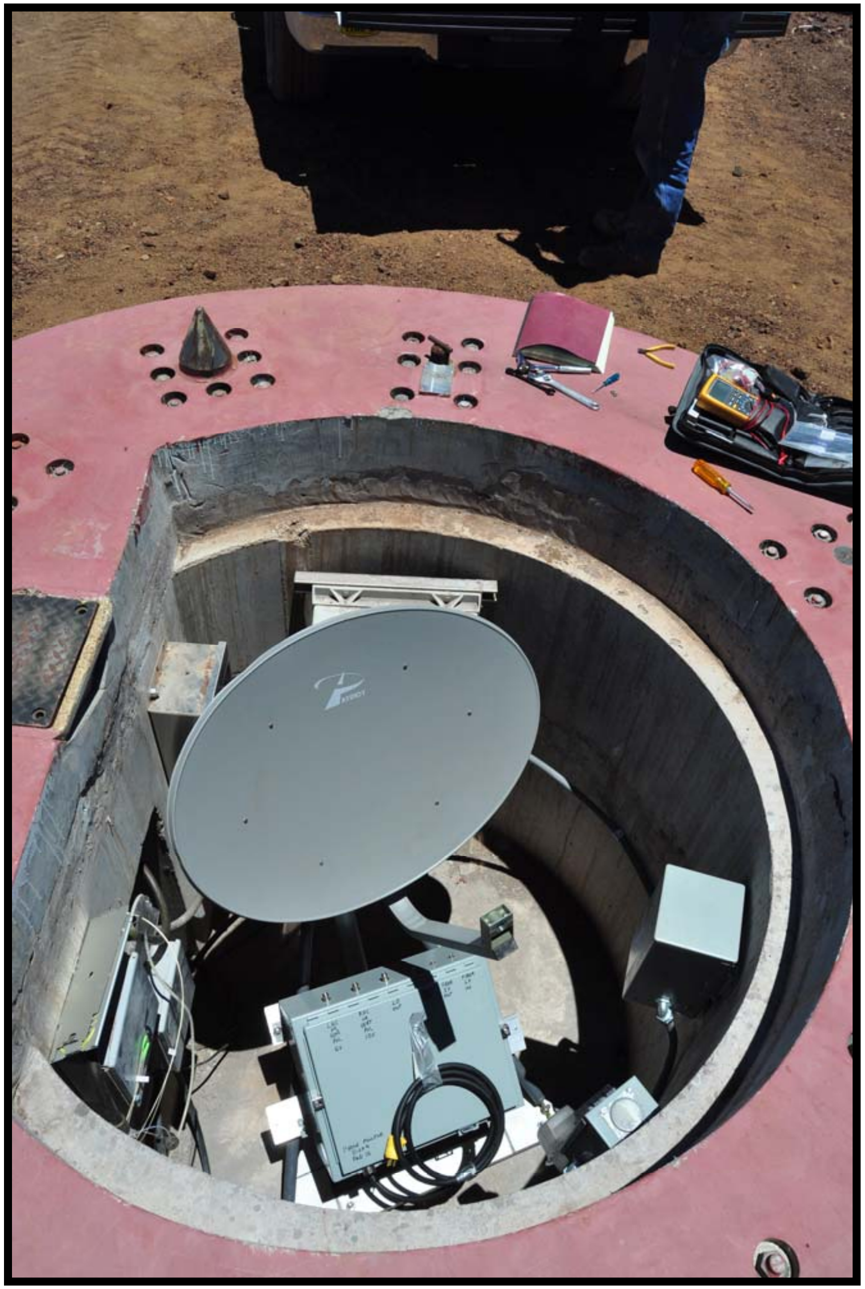
$$\Phi_{rms} = ((n/s) / (B\,\tau))^{1/2}$$

Where:

