SVN-49 Signal Anomaly

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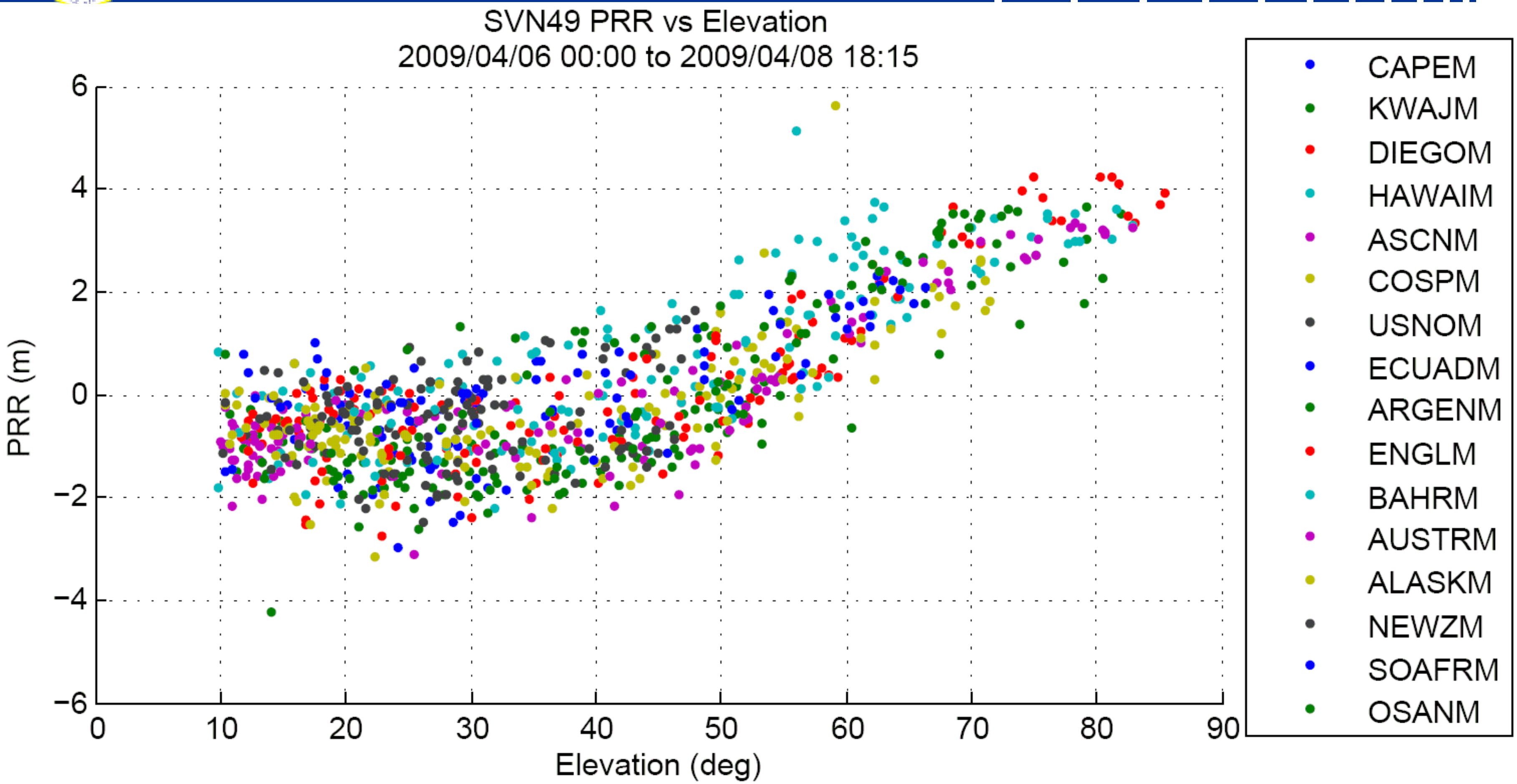
Introduction

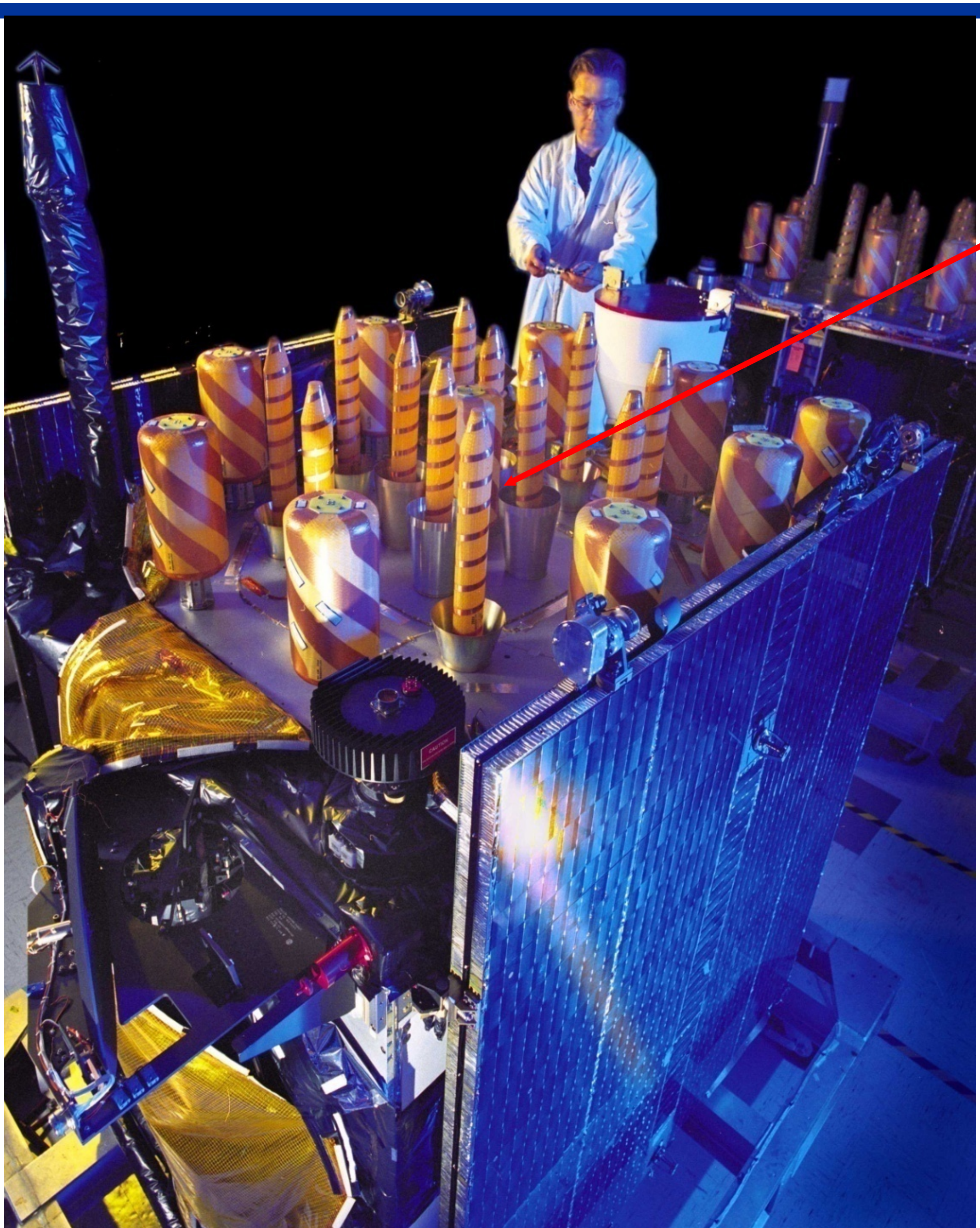
- **GPS IIR-20, SVN-49 (PRN 01), carries an L5 Demonstration Payload**
  - The L5 signal was not for operational use
  - The intent was to “bring L5 into use” for ITU purposes
- **The demonstration payload made use of an Auxiliary Payload port on the spacecraft**
- **No impact on the L1 and L2 signals was intended or expected**
- **However, 2SOPS and Aerospace reported unusually high and elevation angle dependent Pseudo Range Residuals (PRR) from the monitor stations**

