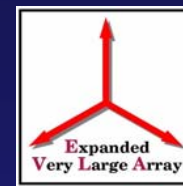




# Round Trip Phase Stability Status



Steven Durand  
&  
Terry Cotter

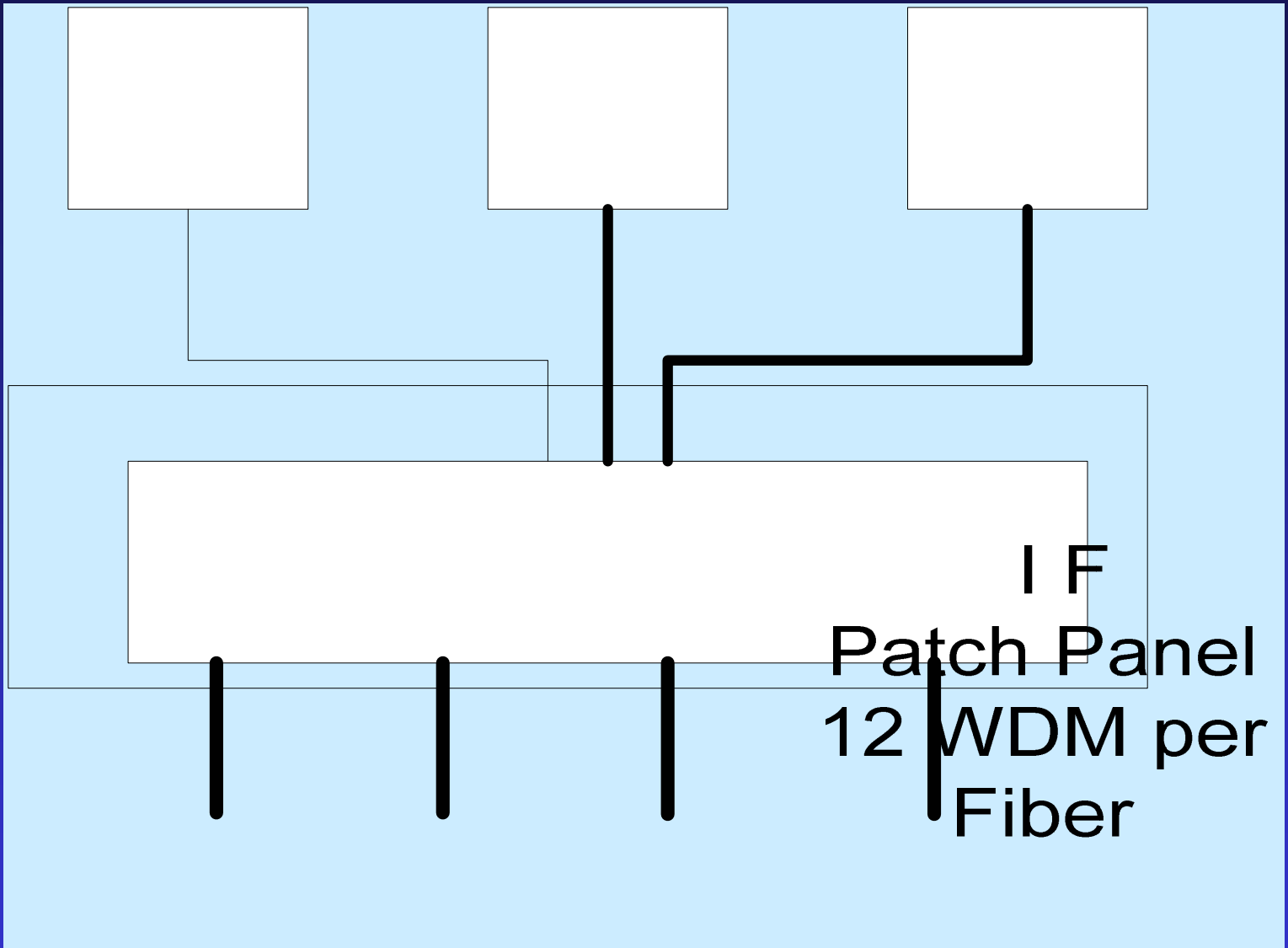
May 19, 2004



# Round Trip Phase



- Fiber System
- Photographic Tour
- Block Diagram
- Temperature Effects
- Movement Effects





# OFS BrightWave Cable



- Double armor loose tube cable
  - Corrugated, copolymer coated carbon, steel tape applied longitudinally
- Polyethylene jacket
  - 1.4 mm outer, 1.2 mm middle, 1.0 mm inner
- Glass/epoxy composite dielectric rod core



# Cable Cross Section





# OFS Matched Cladding Fiber



- Matched cladding single-mode
  - Nonzero-dispersion optical fiber
- Gel-filled buffer tubes
  - Installed in a reverse oscillation lay
  - 12 fibers per tube



# OFS Matched Cladding Specifications @ 1310 nm



- Attenuation coefficient: 0.31-0.35 dB/km
- Chromatic dispersion: -9 ps/nm-km
- Dispersion slope: 0.88 ps/nm<sup>2</sup>-km
- Group index of refraction: 1.471
- Polarization M dispersion:  $\leq 0.5$  ps/(km)<sup>1/2</sup>
- Rayleigh Backscattering: -49.6 dB
- Coefficient of Expansion\*: 6 PPM/°C

\* NRAO Estimate



# LO Technical Requirements

Based on the Scientific Goals  
after all Round-Trip Corrections



- Short Term:  $< 0.5$  ps RMS per second
- Long Term:  $< 1.4$  ps per 30 minutes  
~20 degrees at 40 GHz
- Delta Slope:  $< 0.2$  ps change per minute  
Over 30 minutes





# Phase Error Allocation

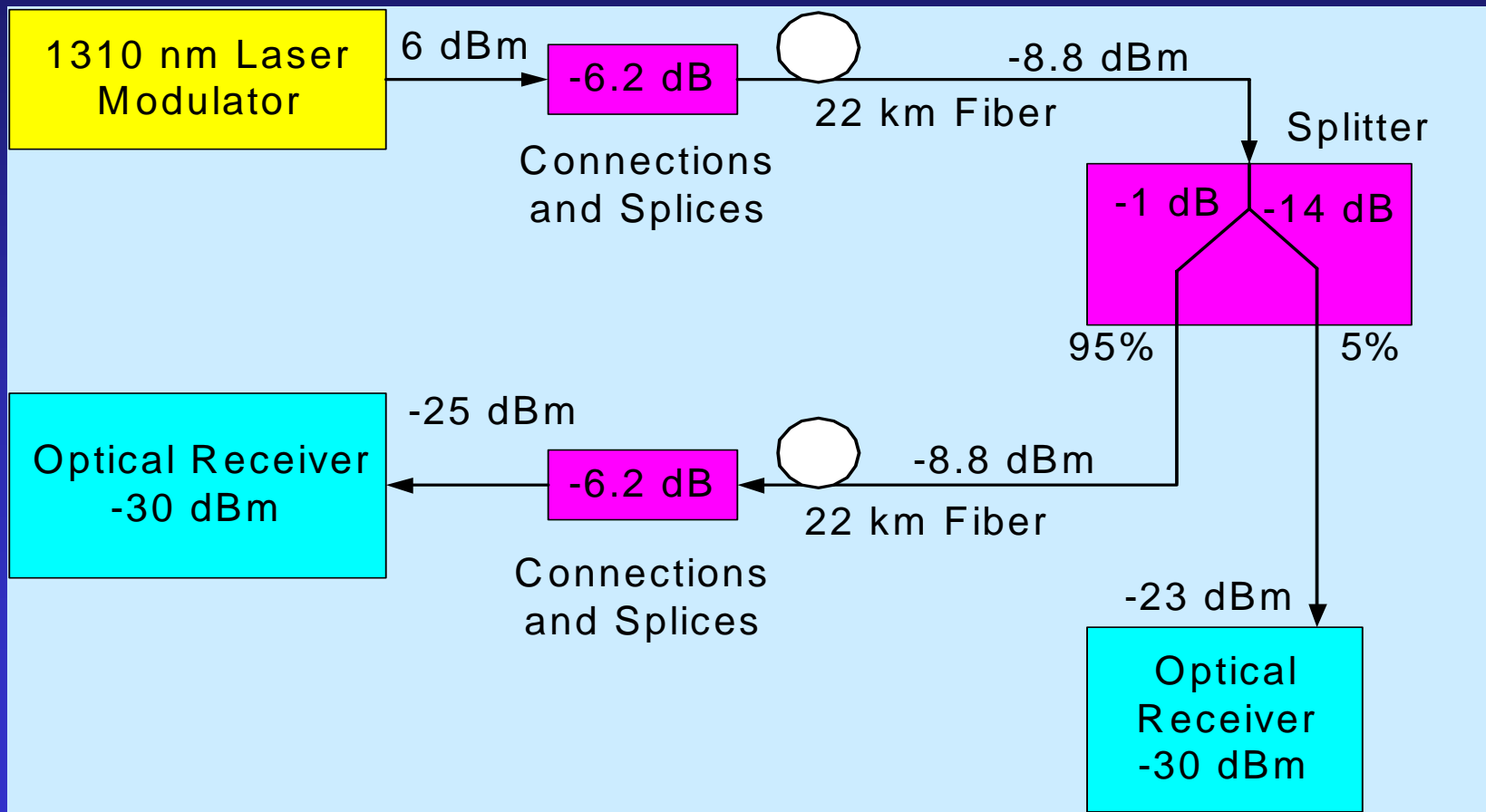


- Front End 0.4 ps per 30 Min
- LO Converters 0.6 ps per 30 Min
- Fiber System (RTP) 0.4 ps per 30 Min
  - RTP measurement accuracy\* 0.01 ps
  - 512 MHz + 128 Hz jitter\* 0.1 ps
  - Fiber induced errors 0.25 ps

