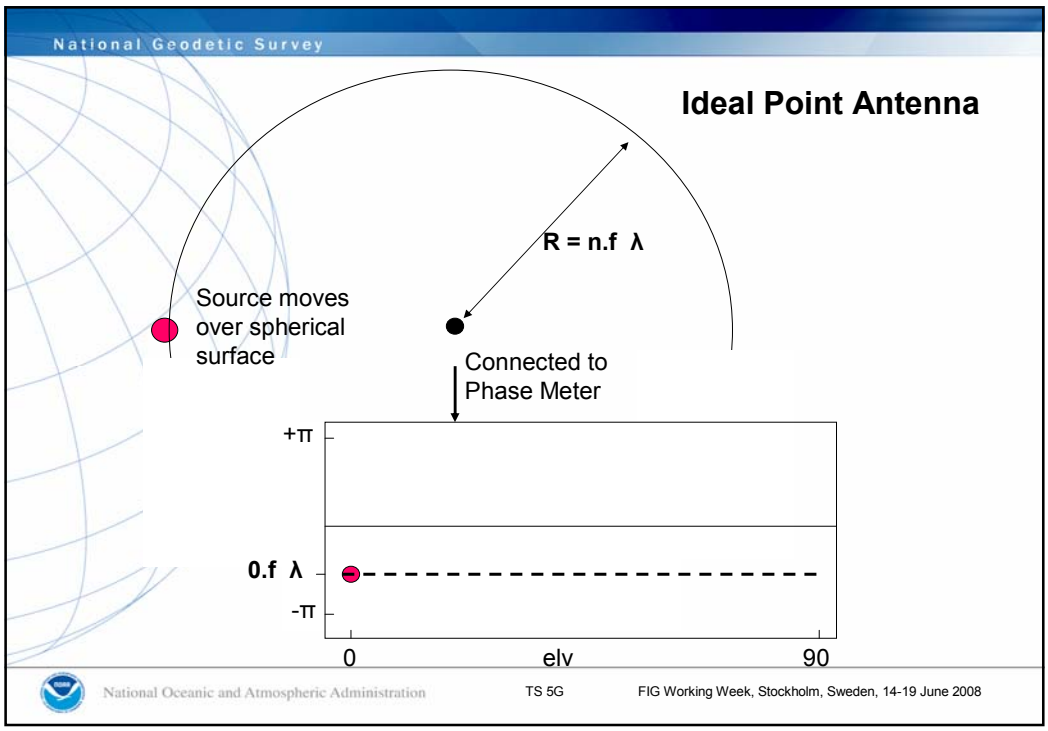
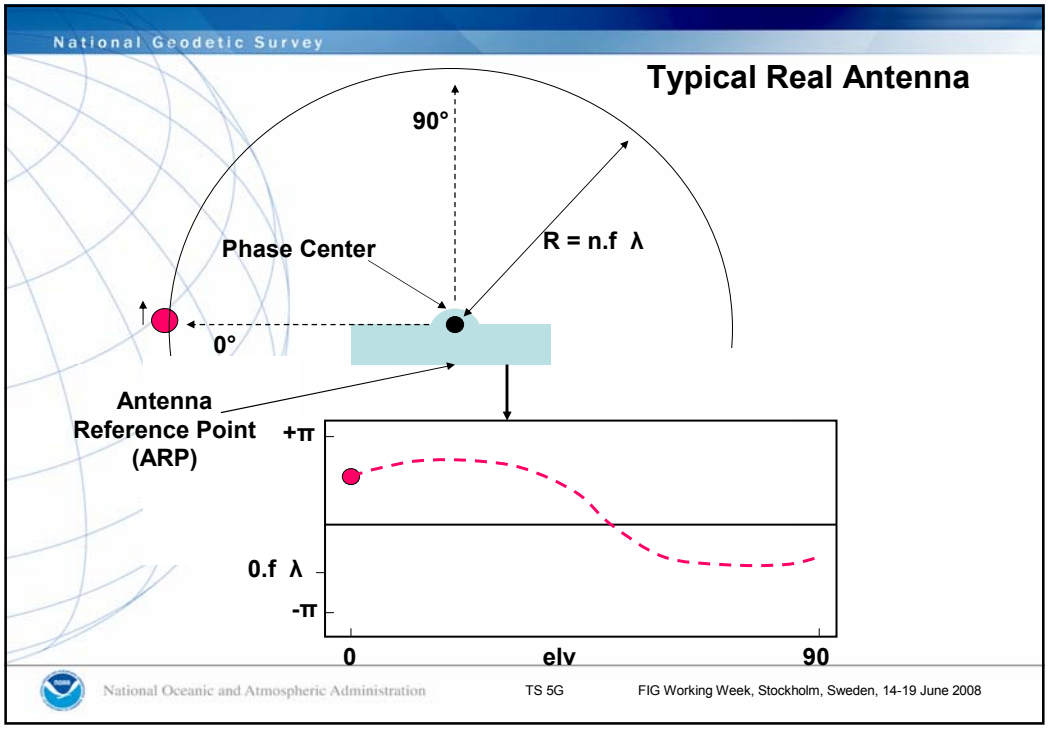
GPS ANTENNA CALIBRATION AT THE NATIONAL GEODETIC SURVEY