Pseudorange Residuals



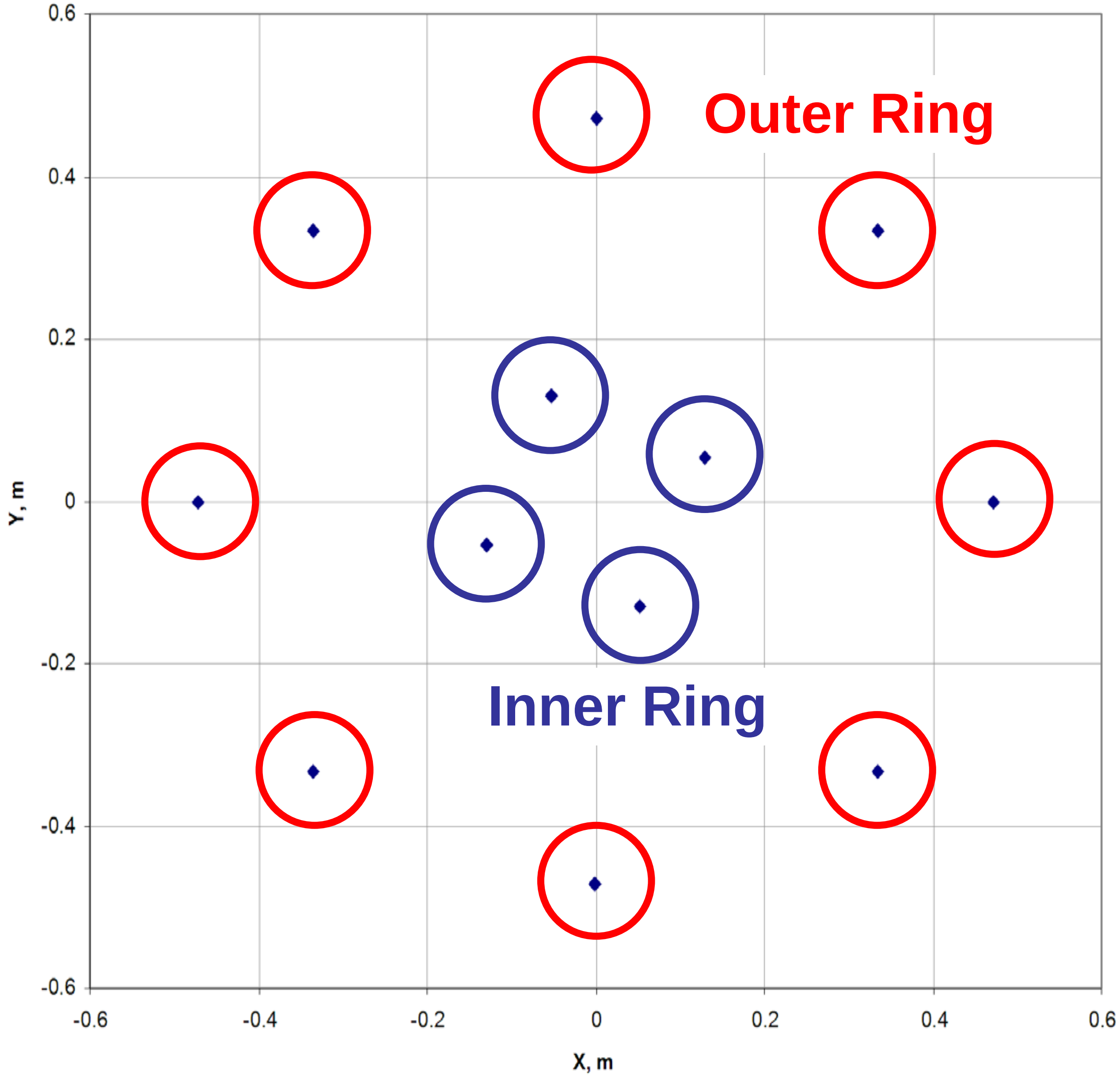
- Ionospheric refraction corrected pseudoranges
- Relative to a “best fit” orbit determined early in the test program
- Roughly a 4+ meter spread from 10 to 80 degrees