\*NRAO estimates



# LO Optical System



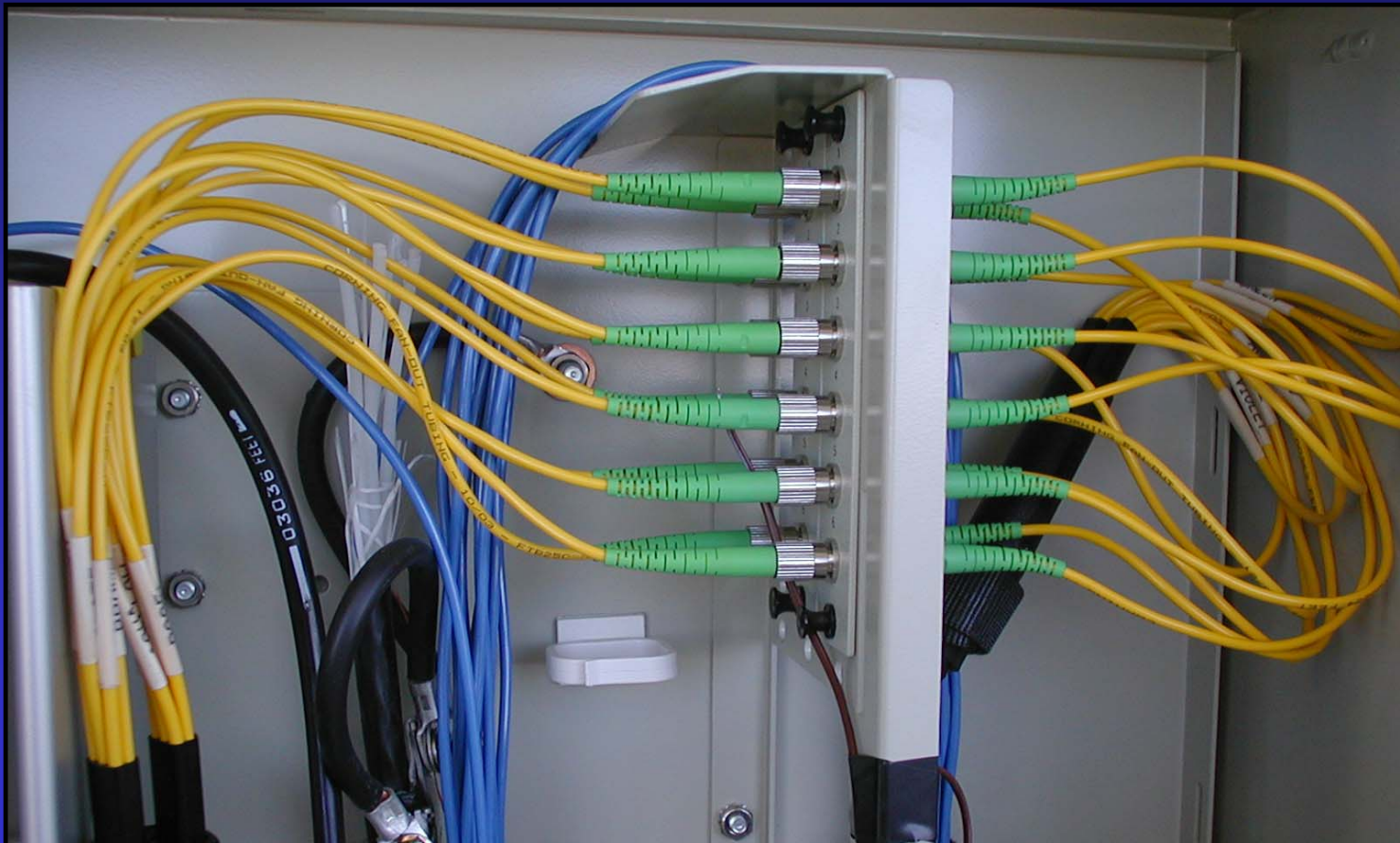


# Pad Enclosure





# Connectors



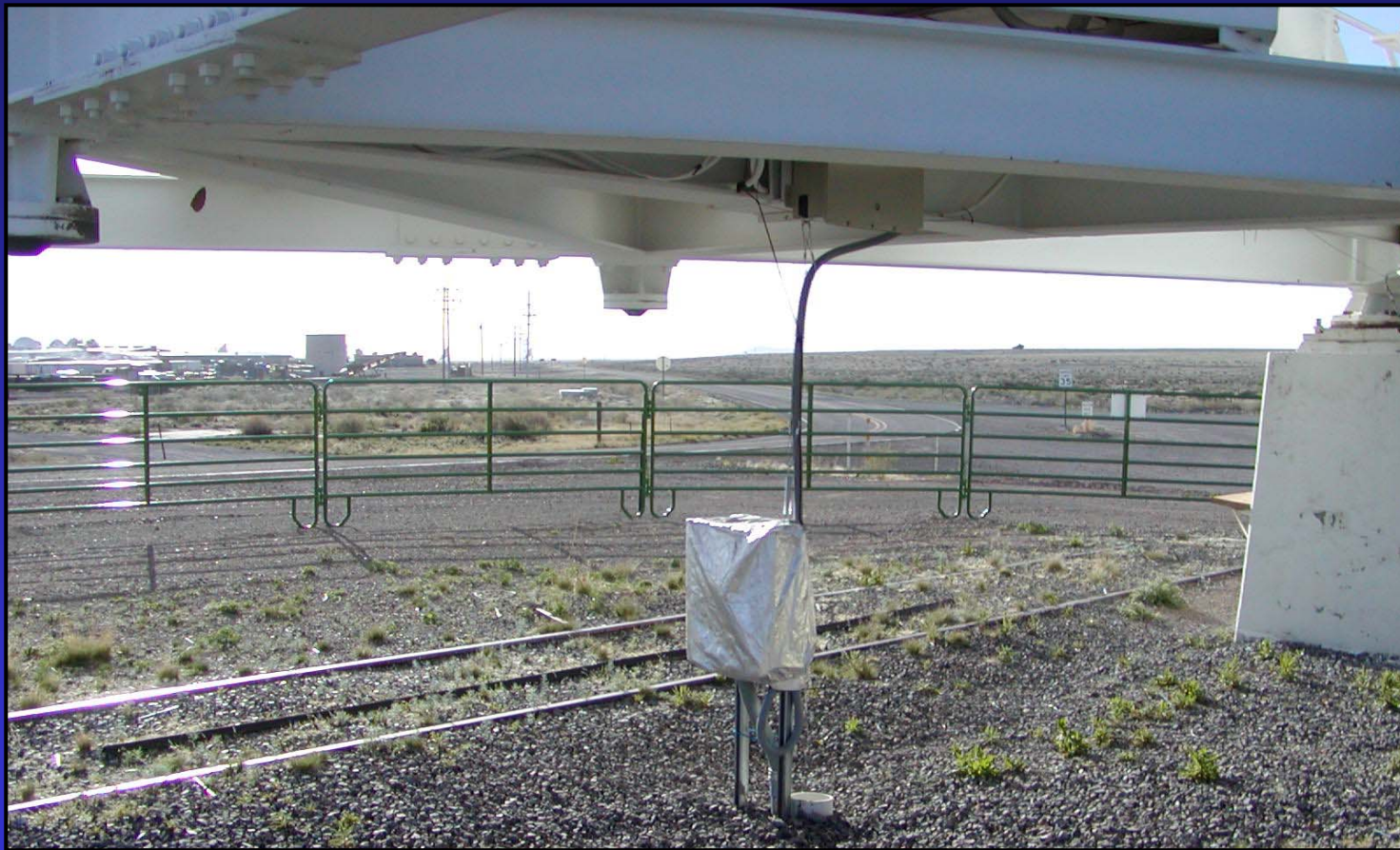


# Fiber Umbilical





# Fiber Umbilical



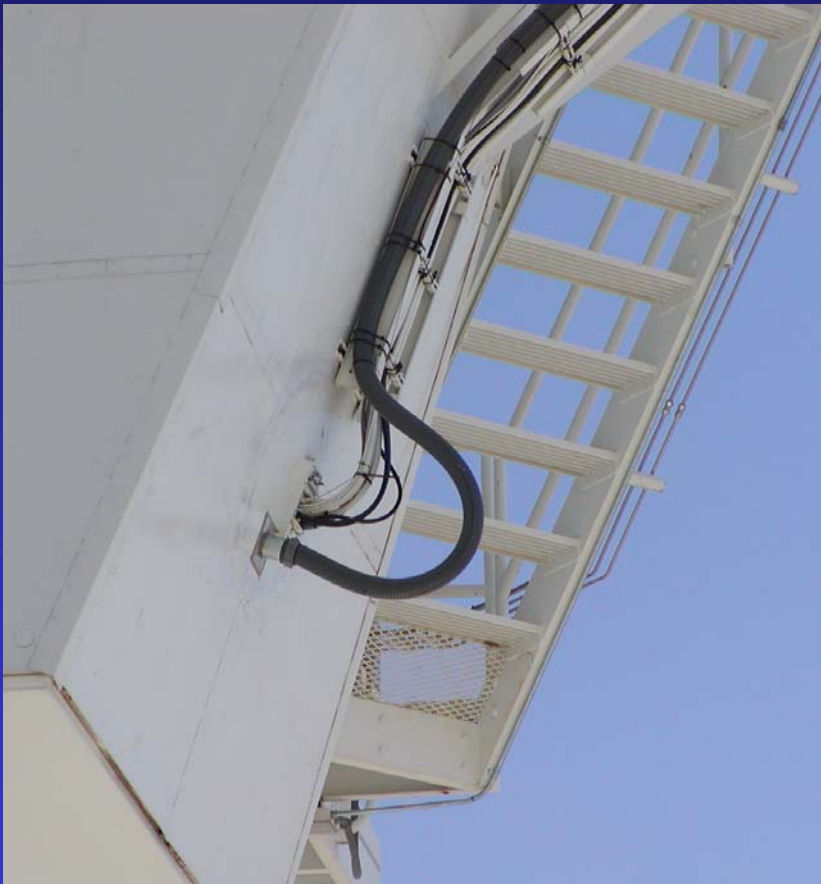


# Fiber Umbilical Antenna Junction Box





# After the Cable Wrap







# Elevation Cable Bend





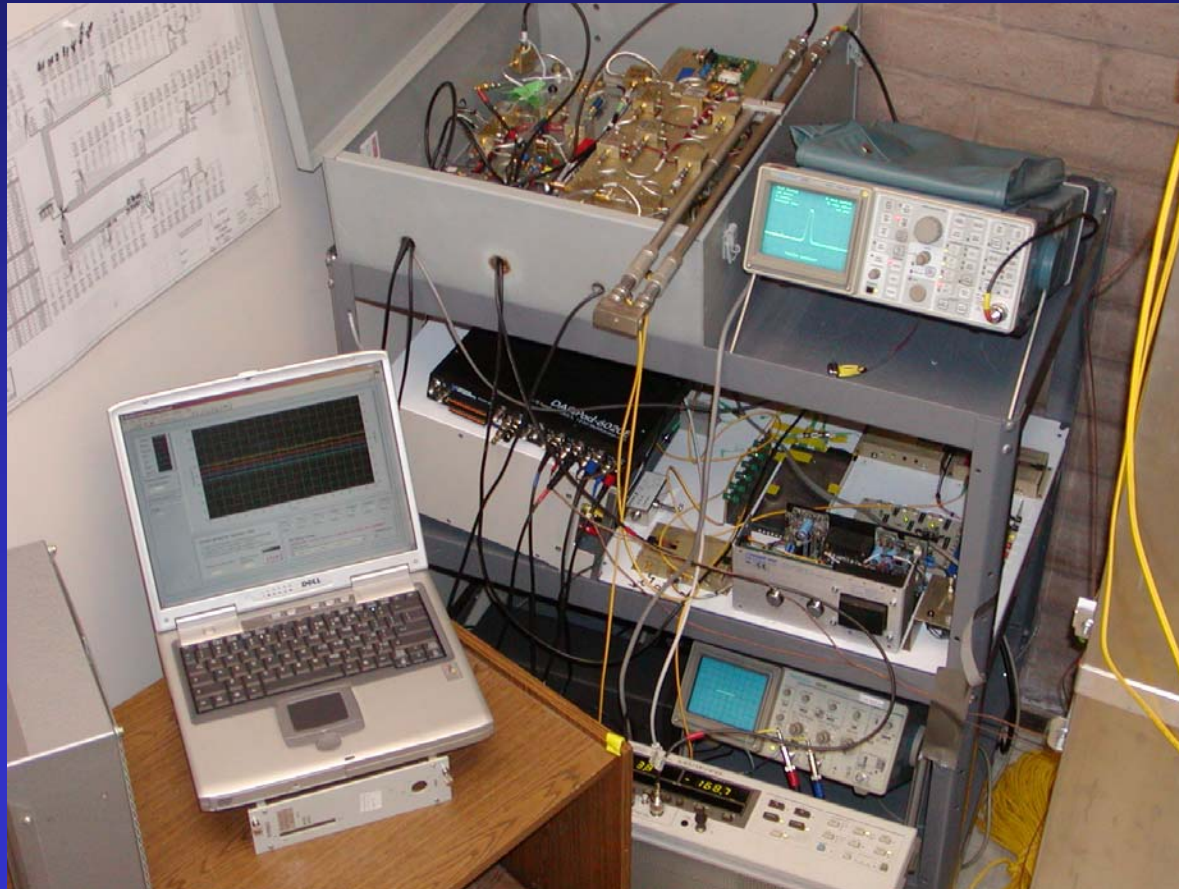