n/s is the noise power to signal power ratio

B is the signal bandwidth Hz

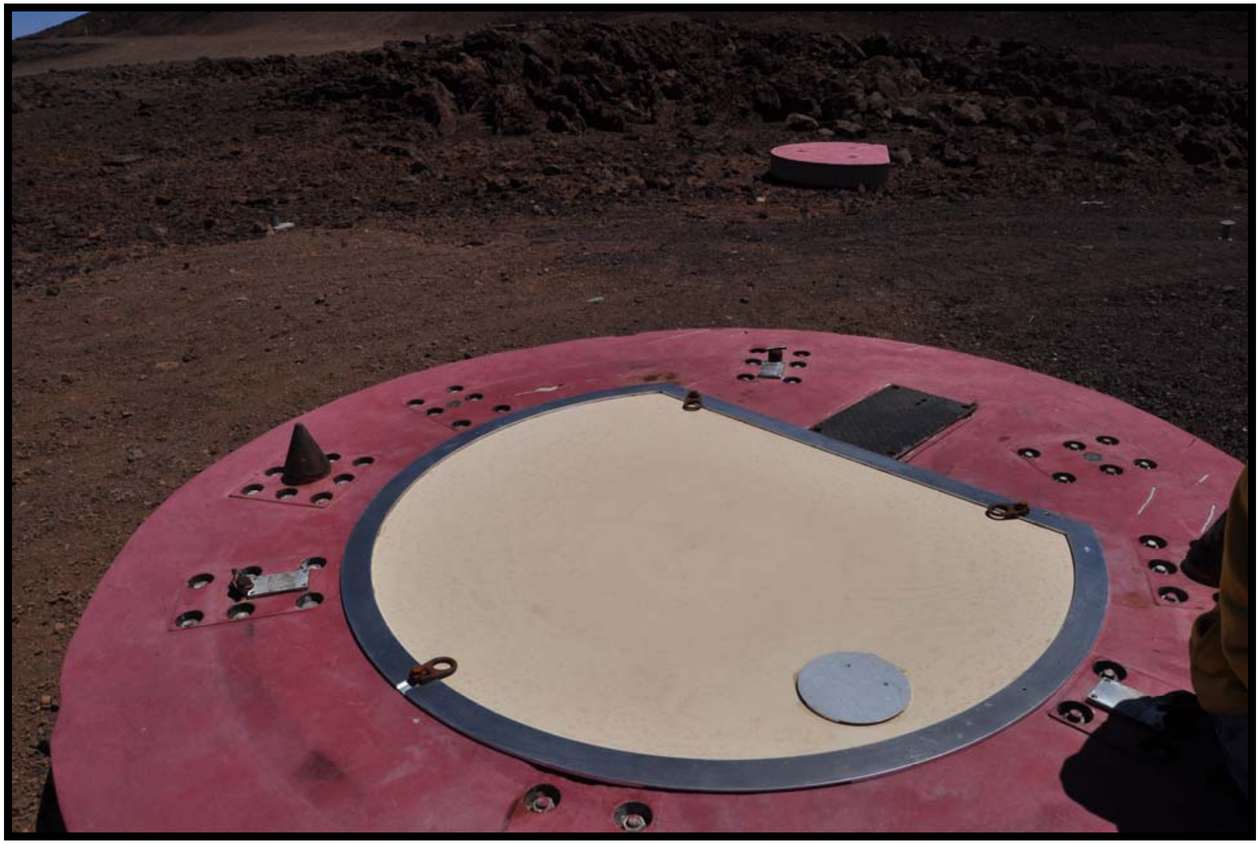
τ is the integration time seconds



It was Antony Schinkel's idea to place the phase monitor antennas within the unused SMA antenna pads

The phase monitor antennas are protected from wind buffeting and diurnal temperature cycling that degraded the prior SMA phase monitor's performance. We use buried optical fibers to send the IF and receiver the LO.

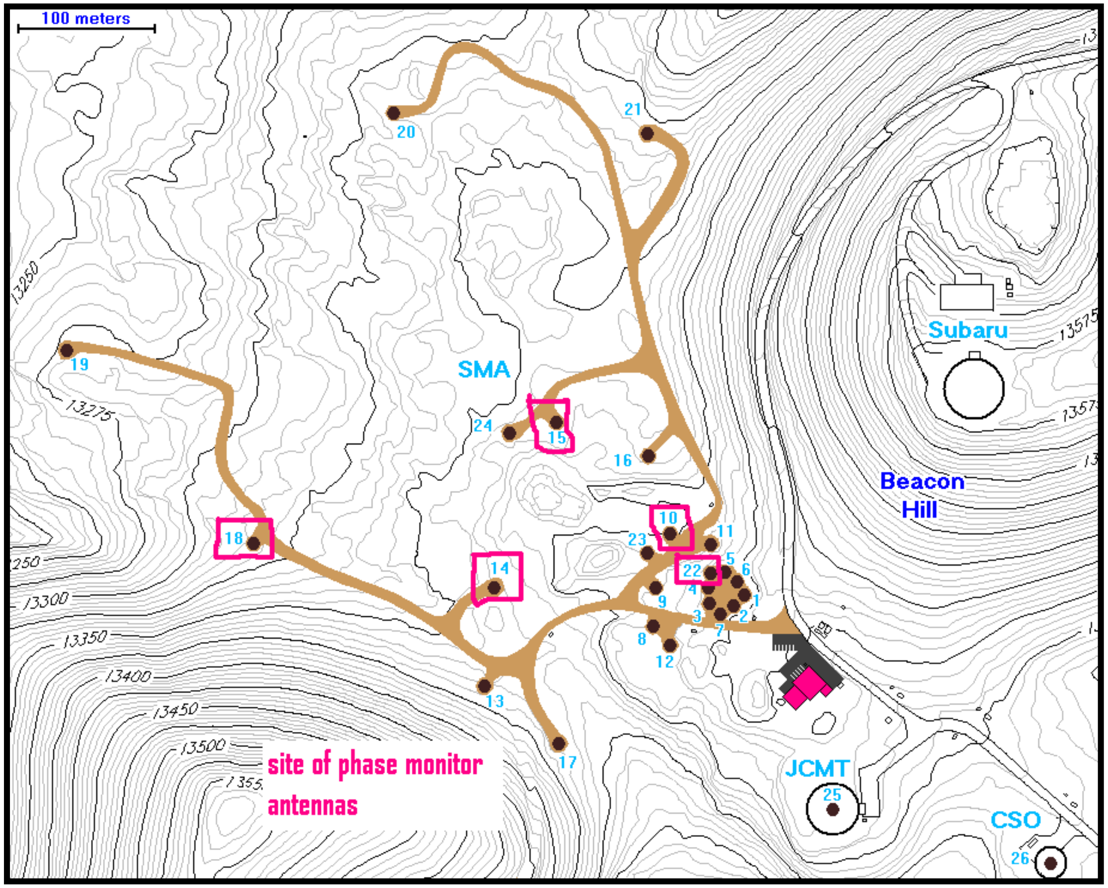
The achieved rms noise floor of 0.02^{o} in 0.1s means that wind buffeting must be less than 1.3 micrometers rms



The pad is covered with a 0.75” thick sheet of marine grade high density polyethylene. The pad is keep dry by a ventilation fan.

Except when covered in dew or puddles the cover is very transparent at 12.5 GHz and provides a clear view of satellites above 40^{o} elevation. Currently we observe the satellite Ciel-2 at 52^{o} elevation

Map of SMA pad positions, red squares mark phase monitor antenna positions



We currently have four phase monitor antennas and six baselines operating, when not covered by SMA antennas. Next year we will have five phase monitor antennas and 10 baselines. The baseline lengths range from about 30 m to over 300 m.