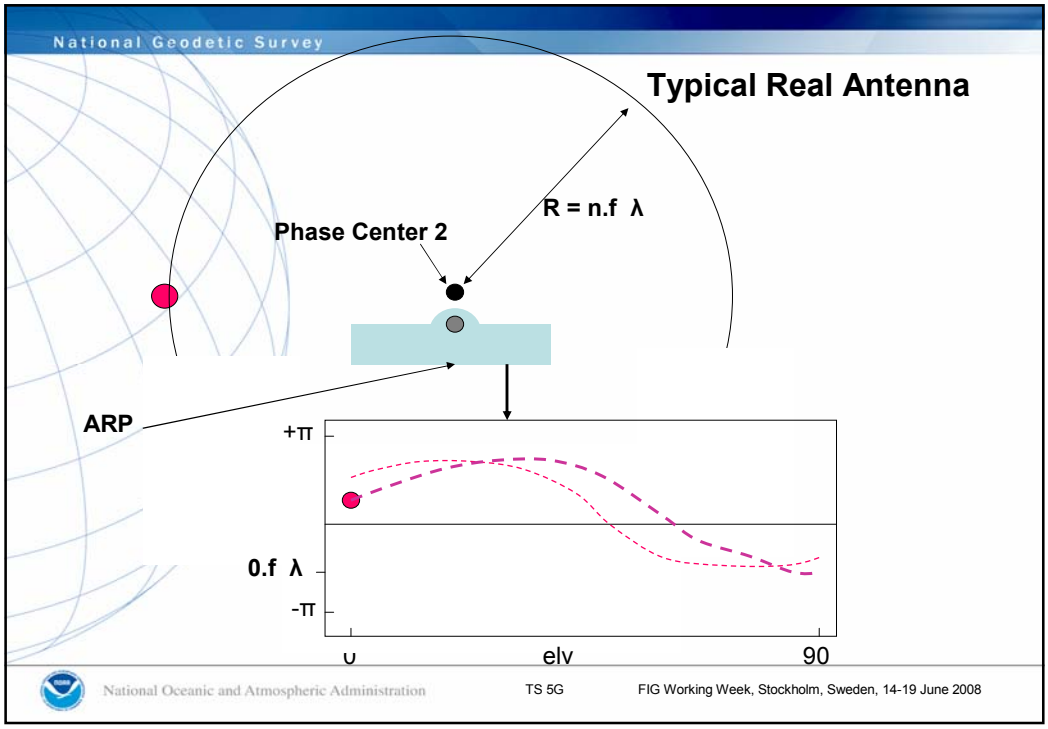
Gerald L. Mader & Neil D. Weston
Geosciences Research Division
National Geodetic Survey, NOAA
Silver Spring, MD. USA

Why GPS Antenna Calibration

- Goal is to determine GPS antenna characteristics which provide accurate geodetic positions.
- Initial questions
  - What is the location of the point being positioned?
  - What does the antenna contribute to the observed phase measurements?


National Geodetic Survey
Ideal Point Antenna
R = n.f λ
Source moves over spherical surface
Connected to Phase Meter
+π
0.f λ
-π
0
elv
90
National Oceanic and Atmospheric Administration
TS 5G
FIG Working Week, Stockholm, Sweden, 14-19 June 2008


National Geodetic Survey
Typical Real Antenna
90°
Phase Center
R = n.f λ
0°
Antenna Reference Point (ARP)
+π
0.f λ
-π
0
elv
90
National Oceanic and Atmospheric Administration
TS 5G
FIG Working Week, Stockholm, Sweden, 14-19 June 2008



The Antenna Models Show

- A phase center may vary and can be estimated
- An offset and phase center variation (PCV) must be applied to yield correct distance to the source
- Different phase centers, when corrected for offset and PCV give identical results
- There is no phase center for which PCV is zero – but can be minimized

Antenna Phase Center Variations (PCV)

- All real GPS antennas have a phase variation pattern
- These phase variations depend primarily on elevation
- Phase variations also depend on the physical components of the antenna and its environment
- Observed phase includes satellite phase and phase due to the local environment and GPS antenna

What's The Effect of PCV?