# Riser





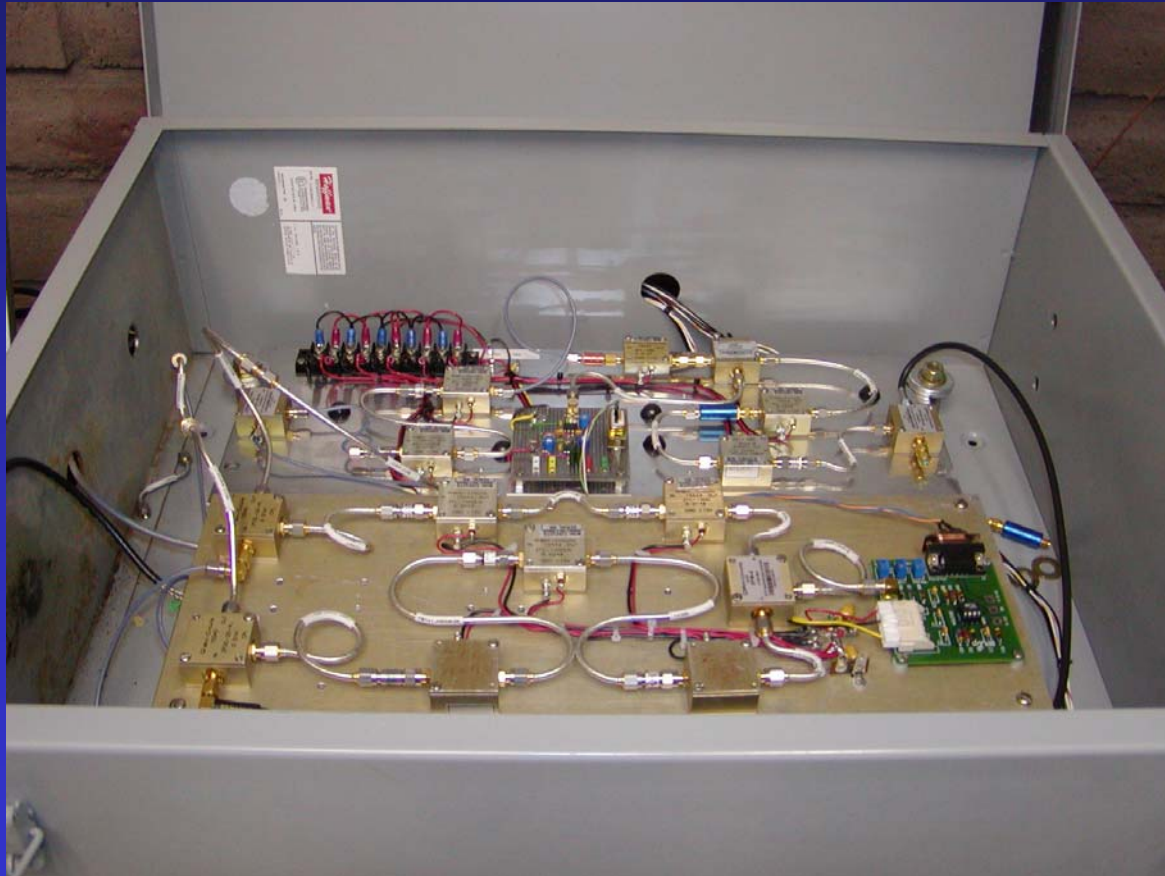


# RTP Test Hardware





# Analog Mixer as a Phase Detector





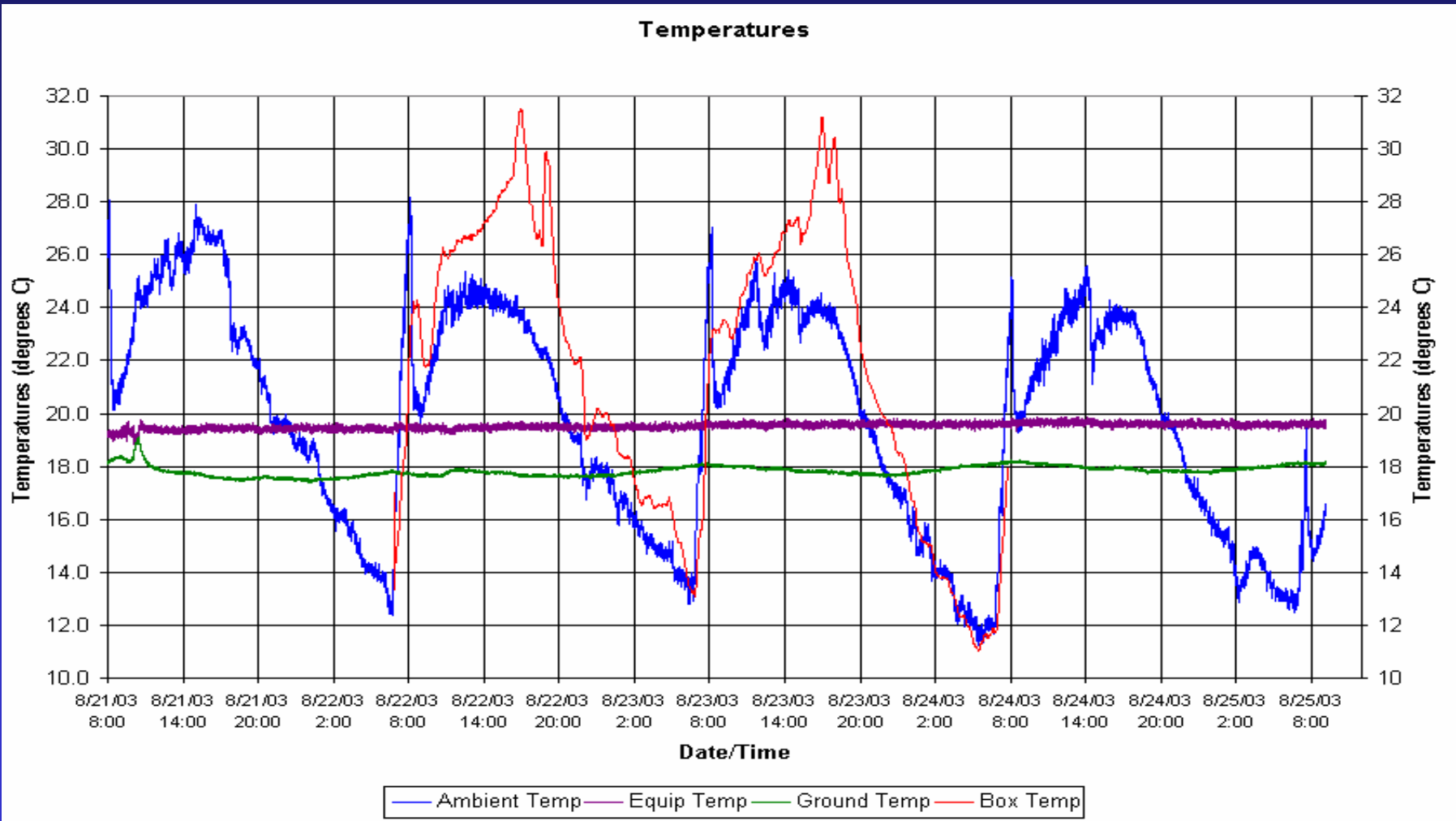
# Temperature Effects



- Seasonal
  - Phase angle changes slowly with ground temperature
- Diurnal
  - Sunrise and direct Sun issues