The multiple baselines allow us to verify the operation by both phase closure and statistical correlation of baseline data

Commercial satellite TV receiver modified to accept external local oscillator

Cost - $65

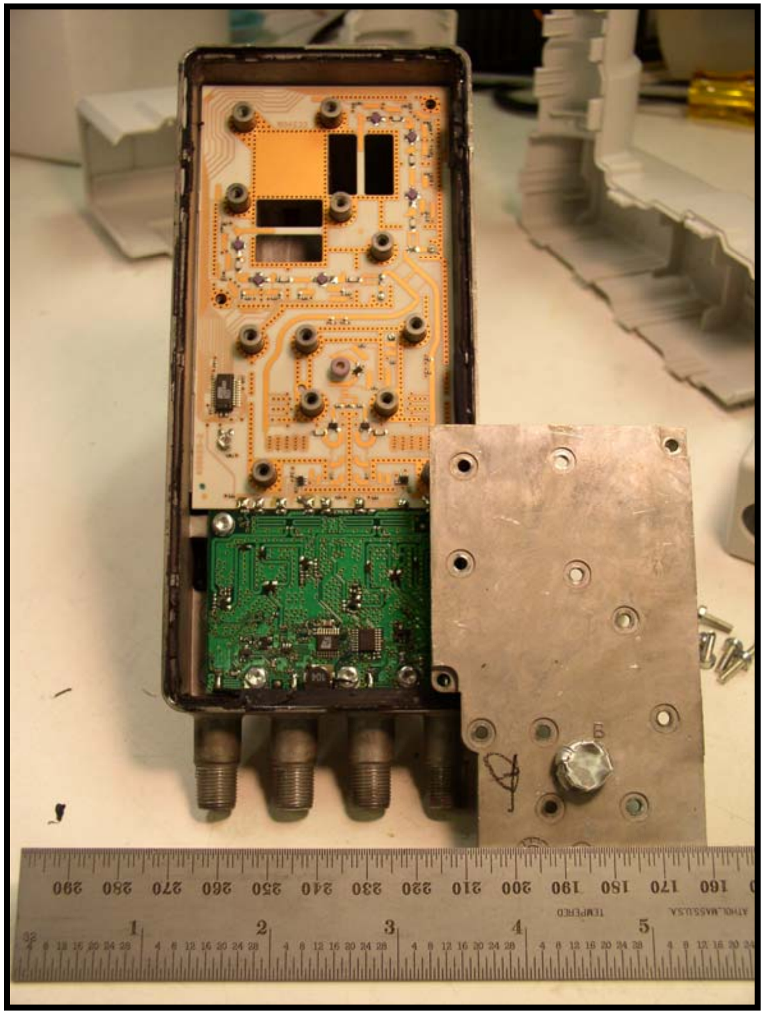
28K noise temperature LNA

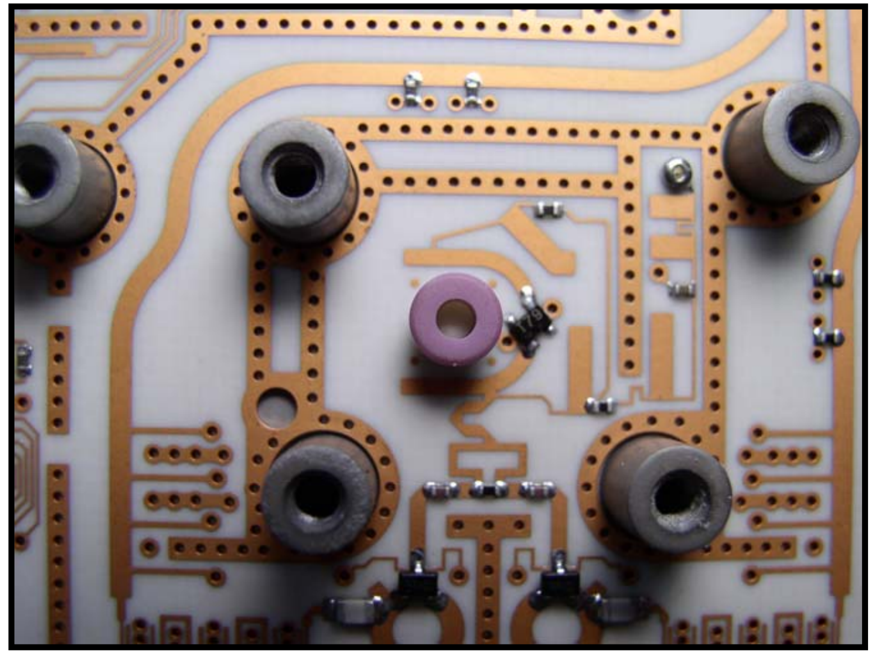
11.7 to 12.7 GHz bandwidth

Both linear and circular polarizations

Scalar feedhorn

Orthomode transducer

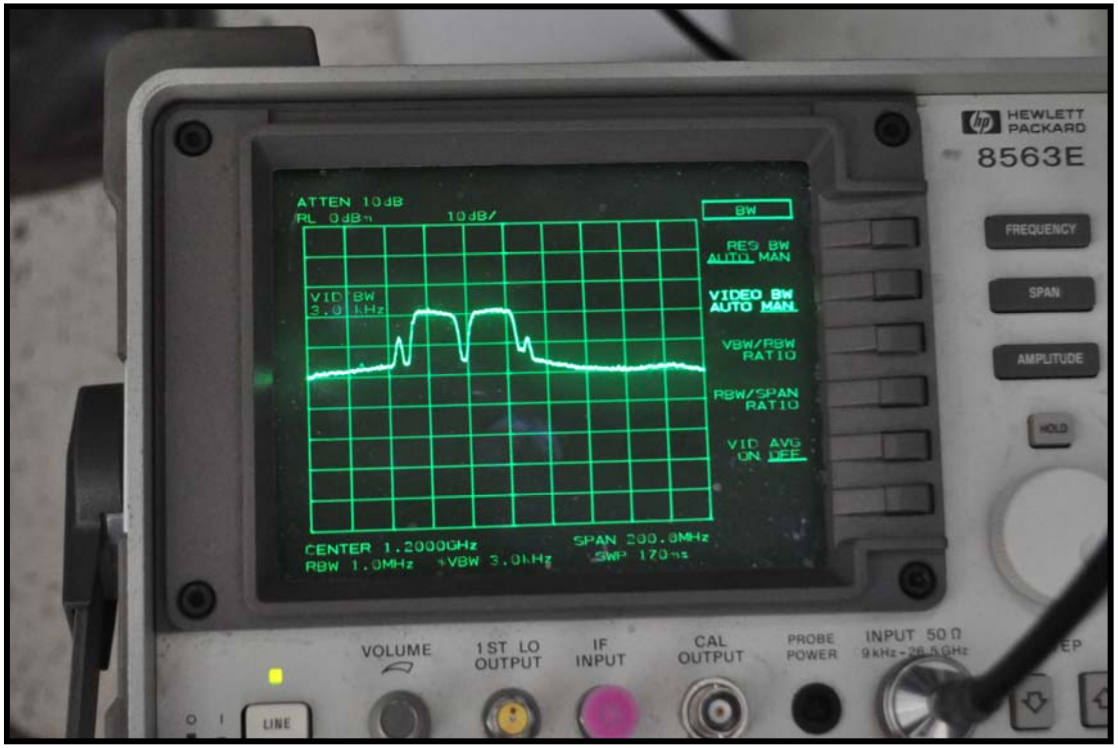




The external local oscillator is coupled to the toroidal dielectric resonator with a wire loop.