- Applies an elevation dependent phase variation to the observed phase data
  - Makes height sensitive to elevation angle
  - Looks like troposphere variation - leads to incorrect tropo scale factors and heights
  - Especially pronounced for mixed antenna baselines - 10 cm height errors are not unusual
  - Mixing antennas and having longer baselines demand good antenna calibrations

Why Do Antenna Calibrations?

- GPS determines position of antenna phase center
- Phase center must be related to physical point
- Phase center locations are not fixed
- Phase center locations depend on direction to satellite
- Phase center variation is different for each antenna type

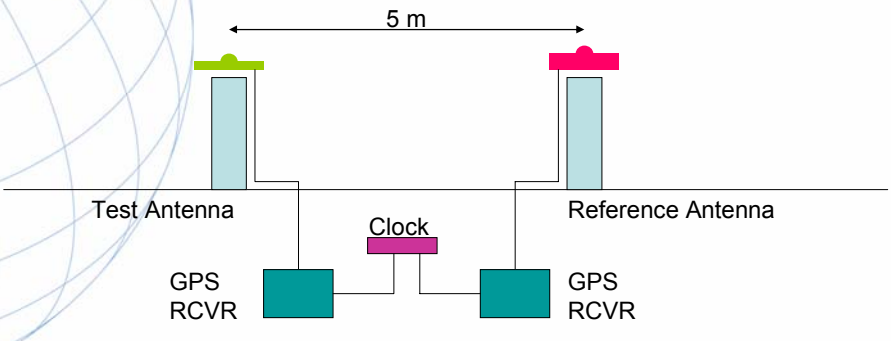
How Can We Do Antenna Calibrations In Practice?

- Could use Anechoic Chamber
  - Signals not reflected from another part of the chamber
  - Expensive, scheduling
- Use GPS constellation, but …
  - Orbits not spherical with respect to the antenna
  - Satellite/receiver clocks mask antenna effects
  - Propagation variation masks antenna effects

Use Differential GPS

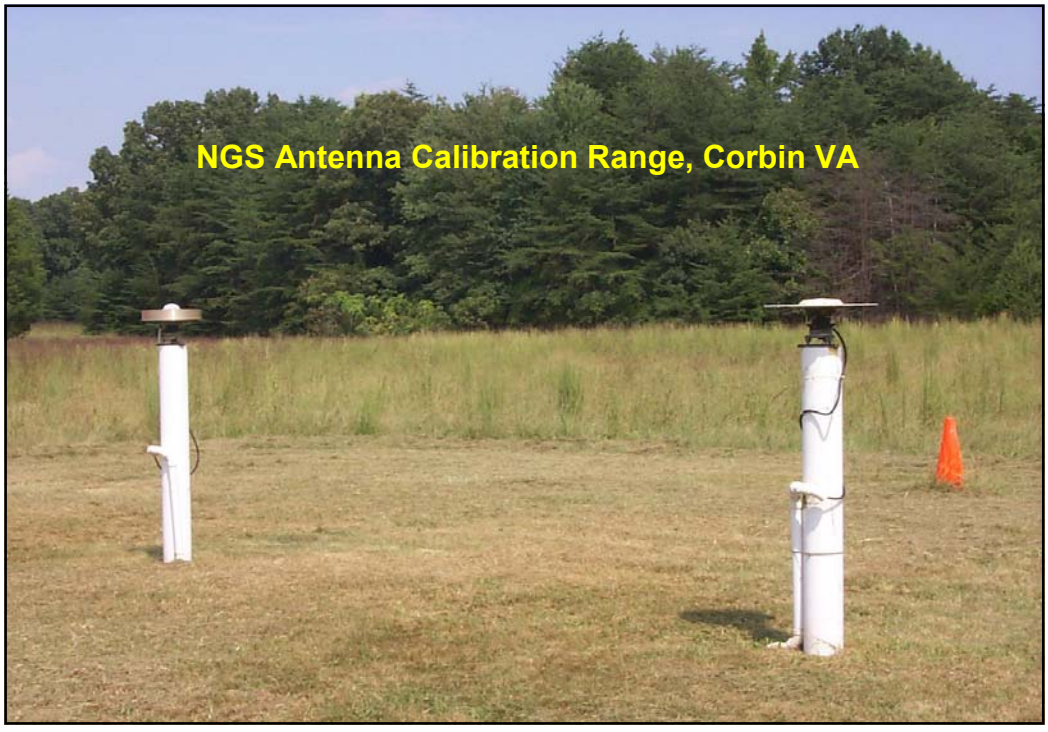
- Short baseline
- Standard reference antenna
- Relative calibrations
- Orbits errors cancel out
- Propagation cancels out
- Satellite clocks cancel out
- Receiver clocks solved for
- What's left over is antenna contribution