# Fiber Enclosure Temperature (Not Insulated)





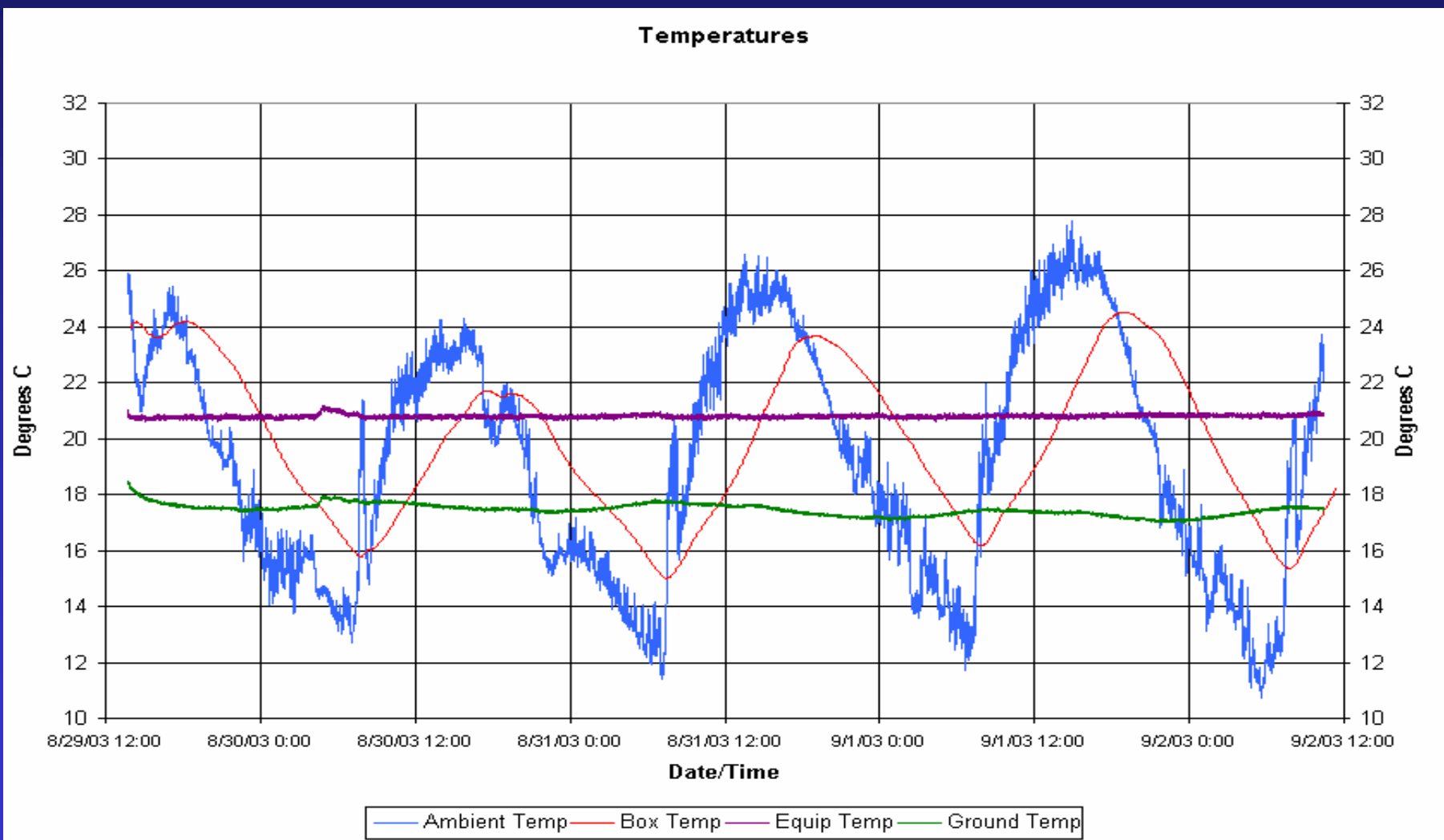
# Pad Box Insulation





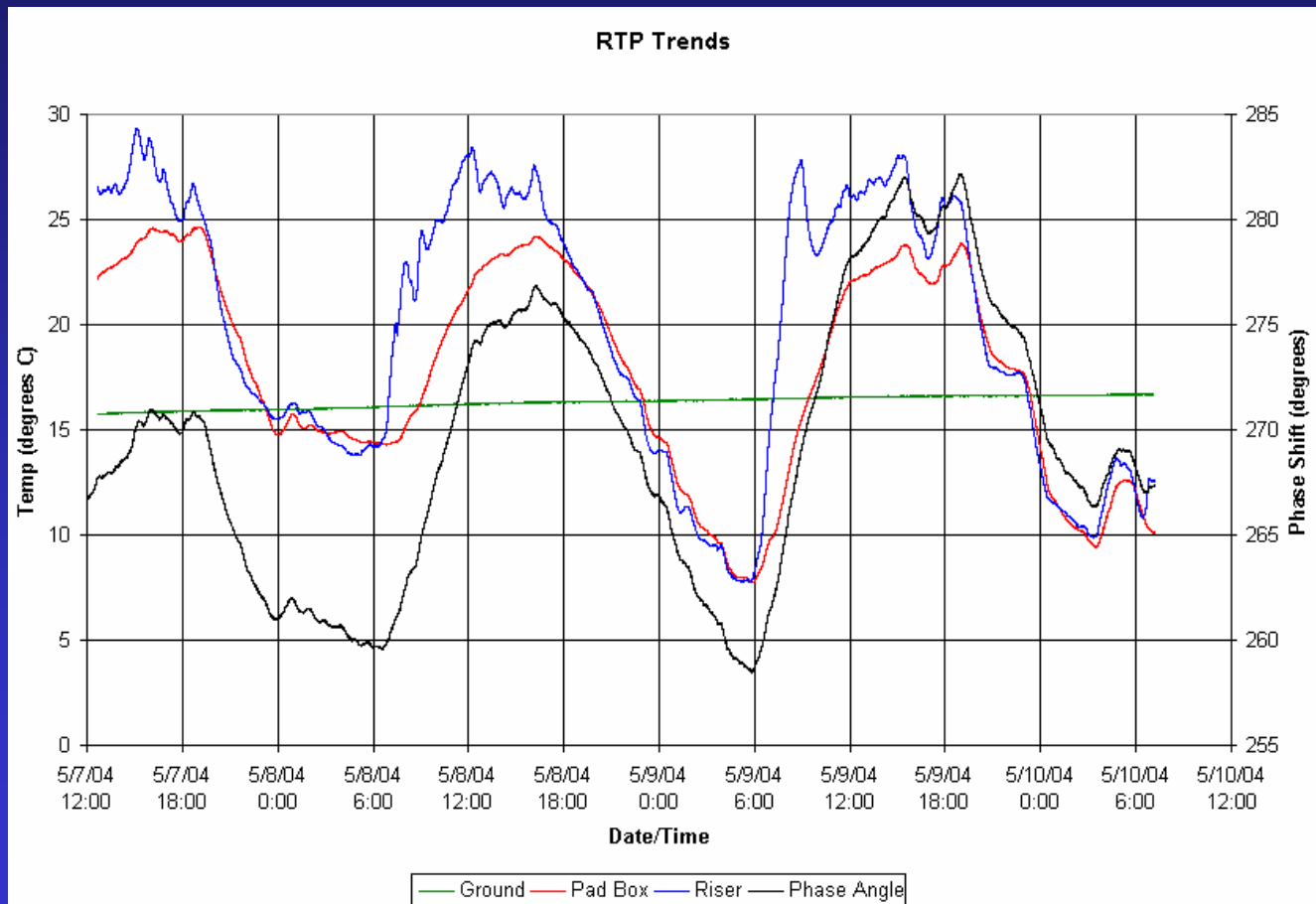


# Insulated Fiber Box Temperatures



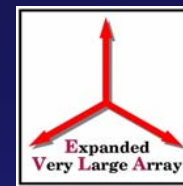


# Temperature Trends

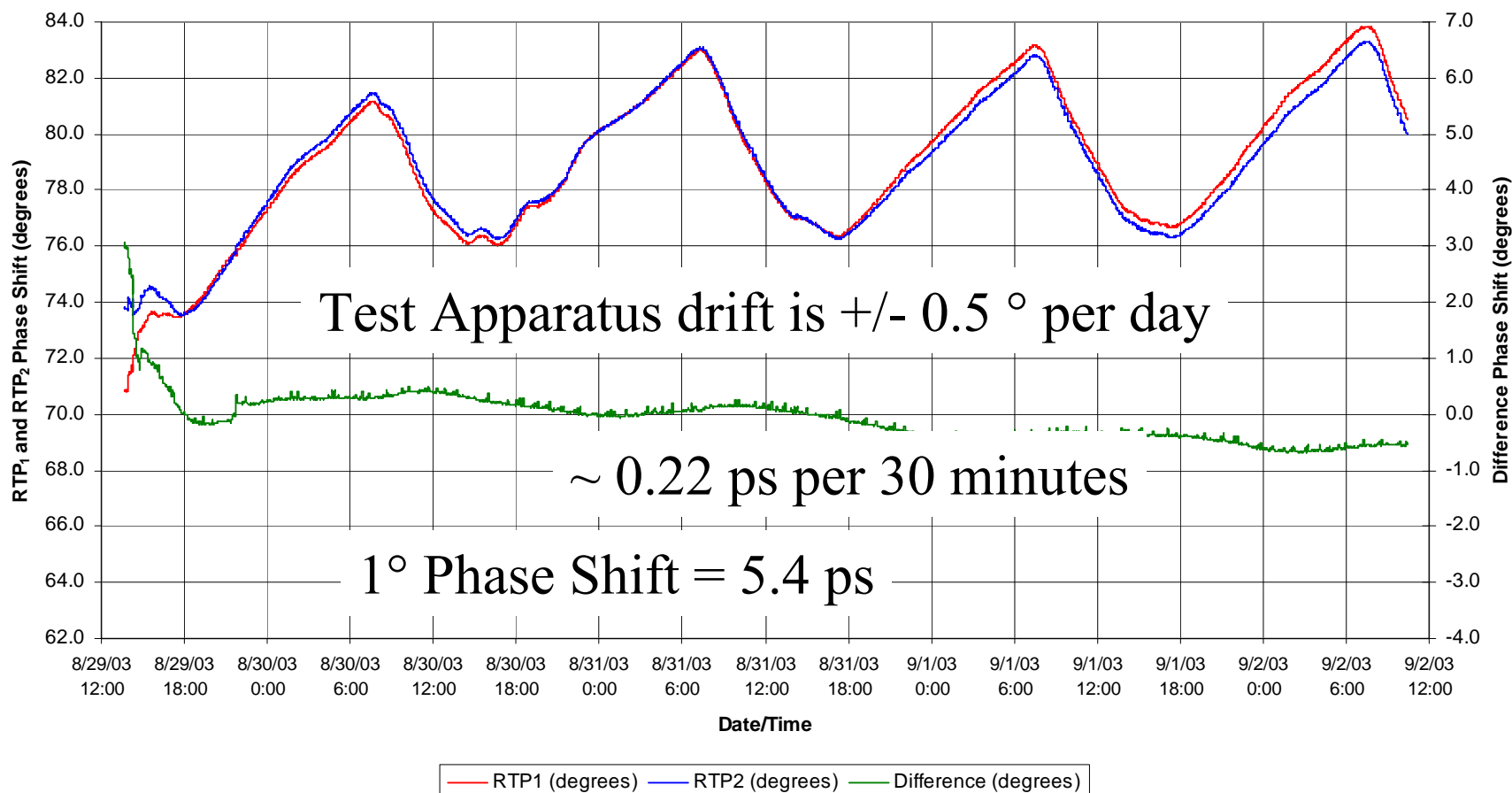




# Old 4-Day Stability Test



RTP<sub>1</sub> and RTP<sub>2</sub>





# Old Test Fixture



- The effects we tried to measure were smaller than the accuracy of the old test fixture.

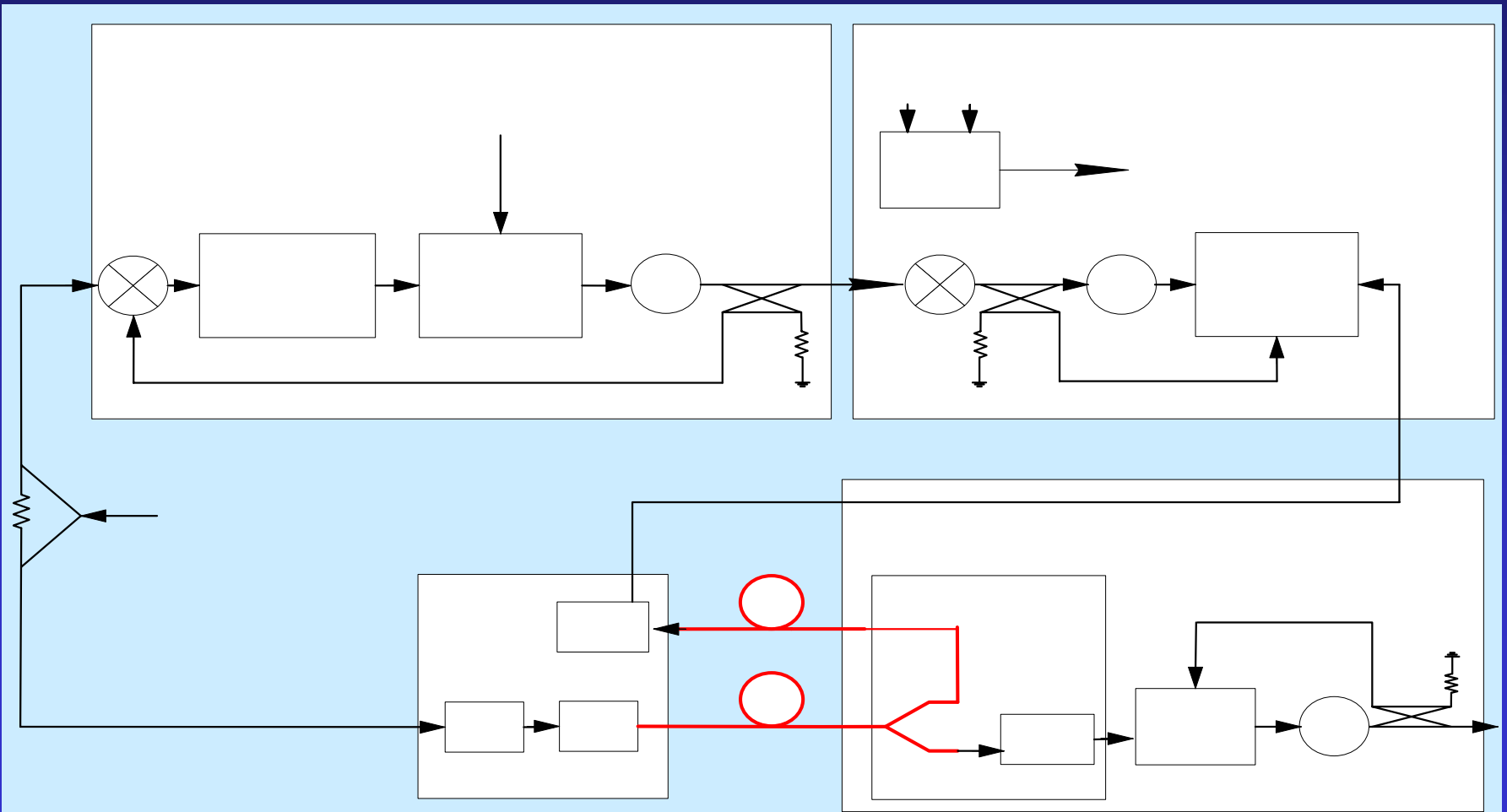
~ 0.5 degrees (2.7 ps) at 512 MHz

*“The Universe is full of Magical things,  
patiently waiting for our wits to grow sharper”*