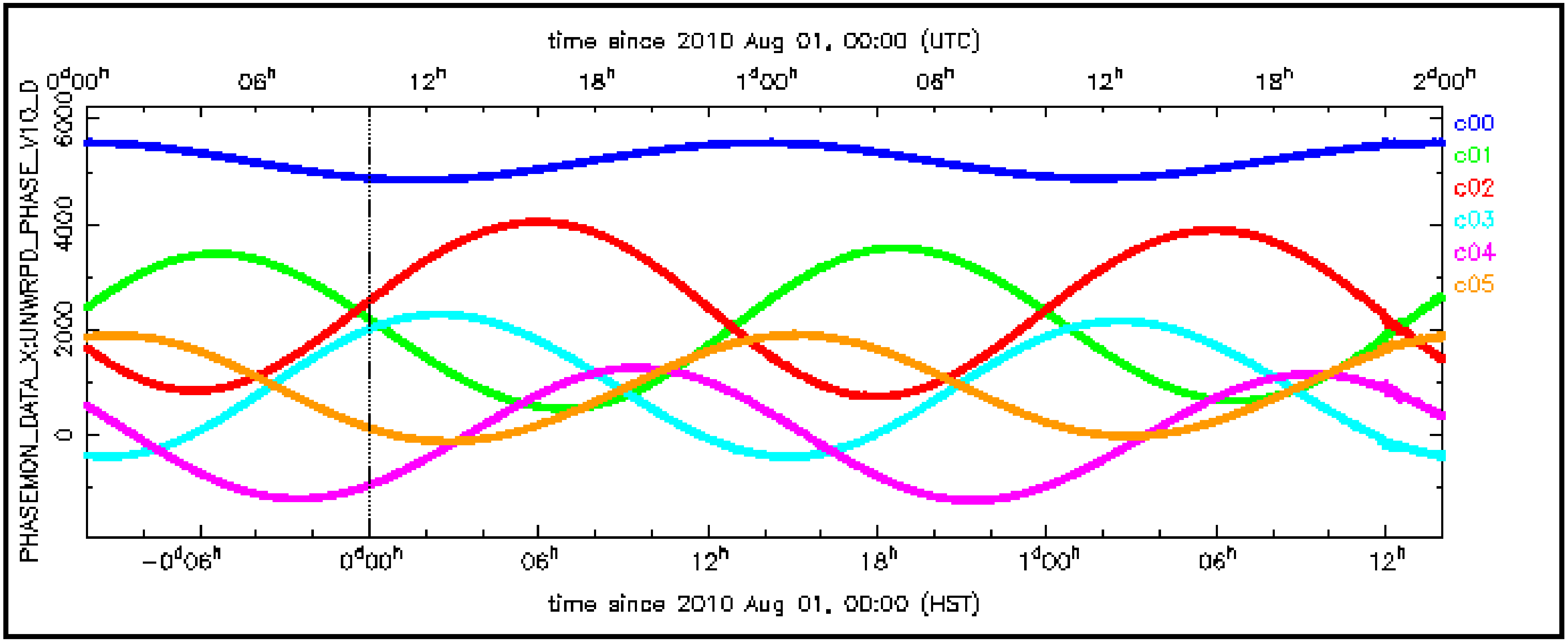
Larry D’Addario and Sander Weinreb took a different approach, injecting the local oscillator into the power splitter just below the toriod. Larry has modified our phase monitor design for use with the Deep Space Network and SKA.

The signal from the satellite has a spectral flux density of about $3*10^7$ Jy.



We took a concept from the BIMA atmospheric phase monitor, that of an equal arm, white noise interferometer using the satellite's digital TV broadcast. The image shows two 30 MHz wide transponder signals from the receivers IF output.