GPS IIR Antenna Farm

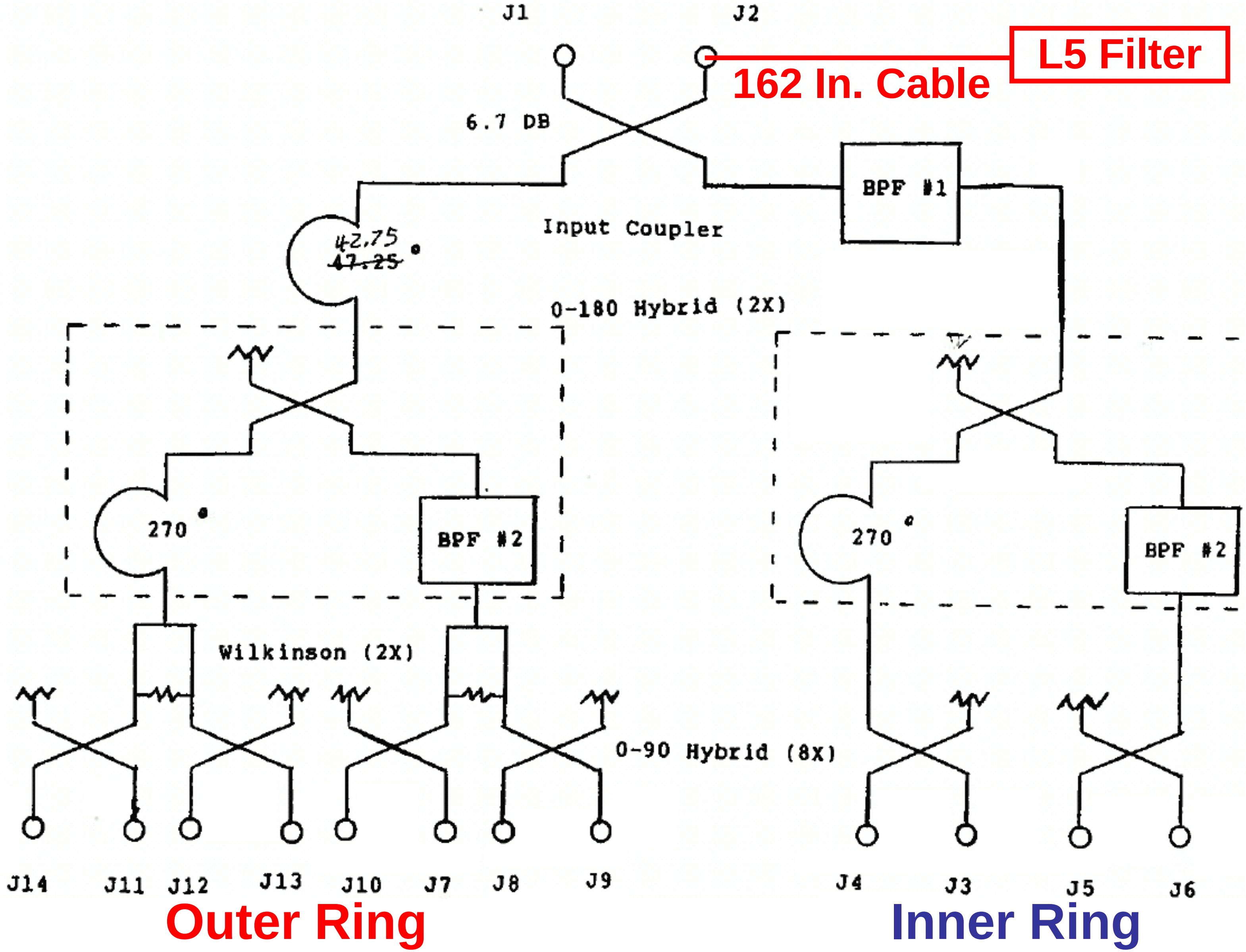


L-Band Antenna Array with 12 Helical Antennas

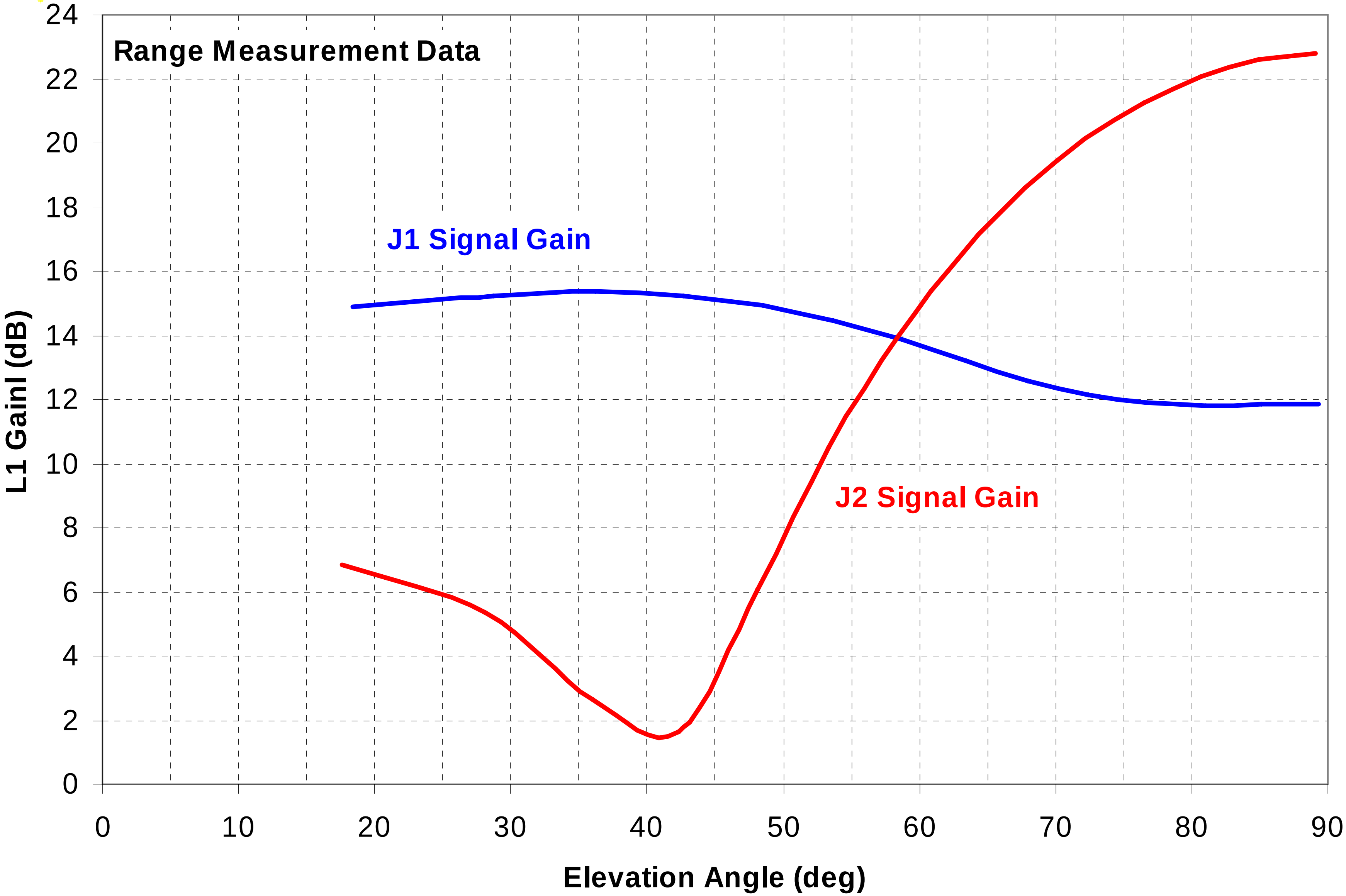
L-Band Antenna Element Locations



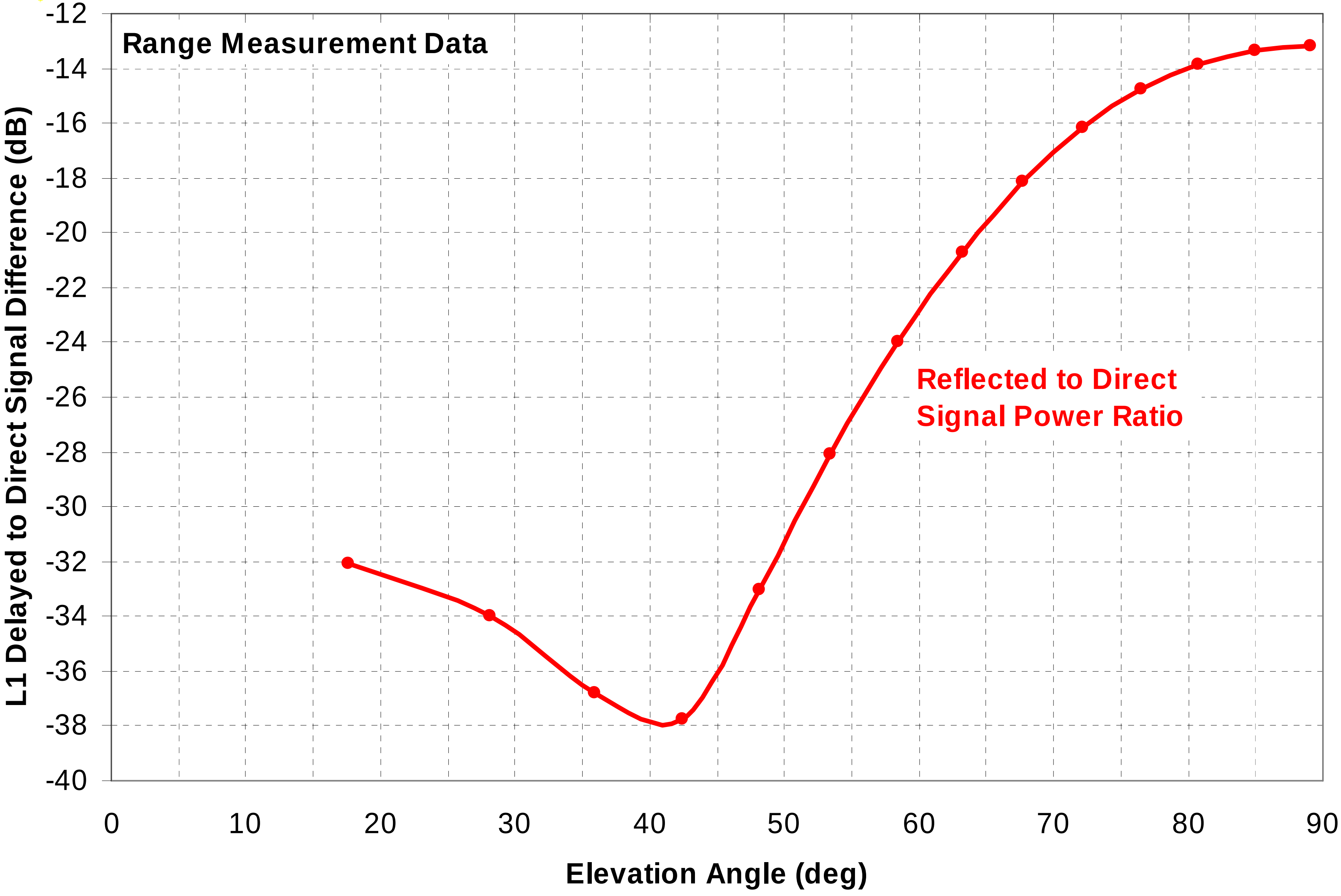
Antenna Coupler Network



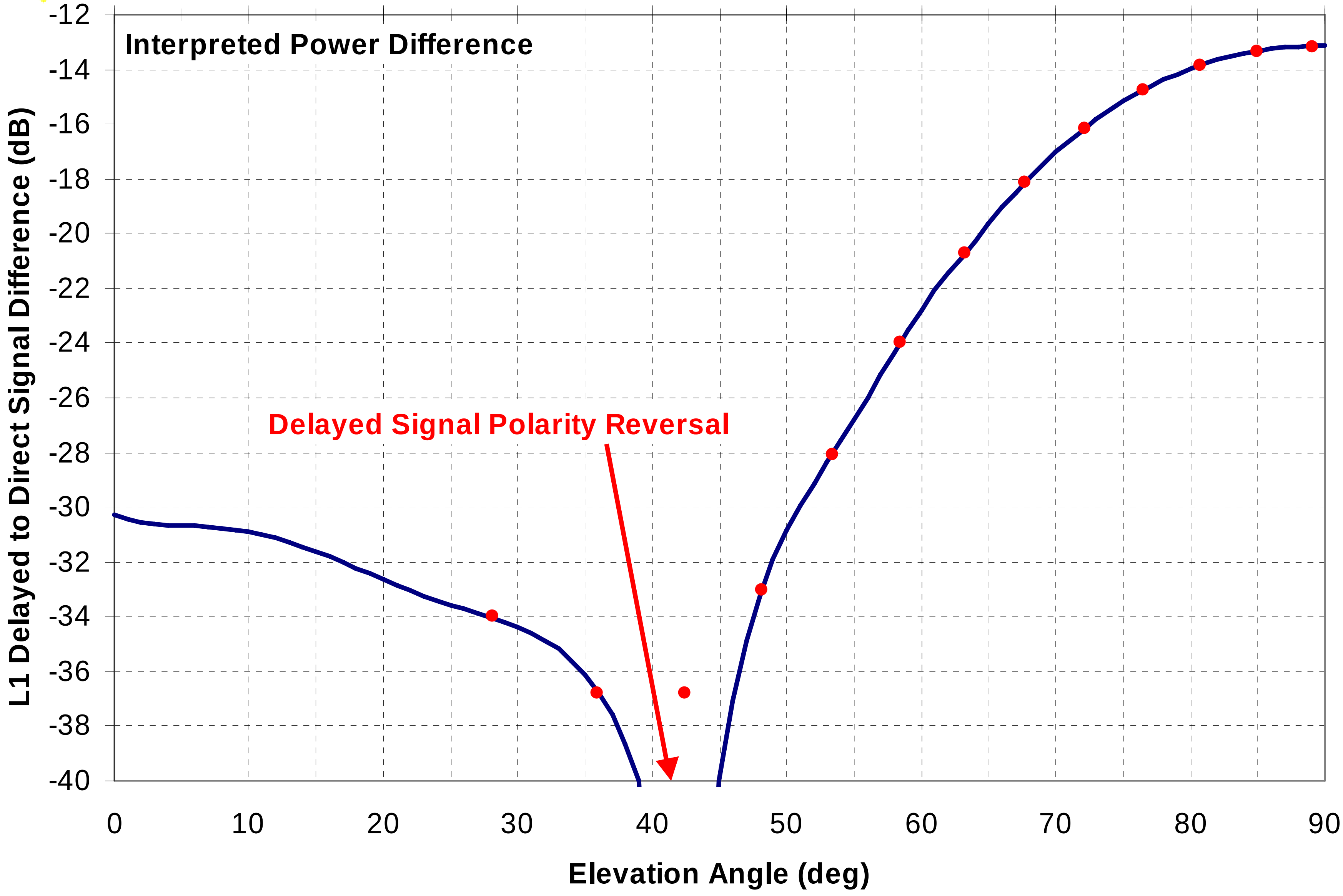
J1 and J2 Antenna Patterns at L1



Reflected Relative to Direct L1 Signal Power