*Eden Phillpots ~ 1900*

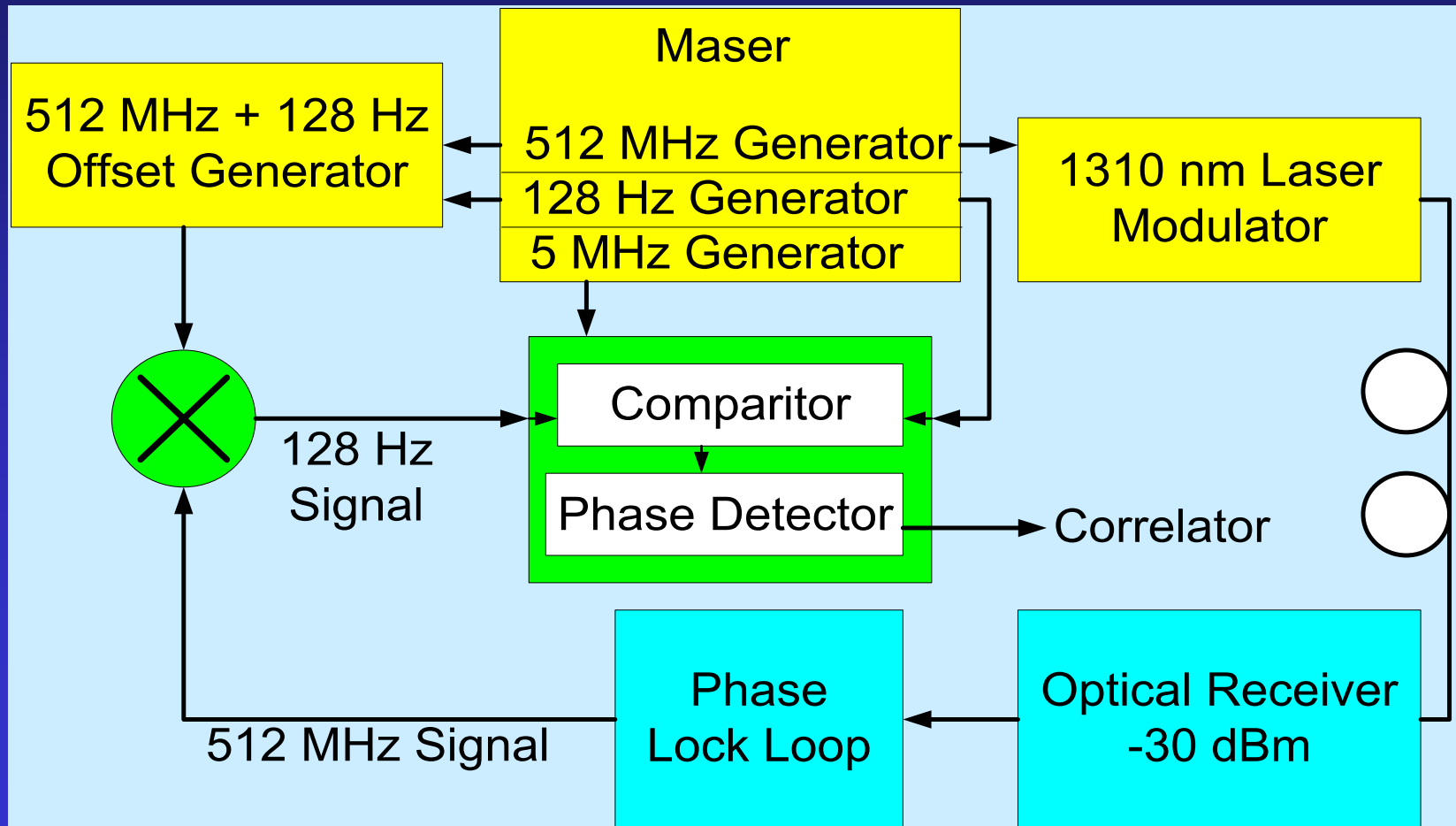


# New RTP Block Diagram



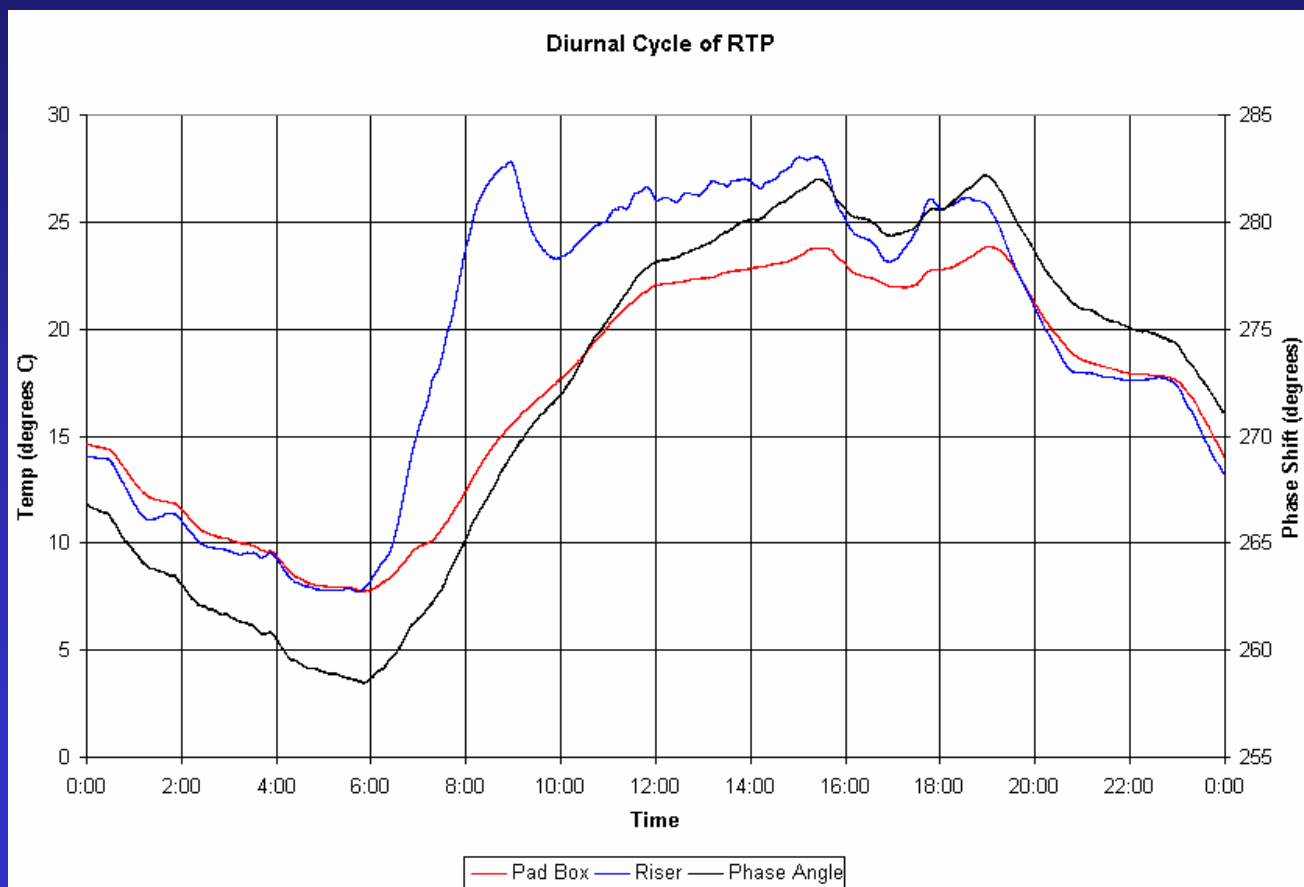
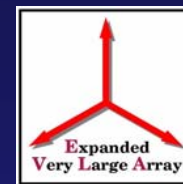