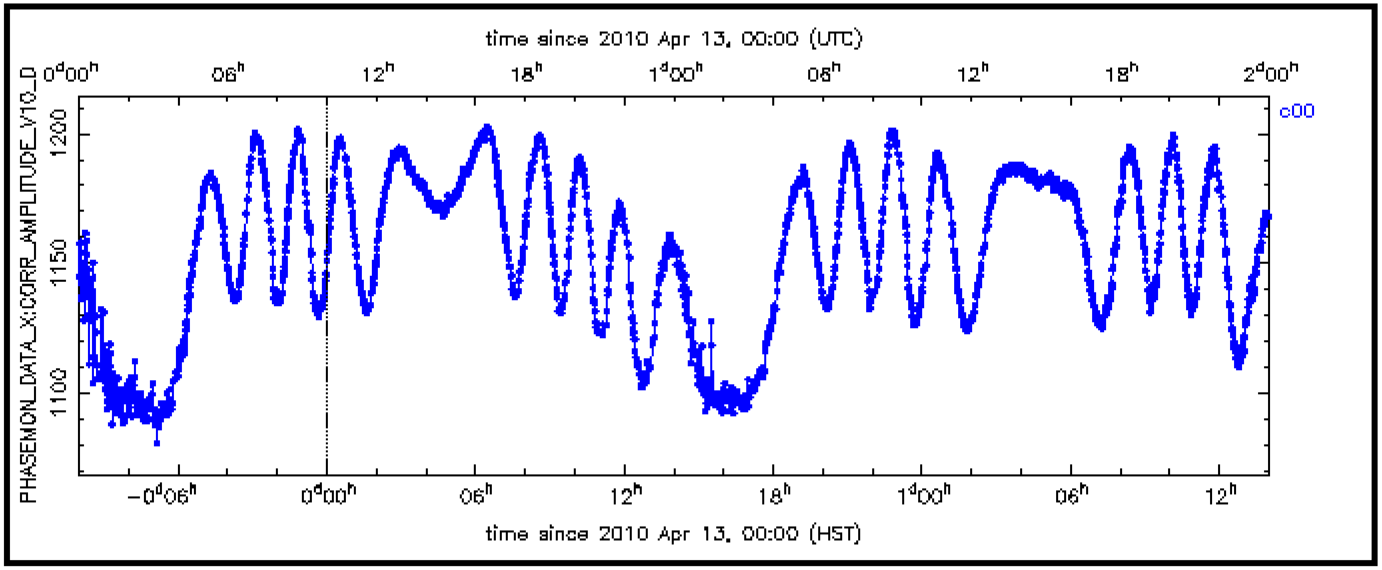
The use of the broad band satellite signal rather than the satellite beacon prevents multipath reflections that would degrade the phase monitor performance.



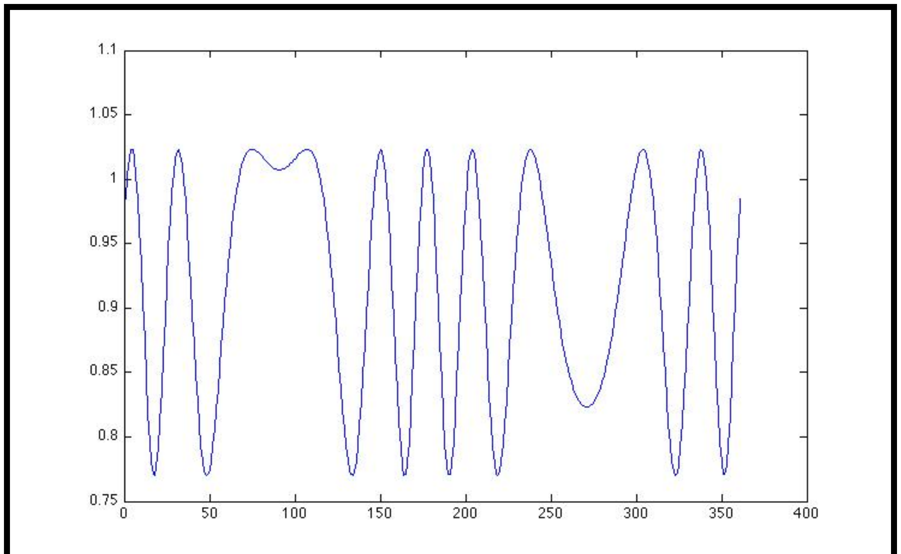
The graph shows the unwrapped phase produced by the diurnal satellite motion. The vertical axis is 8000° and the horizontal axis is about 2 days.

Bob Wilson used a sinusoidal least squares fit to remove the satellite induced phase drift and reveal the atmospheric phase noise. This is in contrast to the polynomial least squares fit that is often used and does not work as well.