Calibration Technique

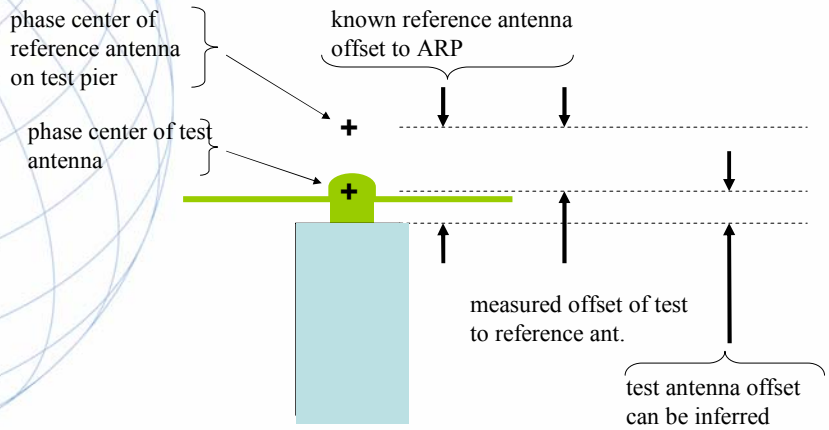


NGS Antenna Calibration

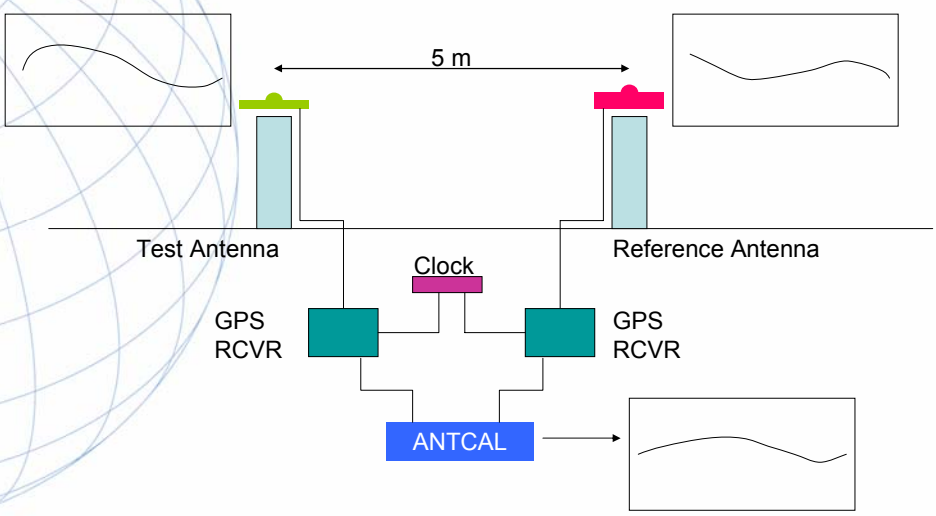
- Permanent antenna testing facility at Corbin, VA
- Dedicated equipment and personnel
- Produce reliable antenna phase offsets/patterns for ‘all’ GPS antennas
- Evaluate reliability and repeatability of antenna measurements
- Establish public distribution of ‘standard’ antenna calibrations