# New Round Trip Block Diagram



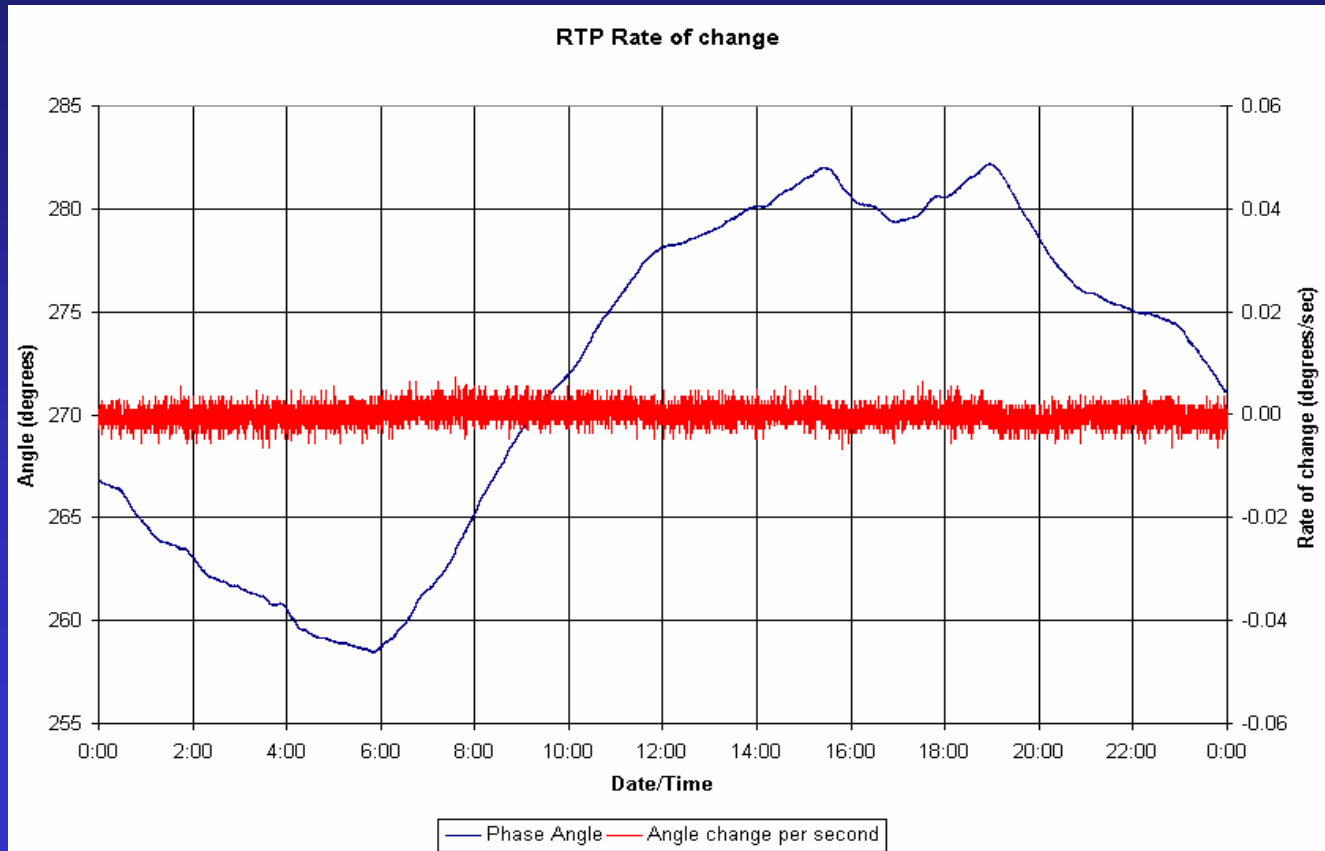


# Diurnal Effects Using New Equipment





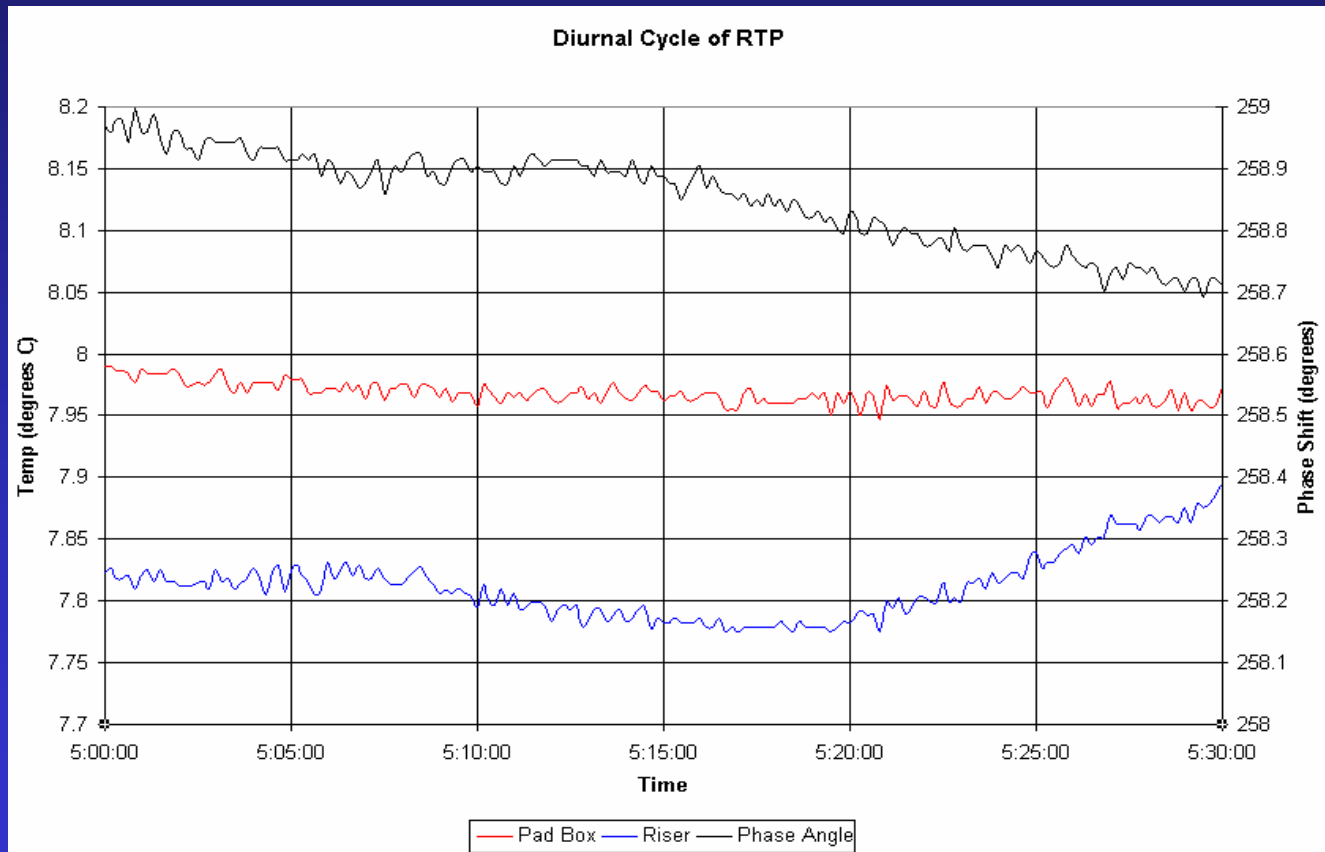
# Rate of Change of RTP New Equipment





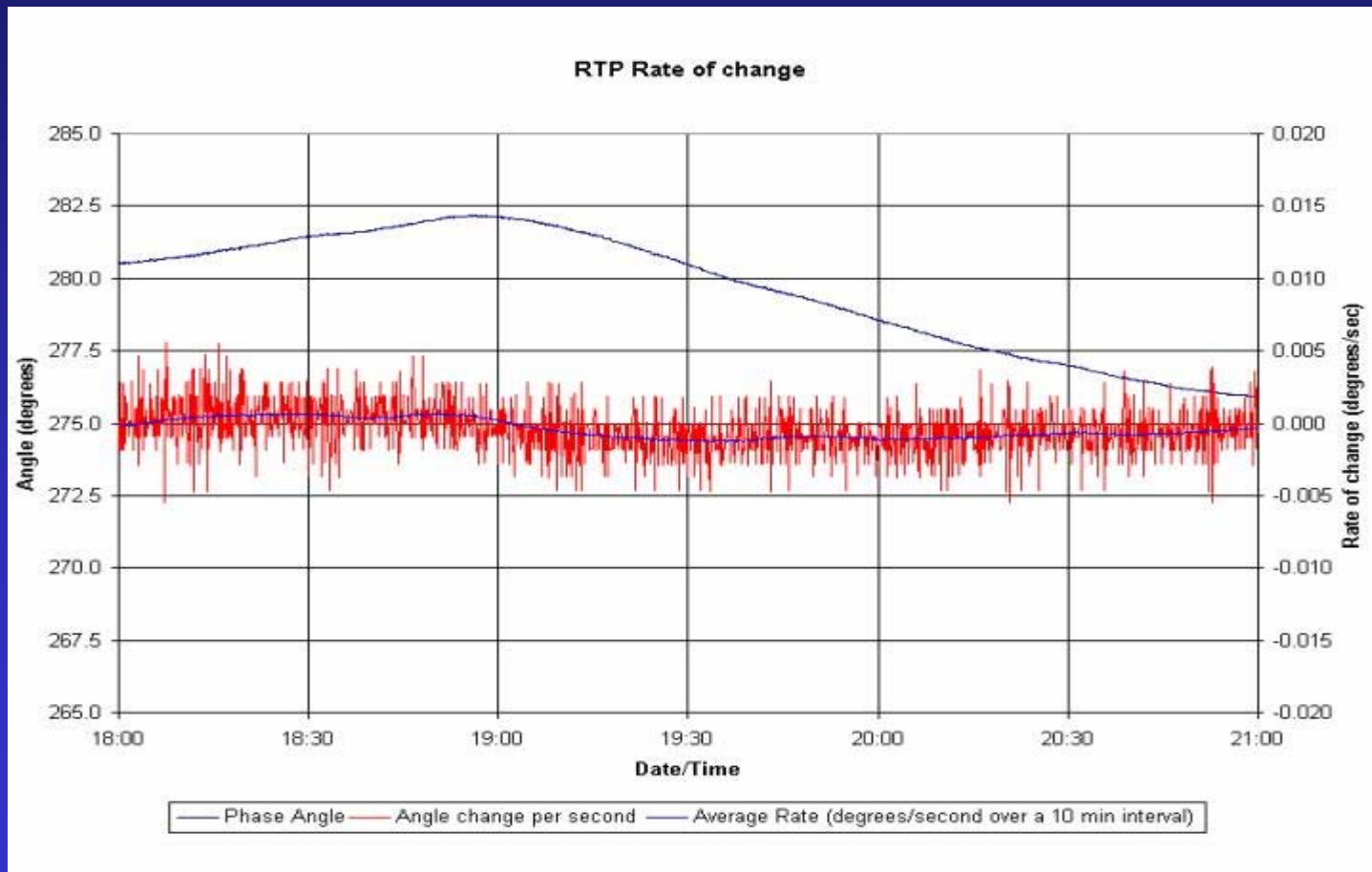


# Rate of Change of RTP





# Rate of Change of RTP

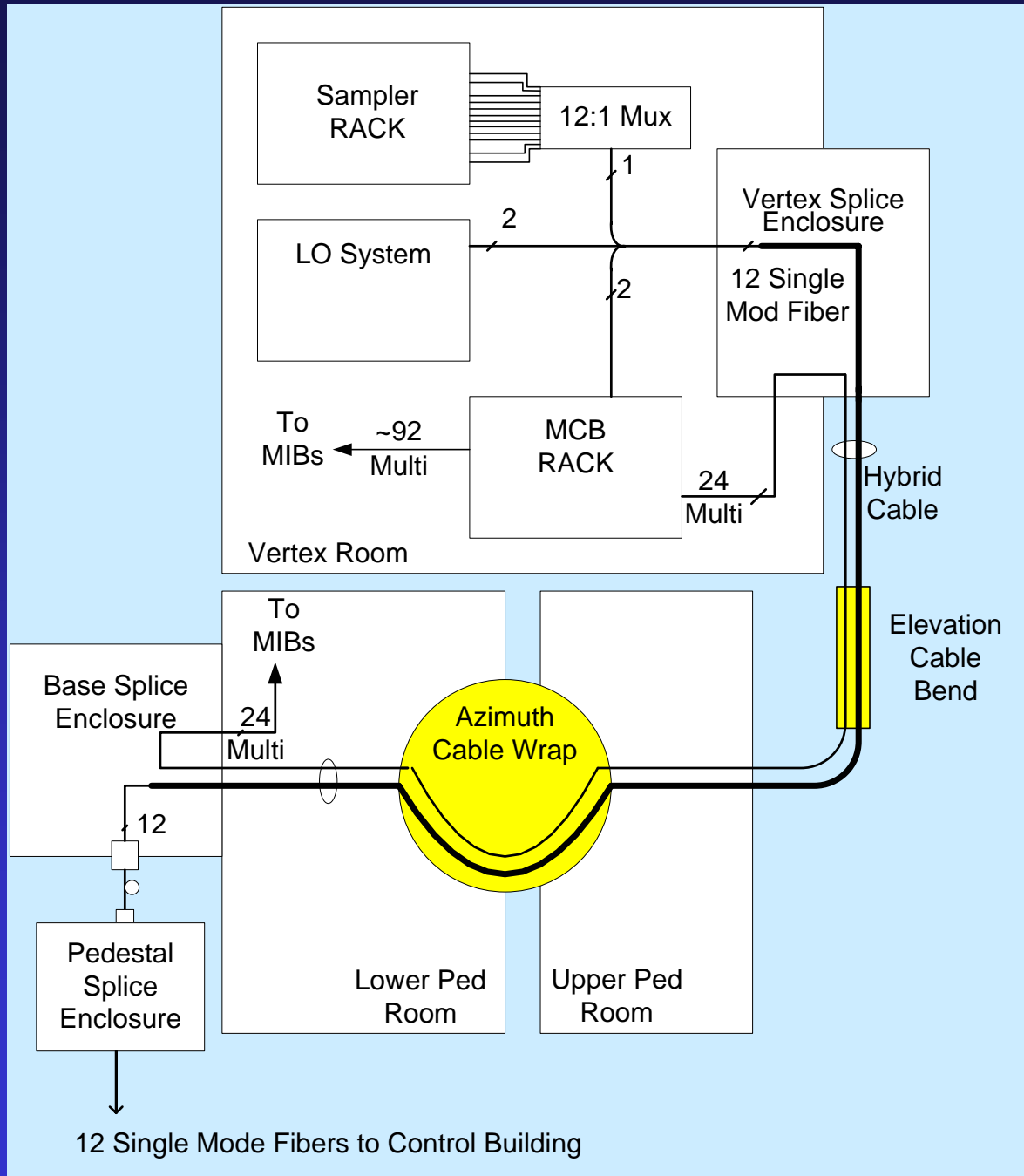




# Rate of Change of RTP

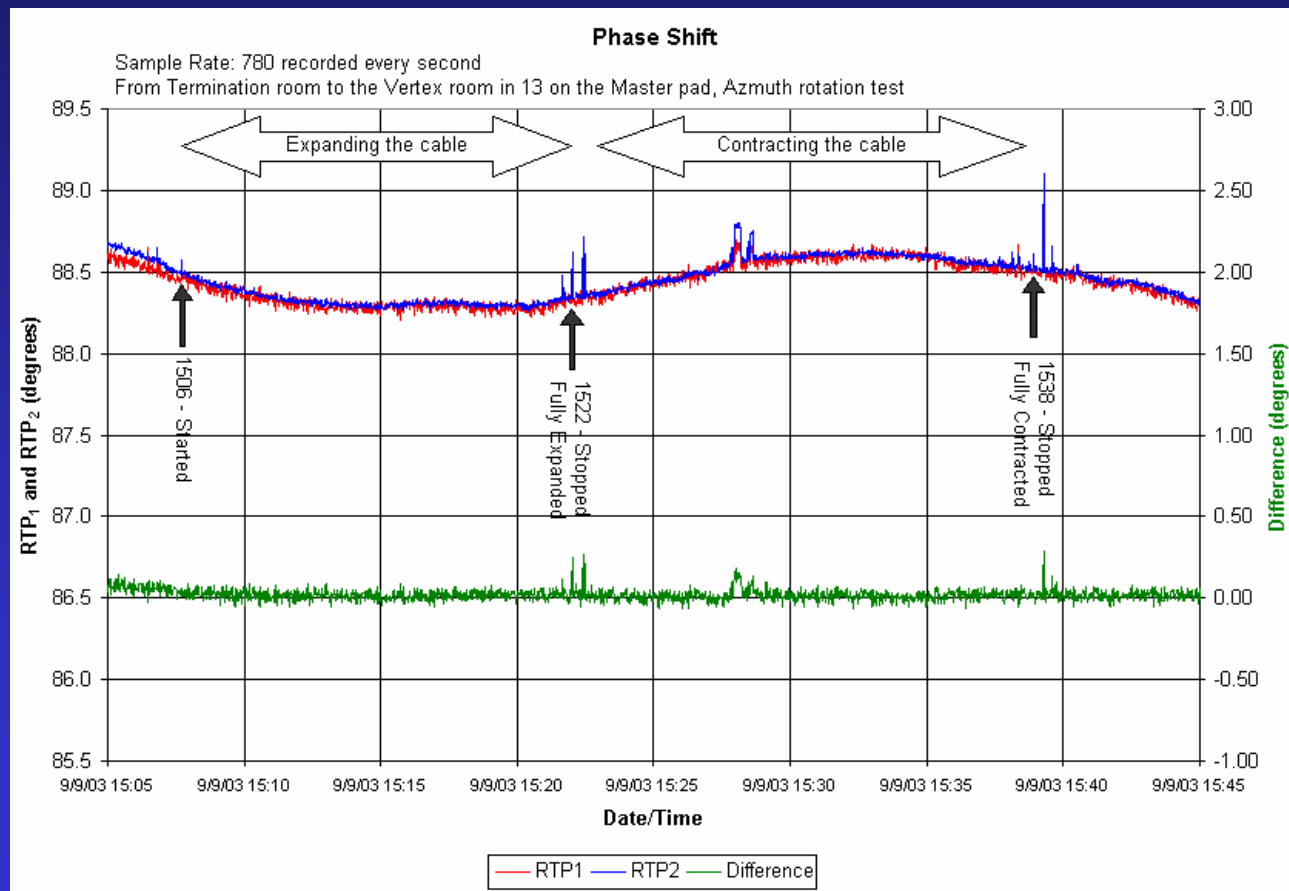


- Is noise limited - about  $0.04^\circ$  accuracy (0.22 ps)
- Goal: RTP measured and adjusted 10 times/second with an accuracy of  $0.01^\circ$  at 512 MHz