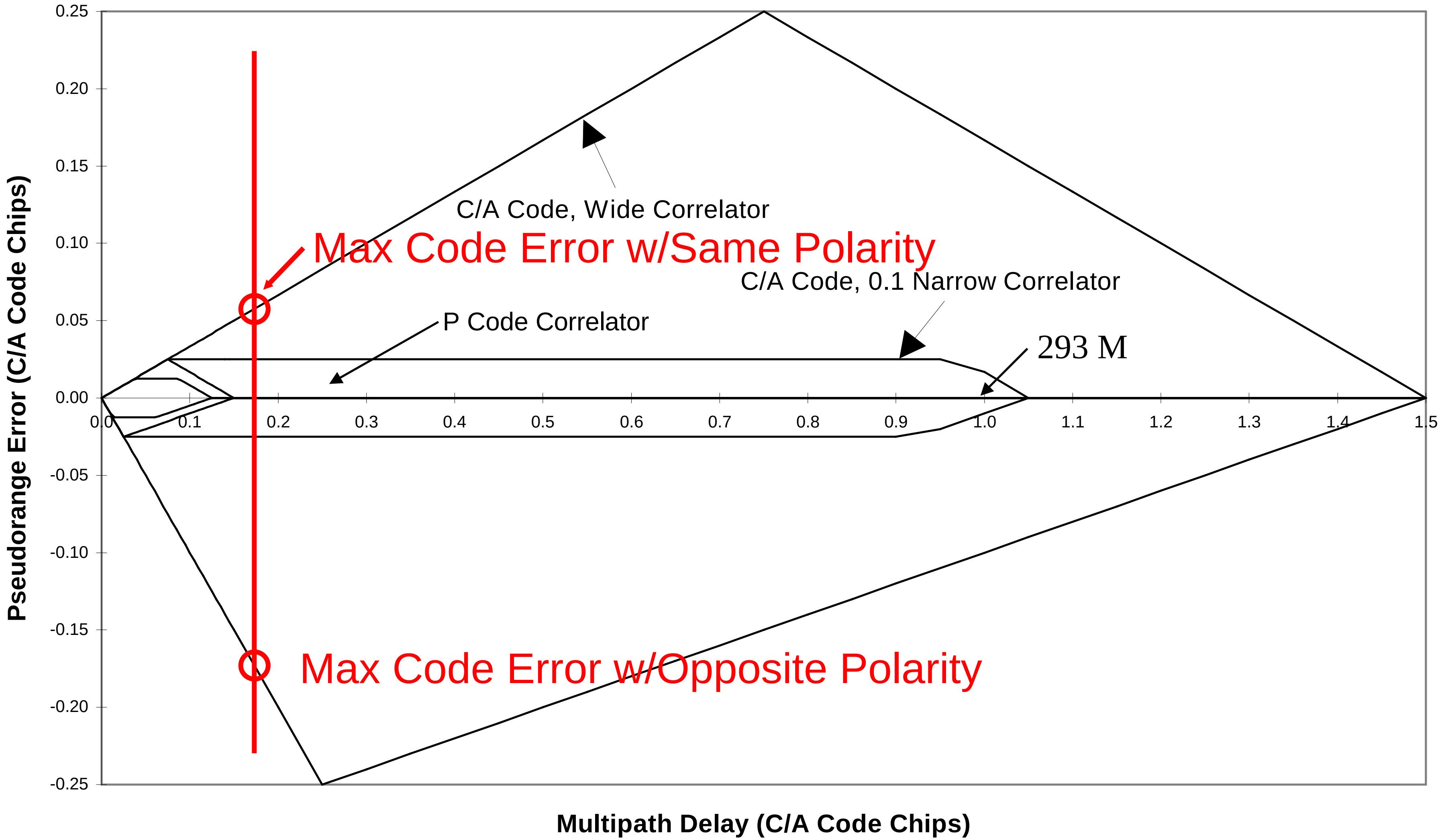


Model of L1 Signal Difference



Early Minus Late Tracking

Effect of Half Voltage Amplitude Multipath Signal - C/A Code Scale



Ionospheric Refraction Calculation

$$L1/L2 = 1575.42/1227.6 = 77/60$$

$$77^2 = 5929$$

$$60^2 = 3600$$

$$77^2 - 60^2 = 2329$$

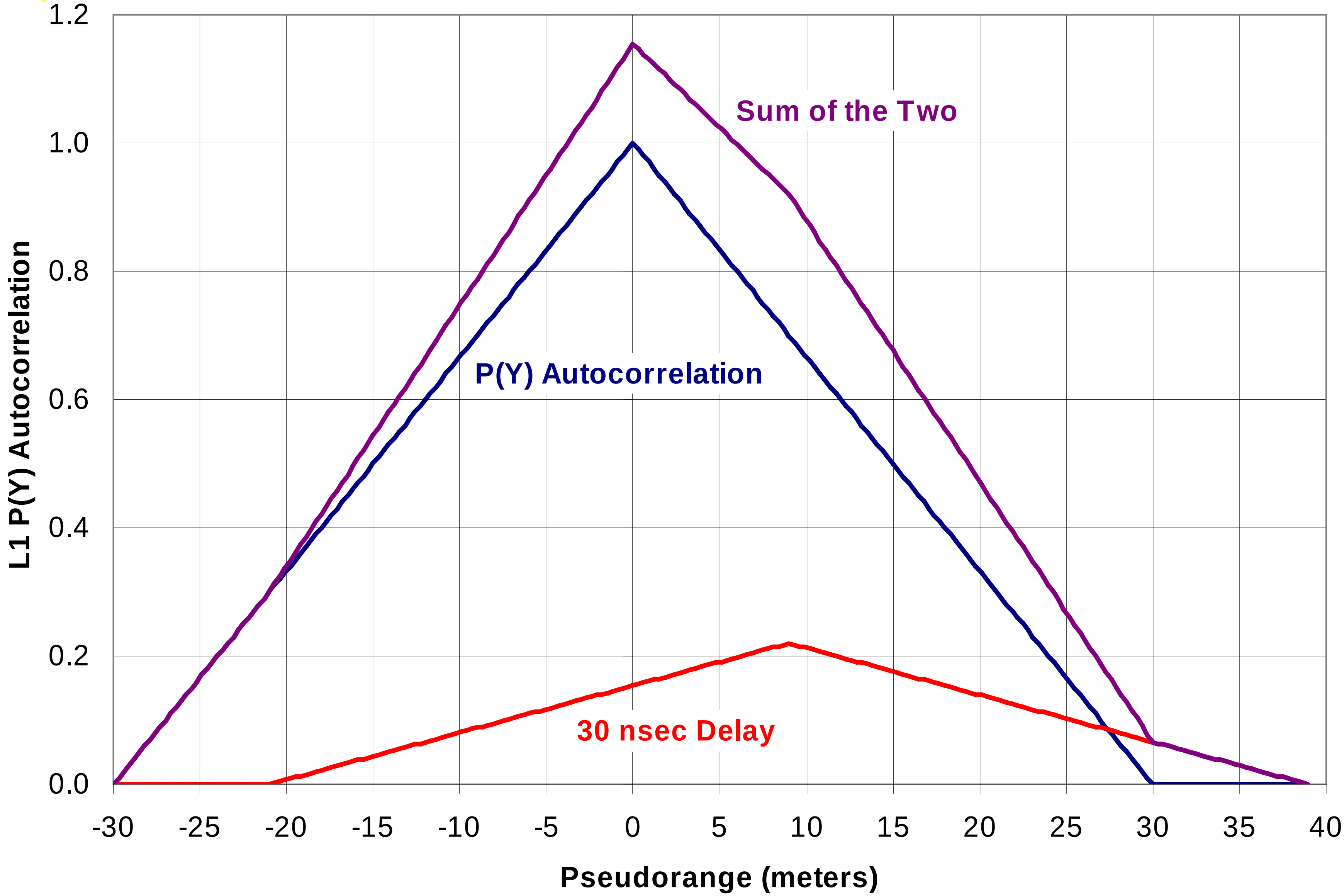
$$PR = (PR_{L1} \cdot 77^2 - PR_{L2} \cdot 60^2)/(77^2 - 60^2)$$