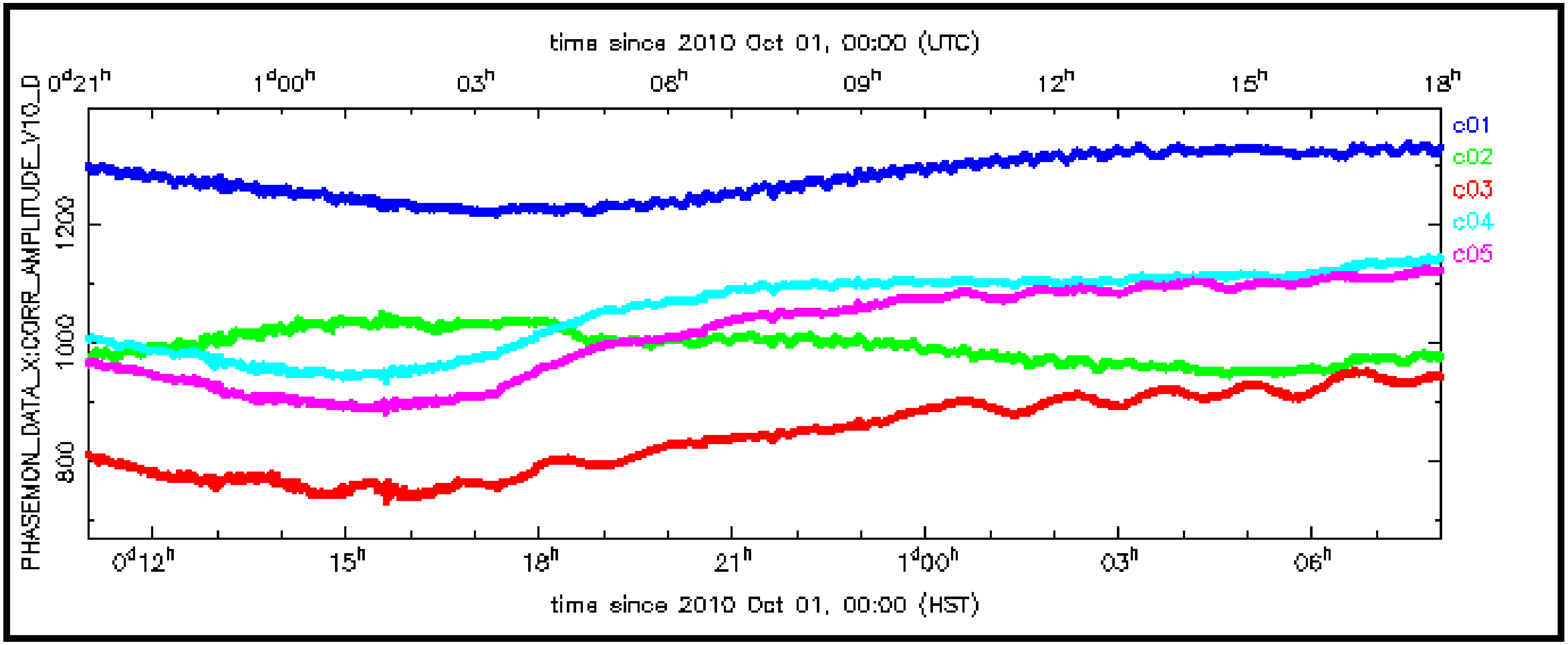
Correlator gain correction



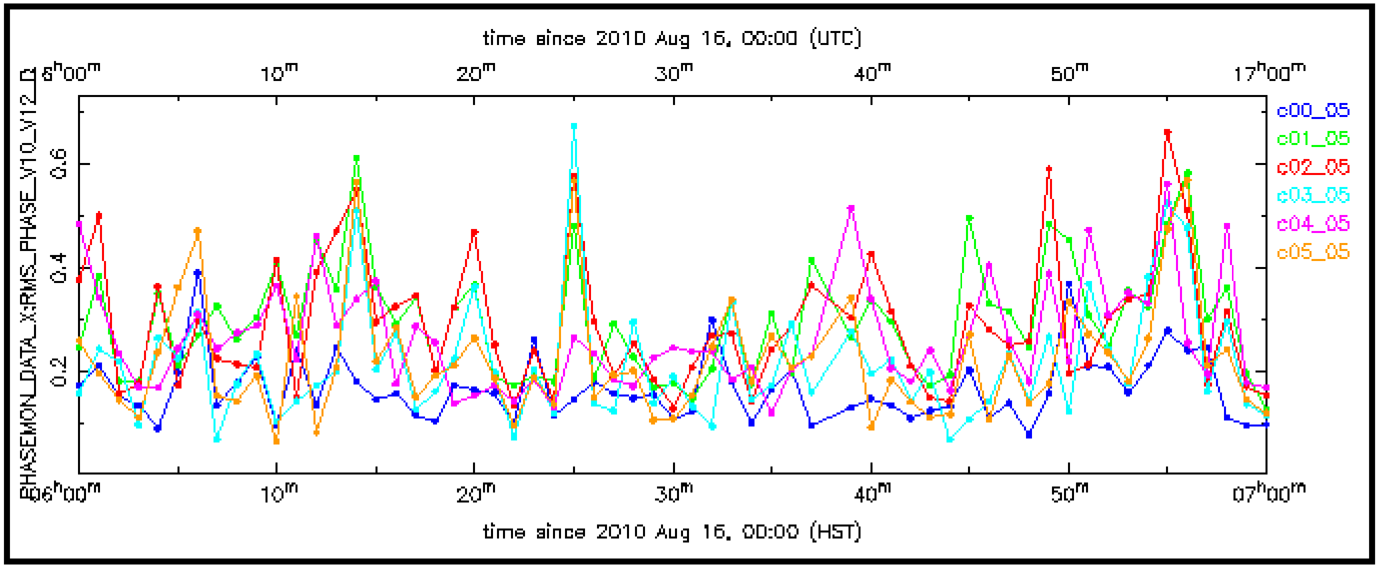
Plot of single baseline correlation magnitude over one and a half days before correction



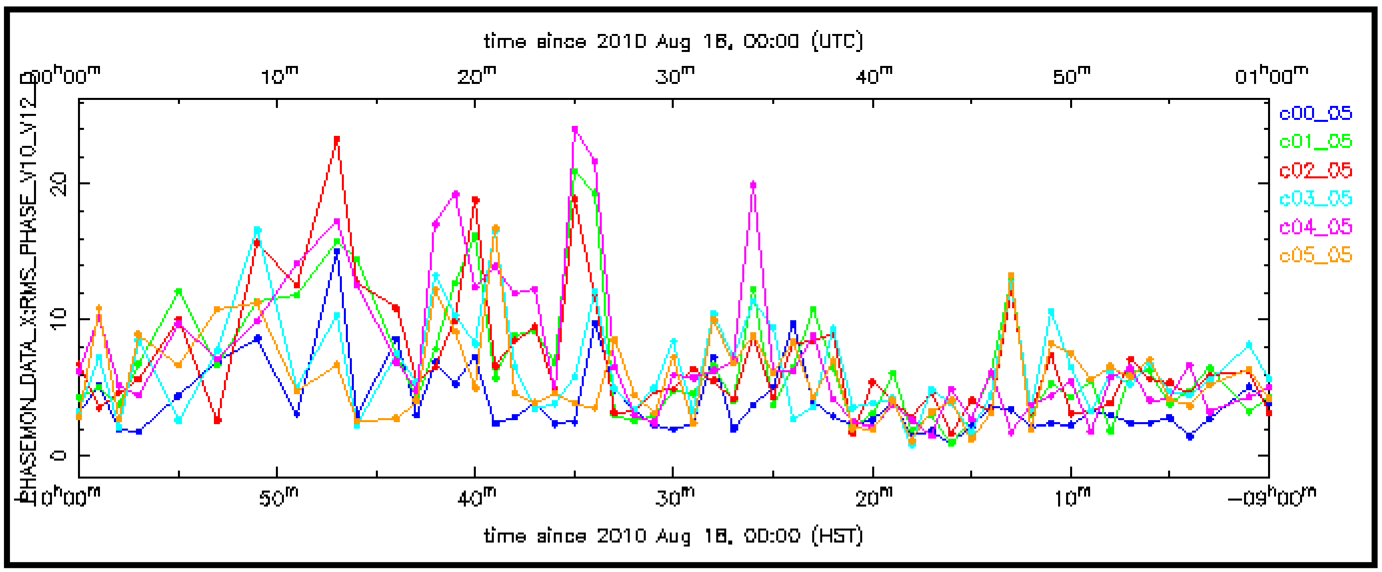
Todd Hunter took a model of unbalanced correlator gains, as seen on the graph to the left, and used a least squares fit to determine the gain errors.