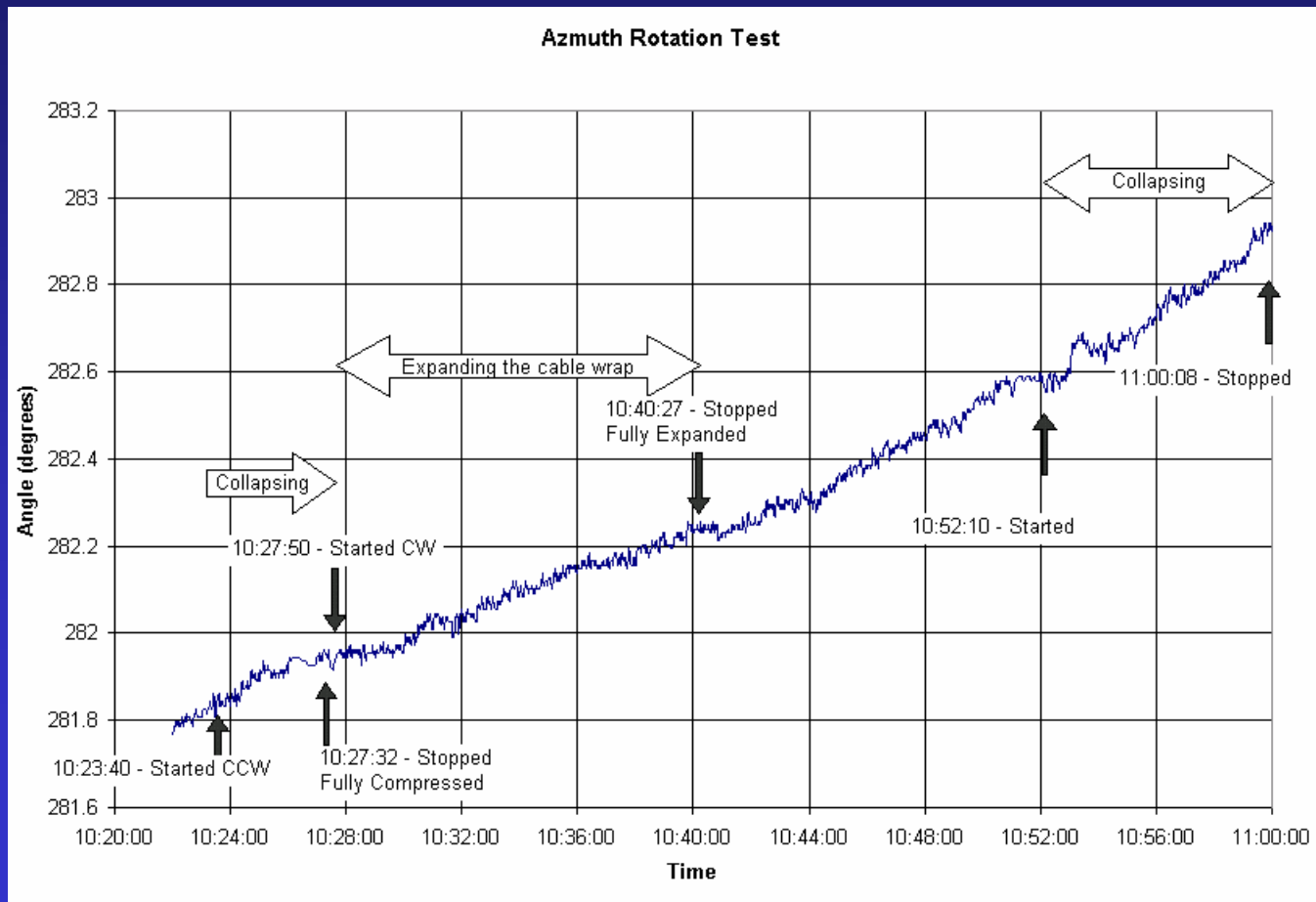


# Old Movement Data





# New Movement Data

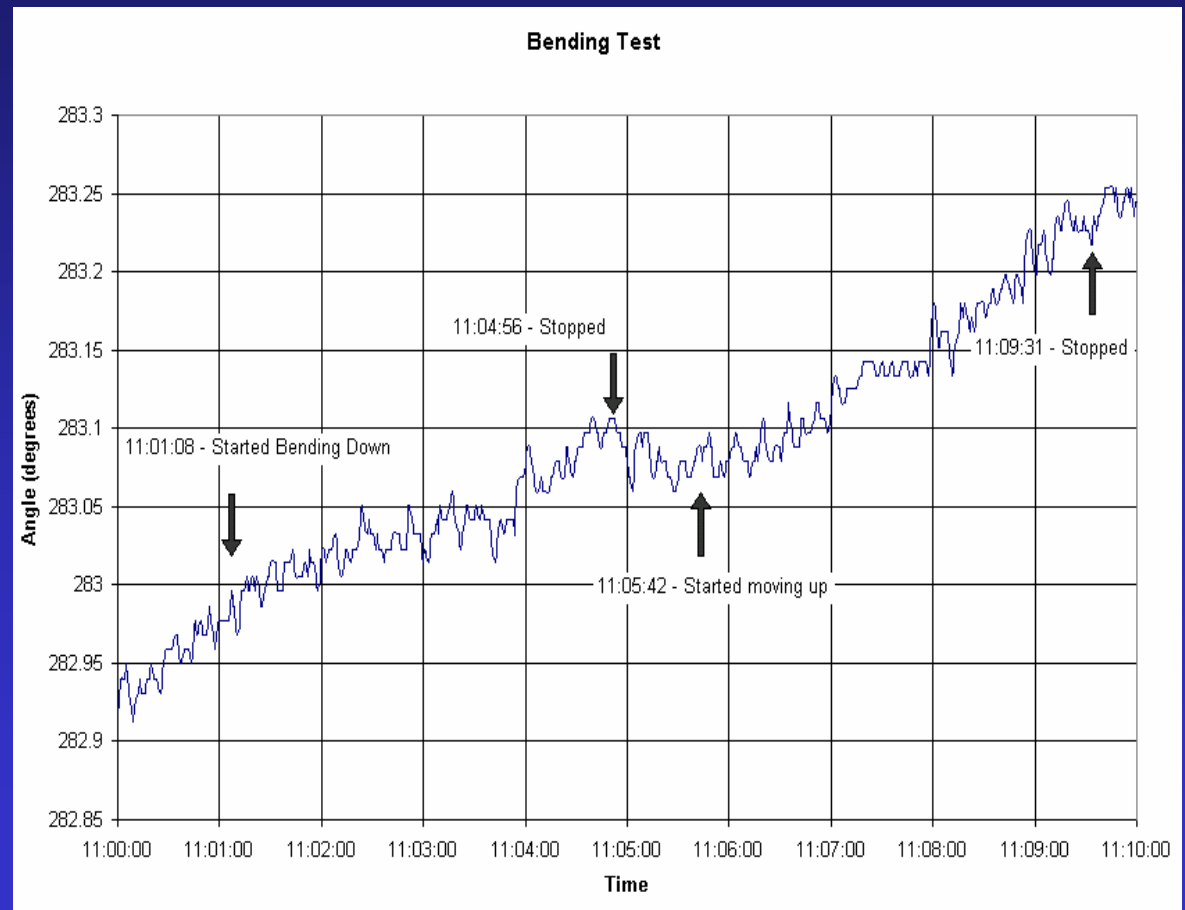




# New Movement Data



- **Test results:**  
**< 0.04 ° shift**  
**@ 512 MHz**
- **0.1° = .54 ps**





# Rate of Change of RTP



- The Round Trip Phase variation is less than the noise and/or accuracy of the measurement system.





# Conclusion



- The Diurnal Magnitude and rate of change of the phase shift is tolerable:

Estimated to be Less than 0.22 ps / Second

- The Magnitude Effects of the motion is smaller than the accuracy of the present equipment: Less than 0.22 ps

We need to determine the un-compensated effects



# What is Next?



- Obtain a better mixer
- Use an A/D to sample the 128 Hz signal
- FFT to determine the phase
- Take more Measurements



# LO Technical Requirements after all Round-Trip Corrections



- Short Term:  $< 0.5$  ps RMS per second
- Long Term:  $< 1.4$  ps per 30 minutes (0.4)  
~20 degrees at 40 GHz
- Delta Slope:  $< 0.2$  ps change per minute  
Over 30 minutes