$$PR \approx 2.55 PR_{L1} - 1.55 PR_{L2}$$

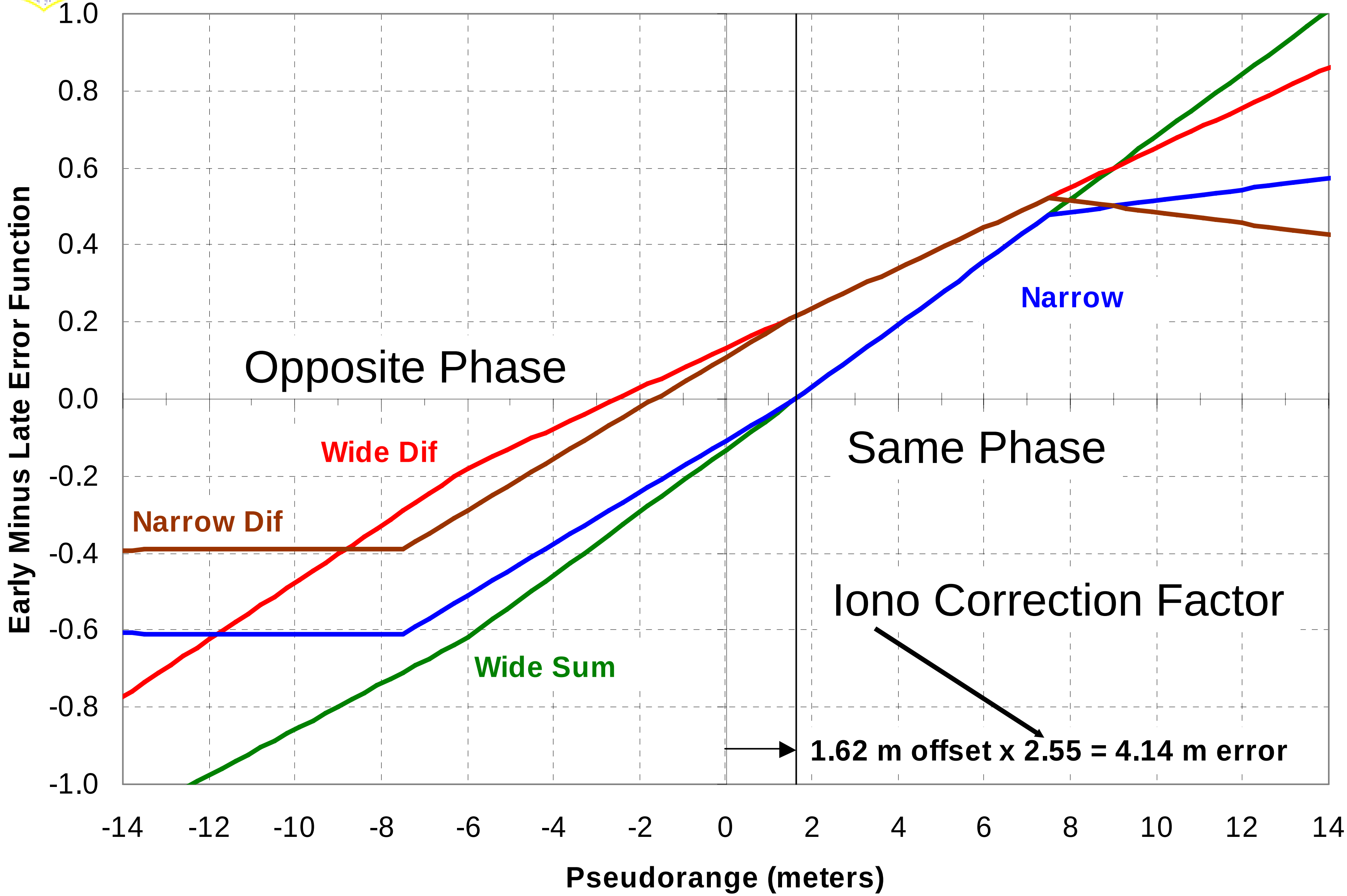
$$\sqrt{2.55^2 + 1.55^2} = 2.984.... \approx 3$$

Ionospheric correction amplifies code noise

Max Impact on L1 P(Y) Autocorrelation



Early Minus Late L1 P(Y) Code Track Error



Useful Observation

- **Receivers with early minus late correlators having similar spacing will have essentially the same tracking error for all signals at one frequency**
  - – e.g., L1 P(Y) and L1 C/A exhibit the same error
- **However, different types of correlators and different correlator spacings very likely will produce different tracking errors**
  - – See next slide with figures from 13 July ’09 GPS World Article

Tracking Error with Different Correlators

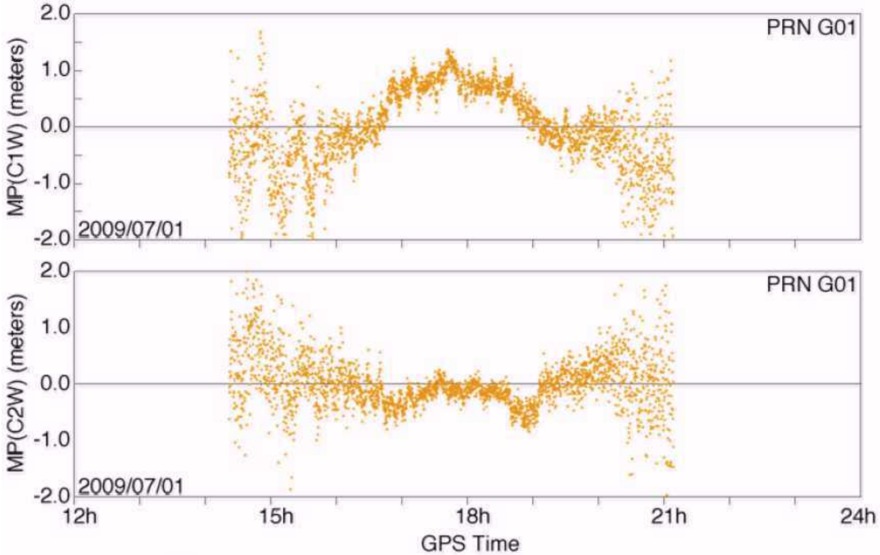


FIGURE 4. Typical SNV49 multipath errors for semi-codeless P(Y)-code tracking on L1 (top) and L2 (bottom) from a conventional correlator.

L1 Typical Semi-Codeless Correlator

L2 Typical Semi-Codeless Correlator

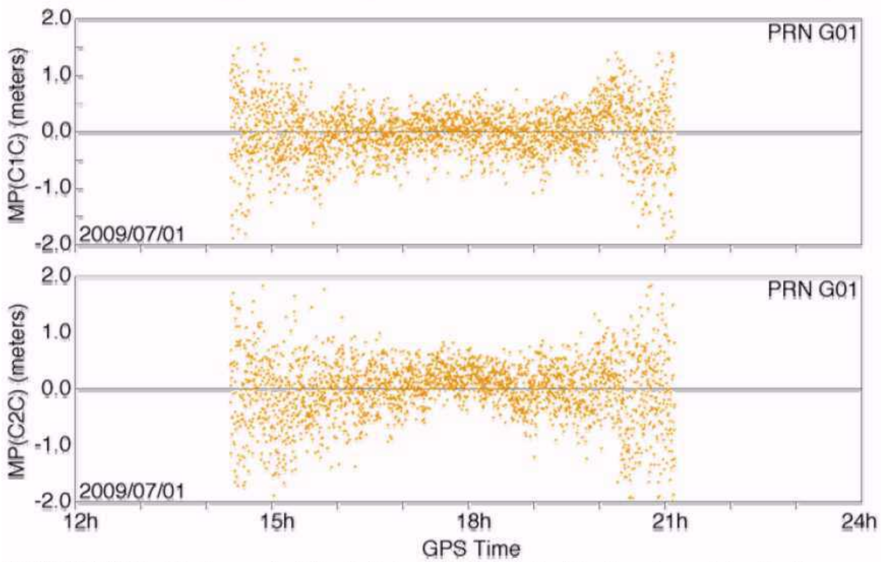


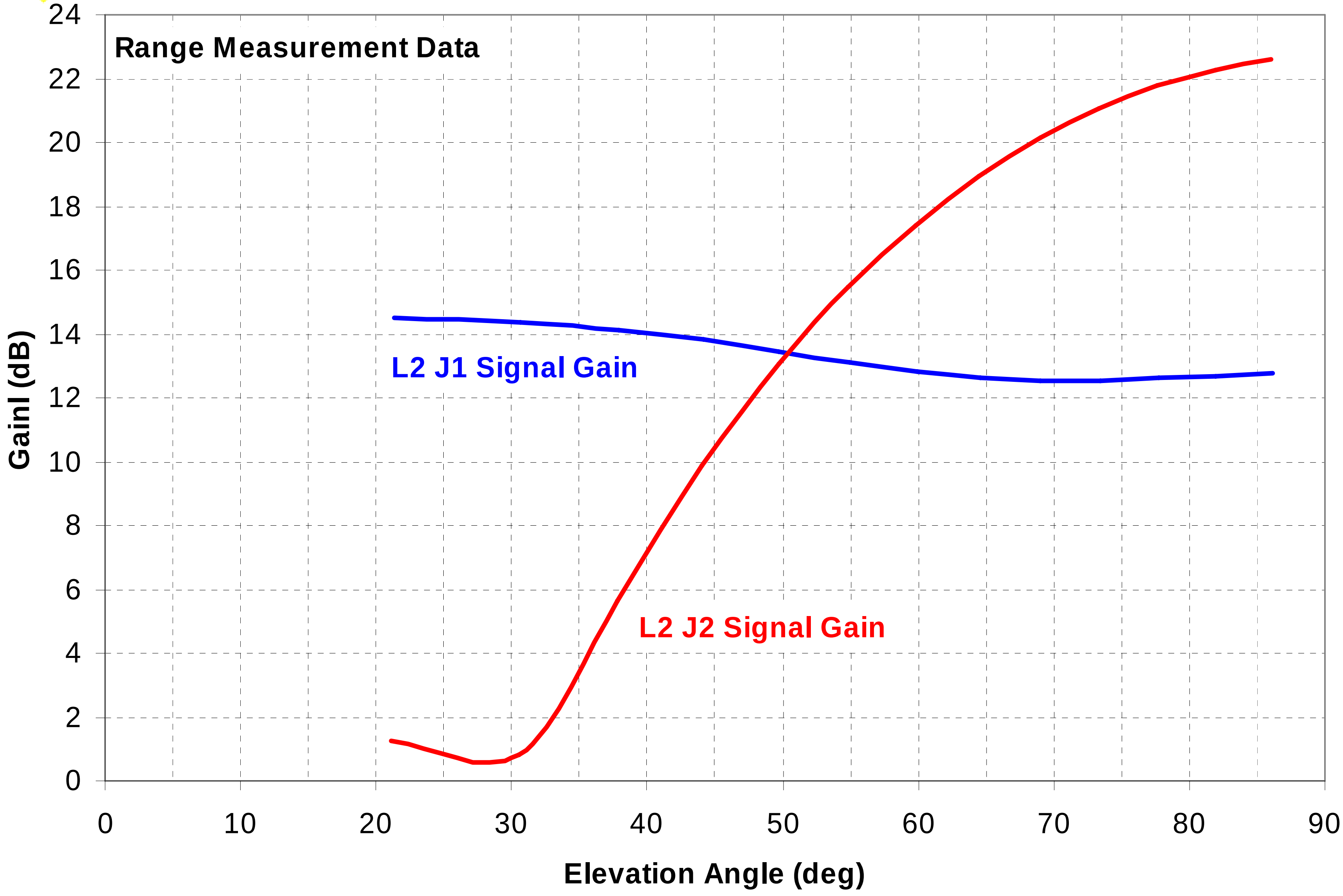
FIGURE 5. SVN49 multipath errors for C/A-code (top) and L2C-code (bottom) tracking using special multipath-mitigation techniques with 20-nanosecond correlator spacing