This graph shows the correlation magnitudes of six baselines with the complex gains corrected. The slow drift is the change in coherence due to satellite motion.

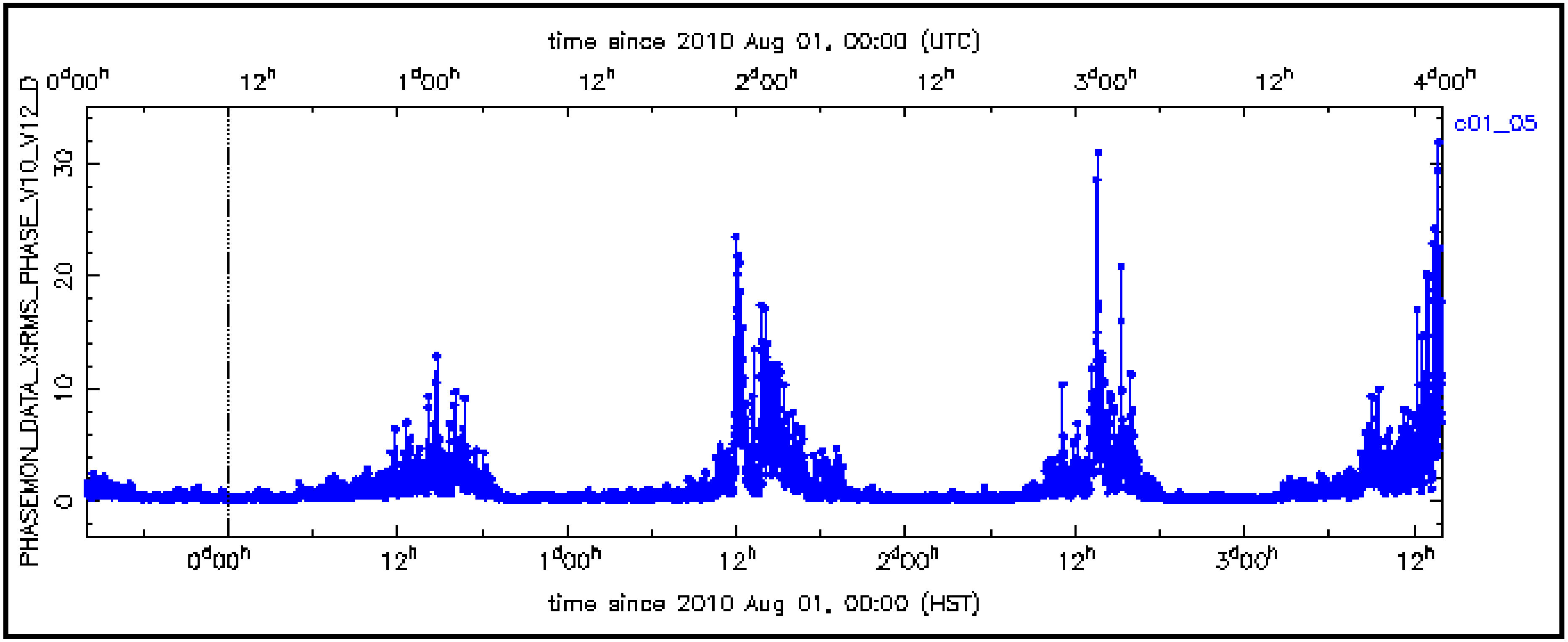


Night time phase noise over one hour. The vertical scale is 0.8° at 12.5 GHz

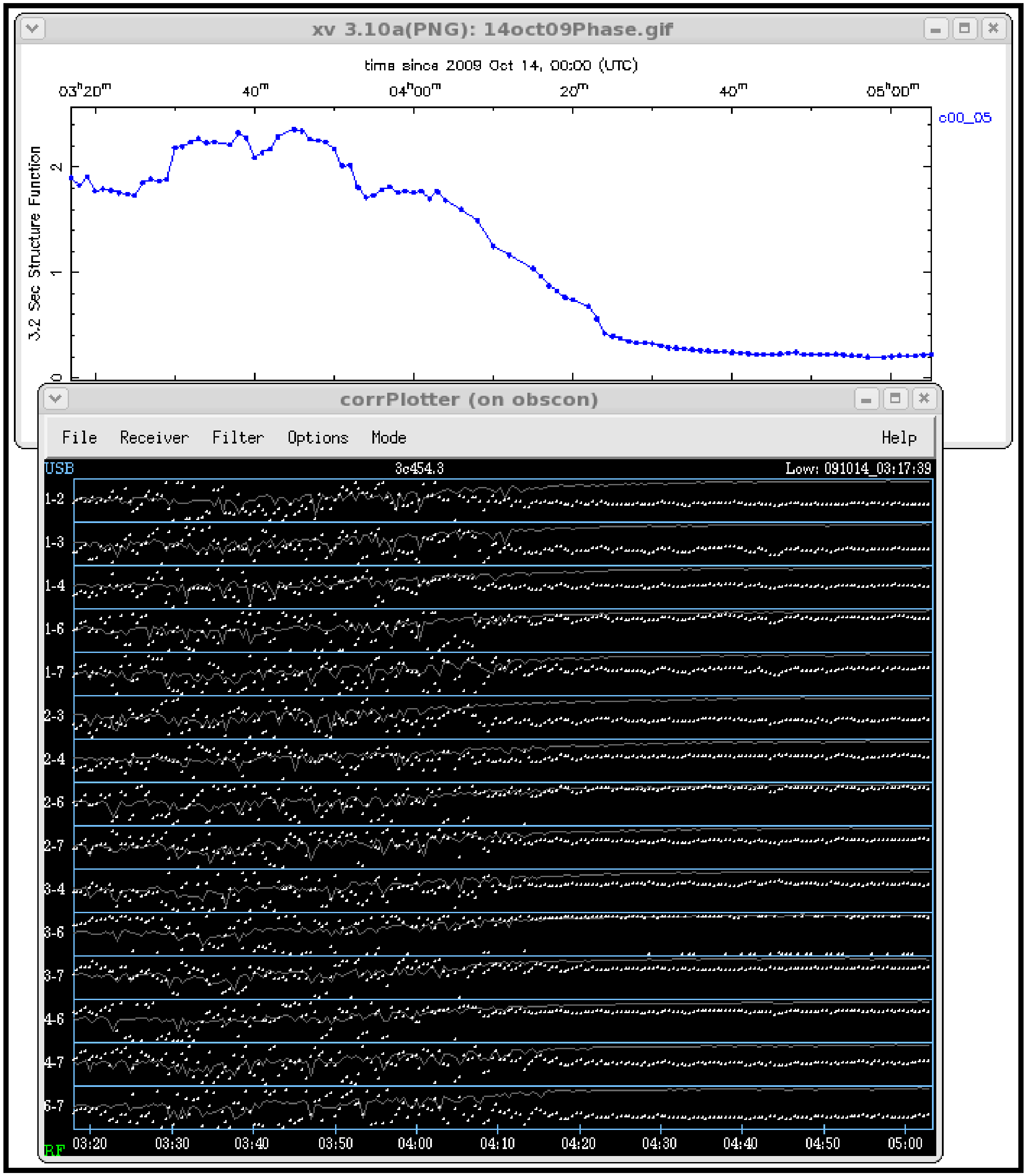


Day time phase noise over one hour. The vertical scale is 24° at 12.5 GHz

Six baseline rms phase data



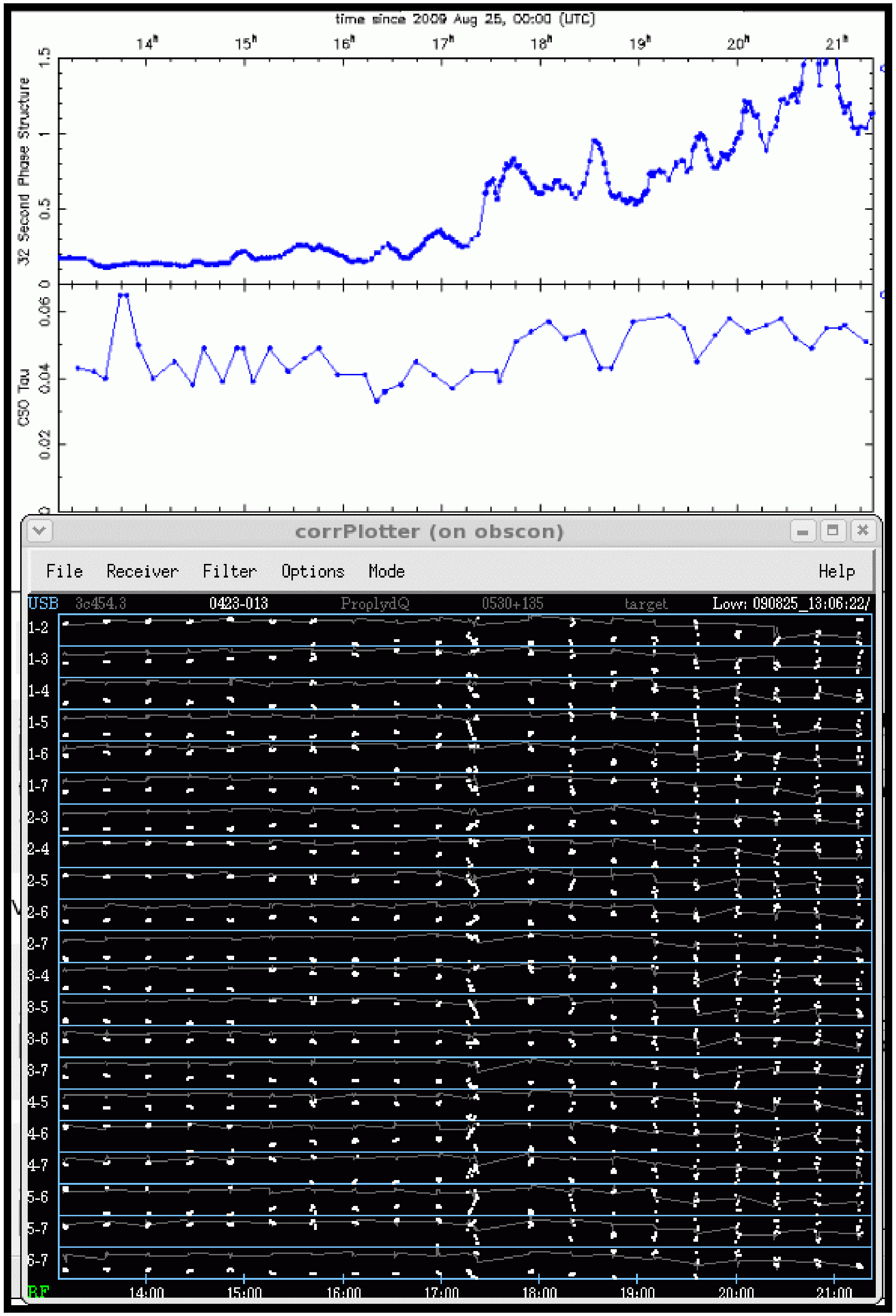
Typical diurnal atmospheric phase noise variation over 4 days



Top graph - atmospheric phase structure function

Bottom graph - SMA correlator phase for 15 baselines while observing quasar 3C454.3

This data taken by Ken Young shows the effect of decreasing atmospheric phase noise



Top graph- atmospheric phase structure function

Middle Graph- CSO tau data

Bottom graph- SMA correlator phase of many baselines while observing quasar 0423-013

This data taken by Ken Young shows atmospheric phase noise degrading observation while tau remains stable

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