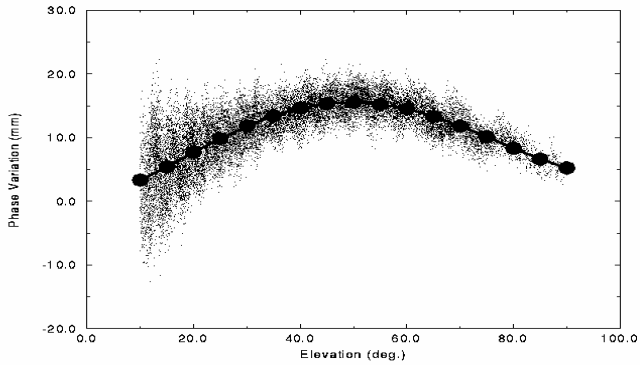
Calibration Technique



Calibration Technique



Phase Variation



$$\Delta = a_0 + a_1\,\theta + a_2\,\theta^2 + a_3\,\theta^3 + a_4\,\theta^4$$

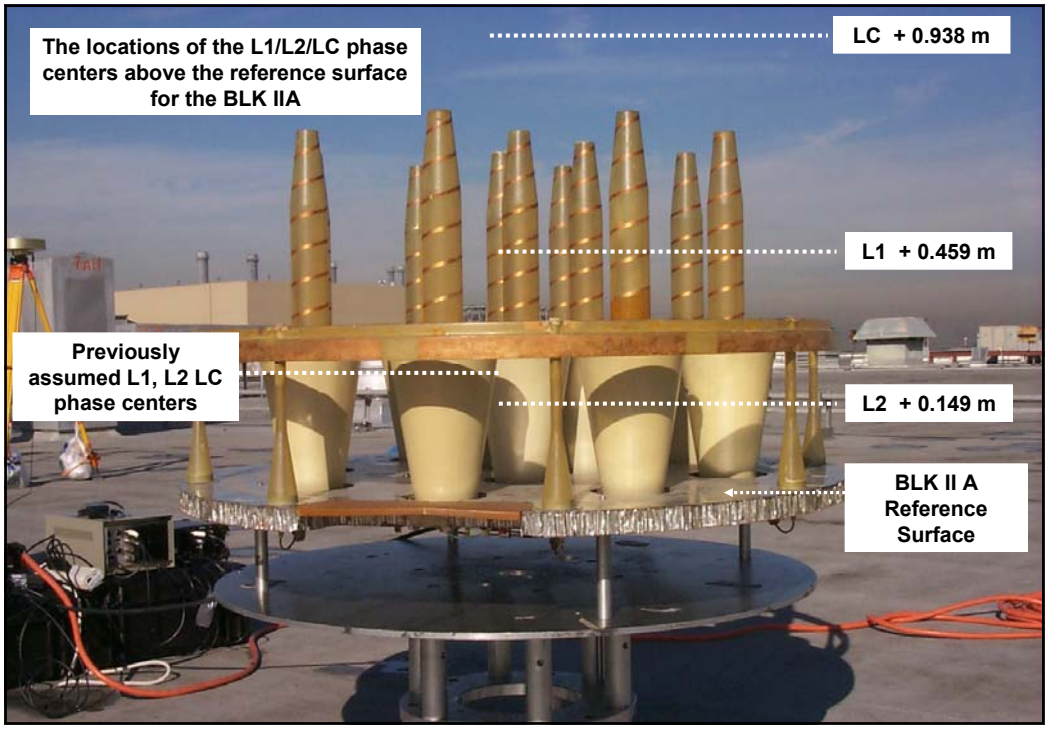
Sample Relative Antenna Pattern

```
ANTENNA ID     DESCRIPTION          DATA SOURCE (# OF TESTS) YR/MO/DY
                                   |AVE = # in average
 [north] [ east] [  up ]                    | L1 Offset (mm)
 [90] [85] [80] [75] [70] [65] [60] [55] [50] [45] | L1 Phase at
 [40] [35] [30] [25] [20] [15] [10] [ 5] [0]      | Elevation (mm)
 [north] [ east] [  up ]                    | L2 Offset (mm)
 [90] [85] [80] [75] [70] [65] [60] [55] [50] [45] | L2 Phase at
 [40] [35] [30] [25] [20] [15] [10] [ 5] [0]      | Elevation (mm)


  ASH700829.A1     SNOW Geodetic III 'Whopper' (USCG) +radome    NGS (  7) 97/10/27
        -1.2        -.8       87.7
     .0   1.6   3.5   5.5   7.5   9.3  10.7  11.7  12.2  12.1
    11.6  10.6   9.2   7.5   5.6   3.7   2.0    .0    .0
          .9      -1.6       59.8
     .0  -2.3  -3.9  -5.0  -5.7  -6.2  -6.5  -6.6  -6.7  -6.7
    -6.6  -6.3  -5.8  -5.0  -3.7  -1.7   1.0    .0    .0
```

National Geodetic Survey

Calibrating the L1 and L2 Phase Centers of a Block IIA Antenna



Thank you

Comments / Questions