L1 Using Multipath Mitigation w/ 20 nanosecond correlator spacing

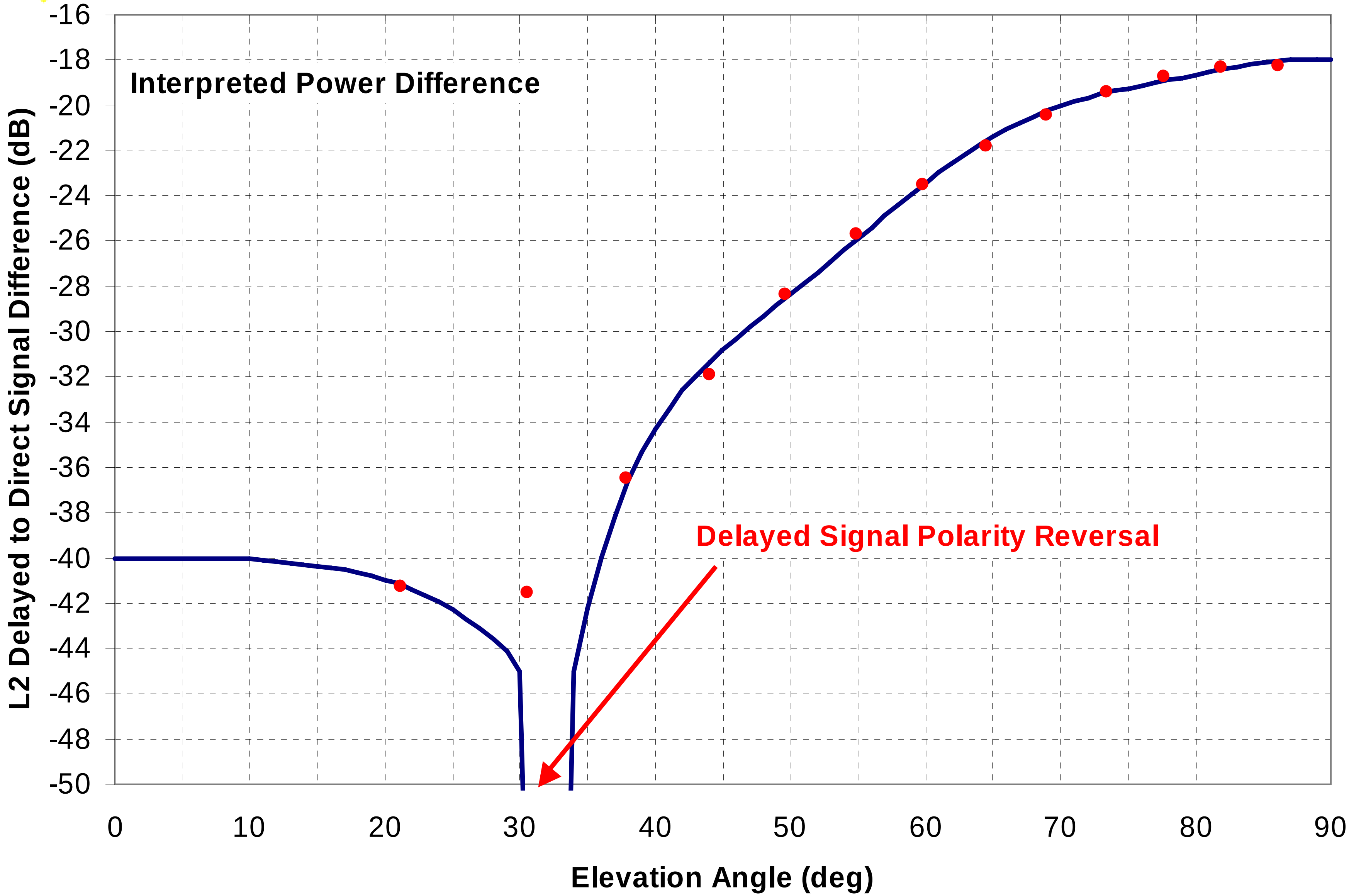
L2 Using Multipath Mitigation w/ 20 nanosecond correlator spacing

Figures courtesy of GPS World, receivers are JAVAD GNSS Triumph receivers

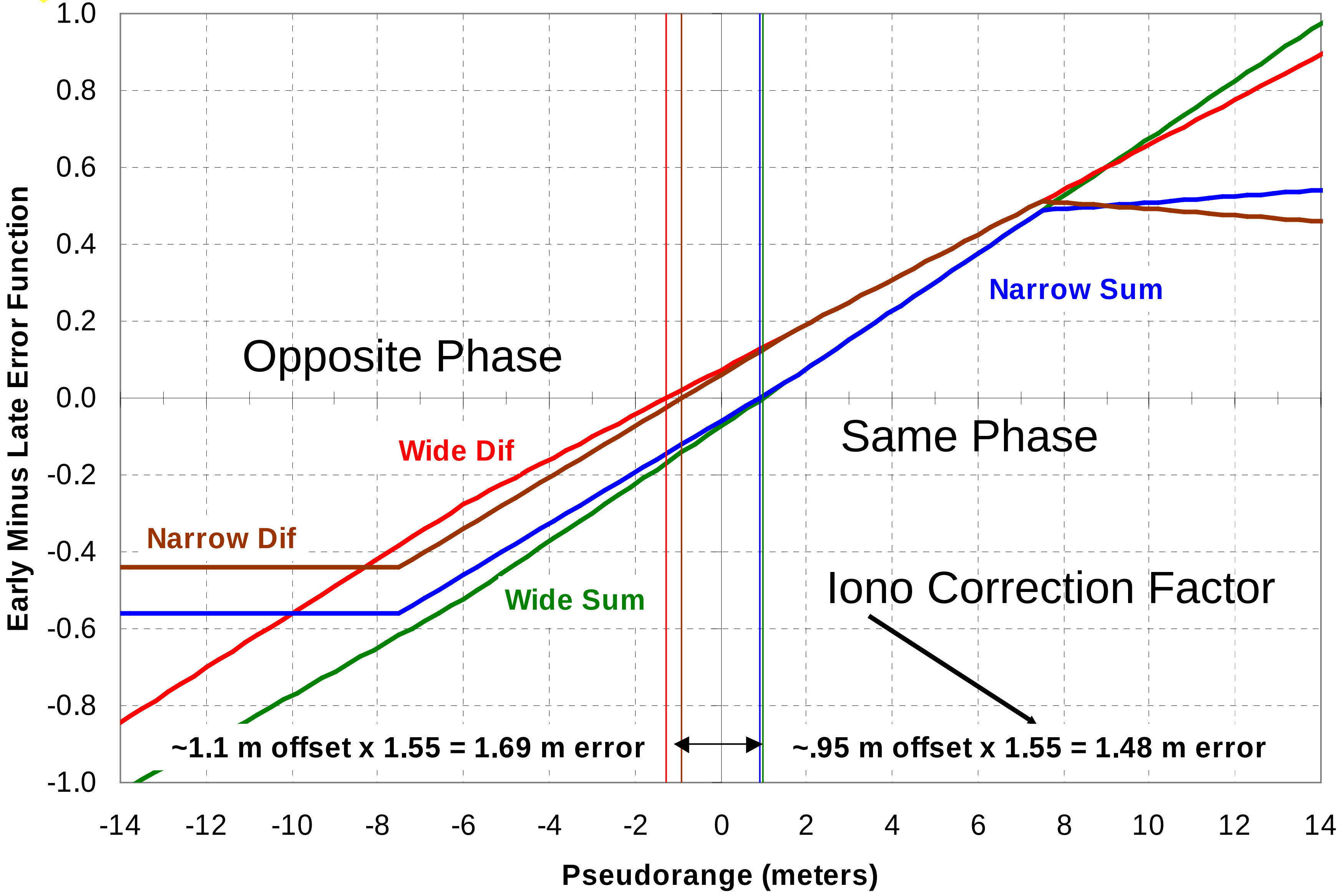
J1 and J2 Antenna Patterns at L2



Model of L2 Signal Difference



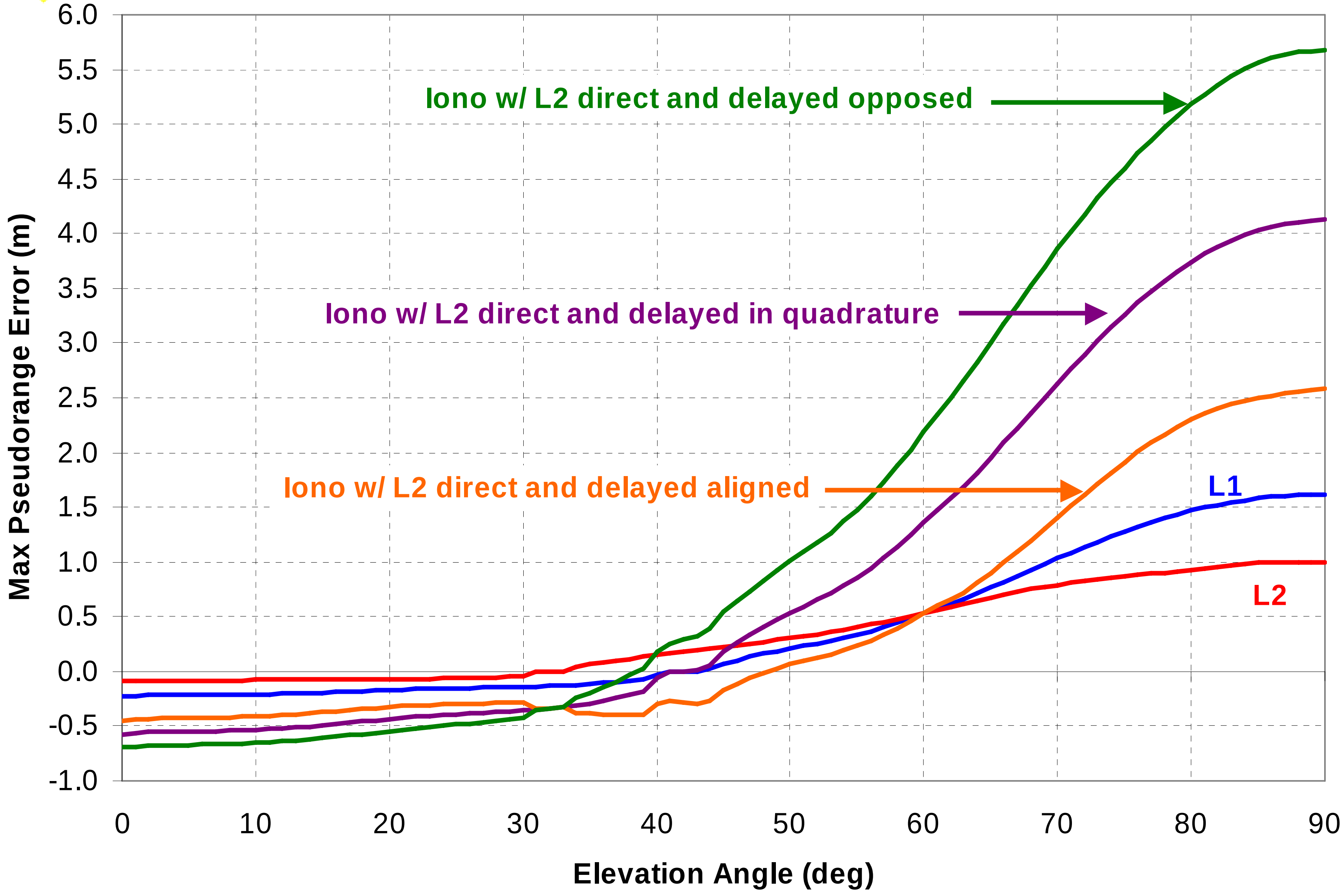
Early Minus Late L2 P(Y) Code Track Error



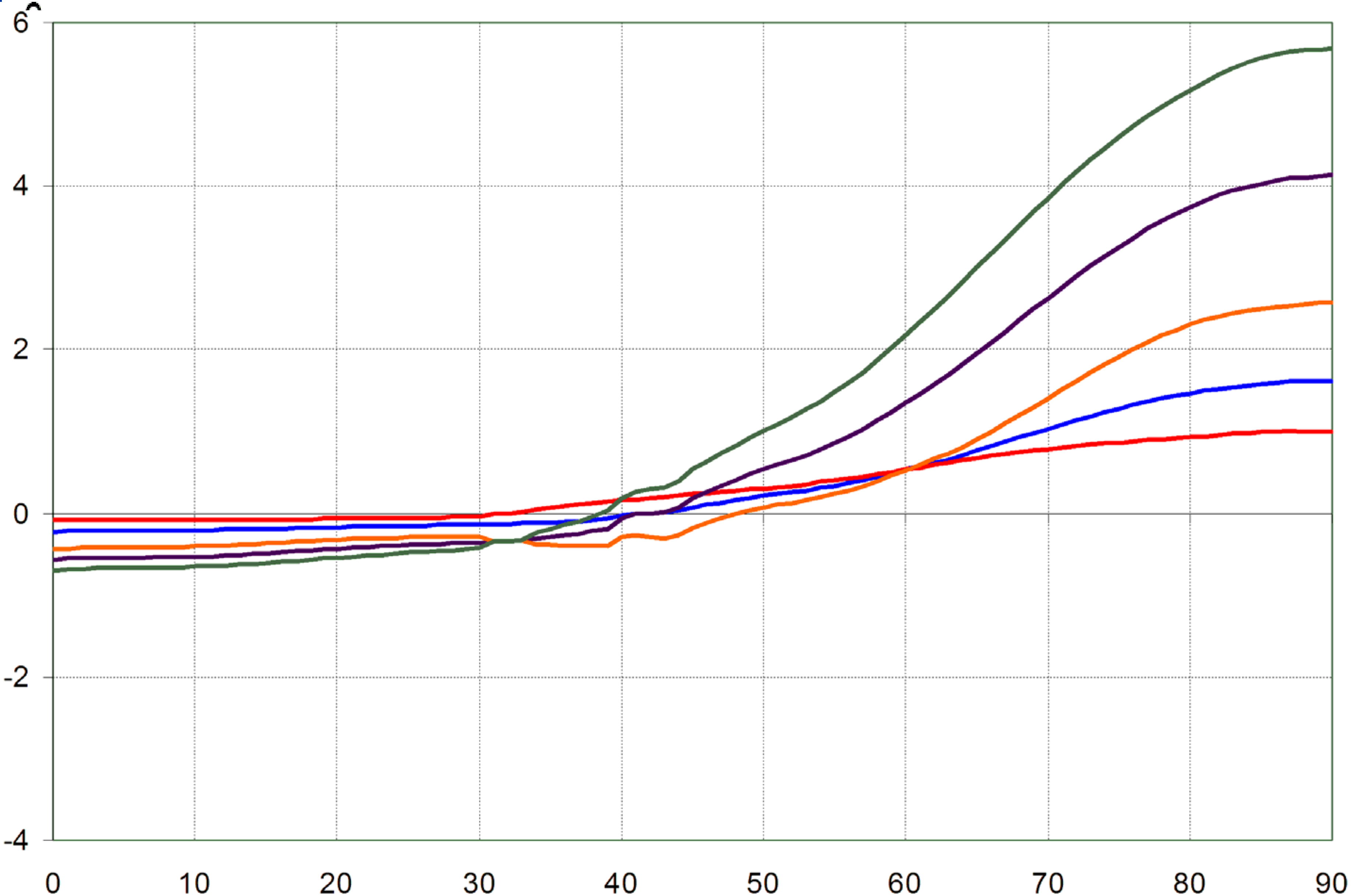
Refraction Corrected Error Possibilities

- **Assume the direct and reflected L1 signals are in phase so at zenith the L1 pseudorange is 1.62 m too long**
- **If the direct and reflected L2 signals are in quadrature, the L2 pseudorange error is negligible**
- **Therefore, the refraction corrected pseudorange error is (2.55 x 1.62 – 1.55 x 0) = 4.14 m**
- **If the direct and reflected L2 signals are in the same phase, the L2 pseudorange error is ~0.95 m**
- **Therefore, the refraction corrected pseudorange error is (2.55 x 1.62 – 1.55 x 0.95) = 2.66 m**
- **If the direct and reflected L2 signals are in opposite phase, the L2 pseudorange error is ~ -1.1 m**
- **Therefore, the refraction corrected pseudorange error is (2.55 x 1.62 – 1.55 x –1.1) = 5.84 m**

Pseudorange Error Model



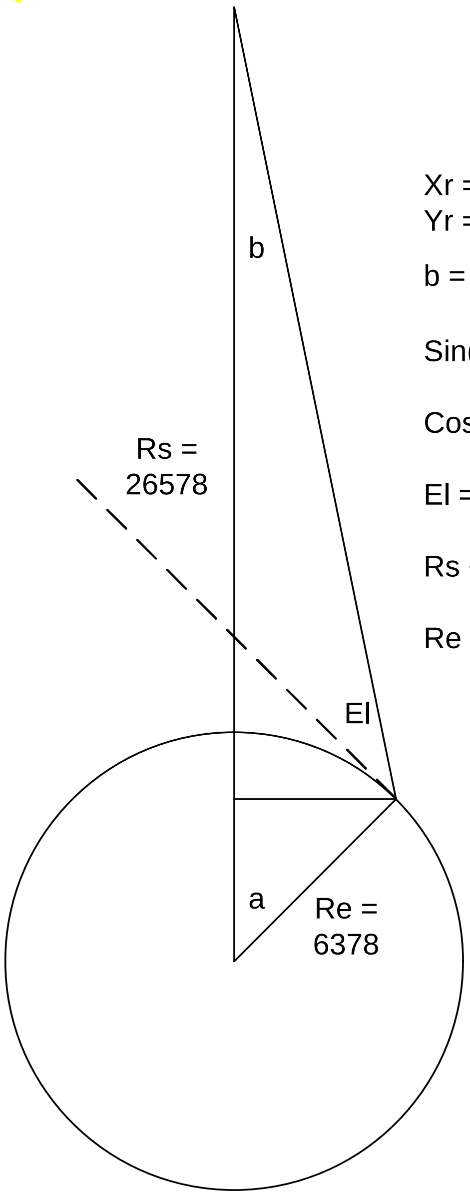
Curves and Residuals Overlay



A Partial Fix

- **In order to reduce the elevation-dependent tracking residuals, 2SOPS has experimented with placing the antenna phase center about 152 meters above the satellite rather than slightly below as normal**
  - (How can you fix a 4-5 meter problem with a 152 meter solution?)
- **The Kalman filter then provides orbit and clock parameters which best fit the tracking data**
  - The key parameter is clock offset
- **Over the next few weeks, different values will be tried and transmitted in the NAV messages**

Raise the Orbit, Offset the Clock



Xr = Re Sin(a)
Yr = Re cos(a)

b = atan(Xr/(Rs - Yr))

Sin(90+El)/Rs = Sin(b)/Re

Cos(El)/Rs = Sin(b)/Re

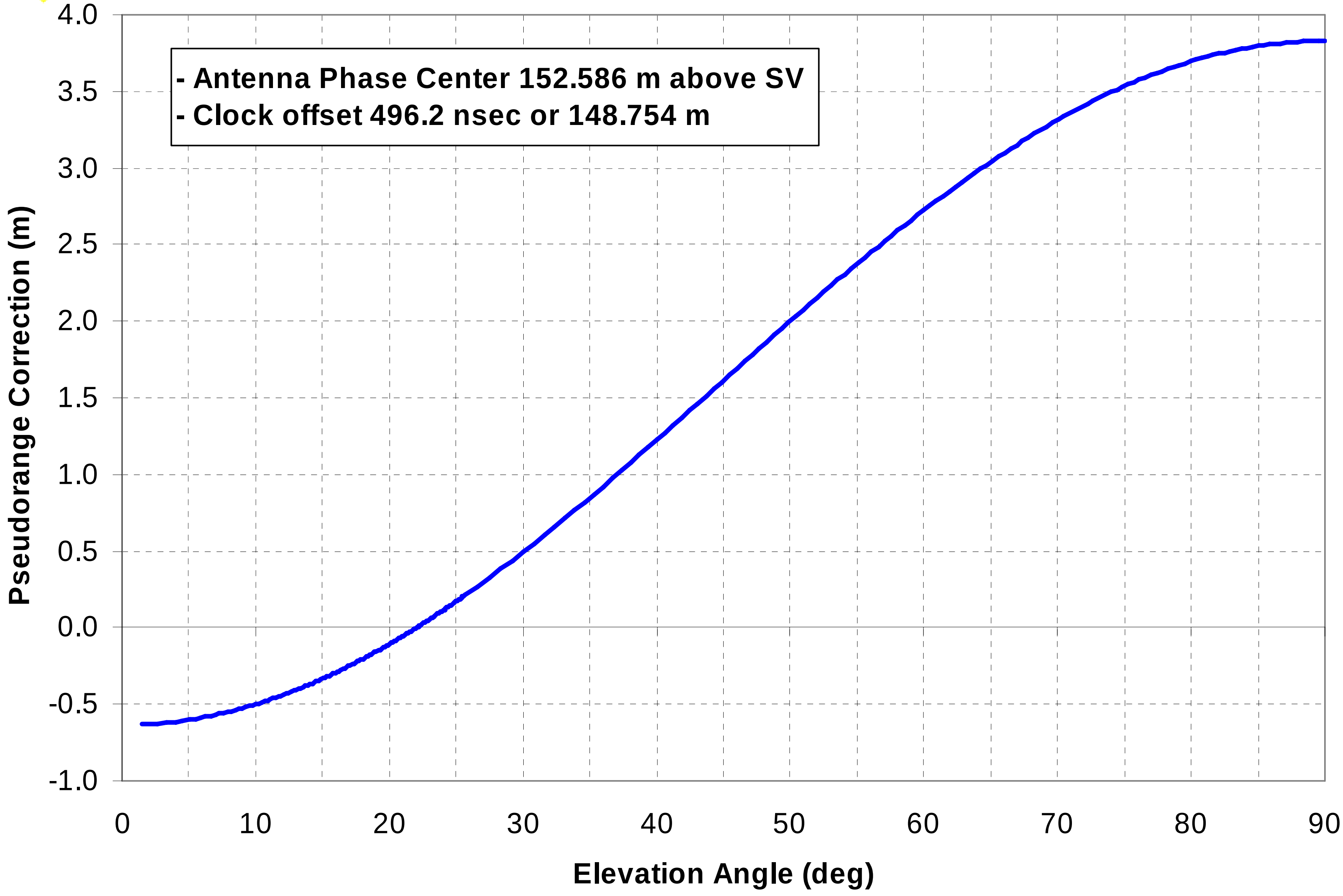
El = acos(Rs Sin(b)/Re)

Rs ~ 26,560,601 meters

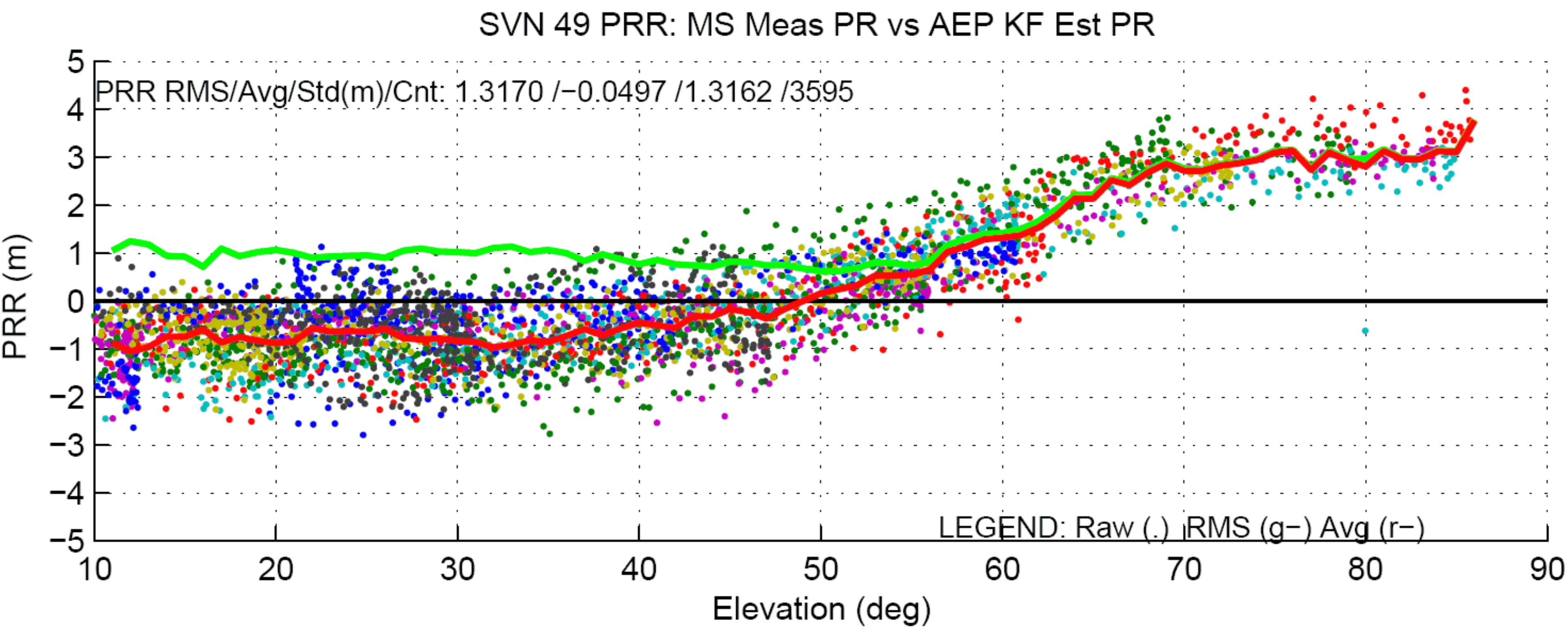
Re ~ 6,378,137 meters at equator

- **If Rs effective = Rs + δ**
- **The impact on pseudorange is δ cos(b)**
- **The following plot shows the effect of δ = 152.586 m with a clock offset of 496.2 nsec (148.754 m)**

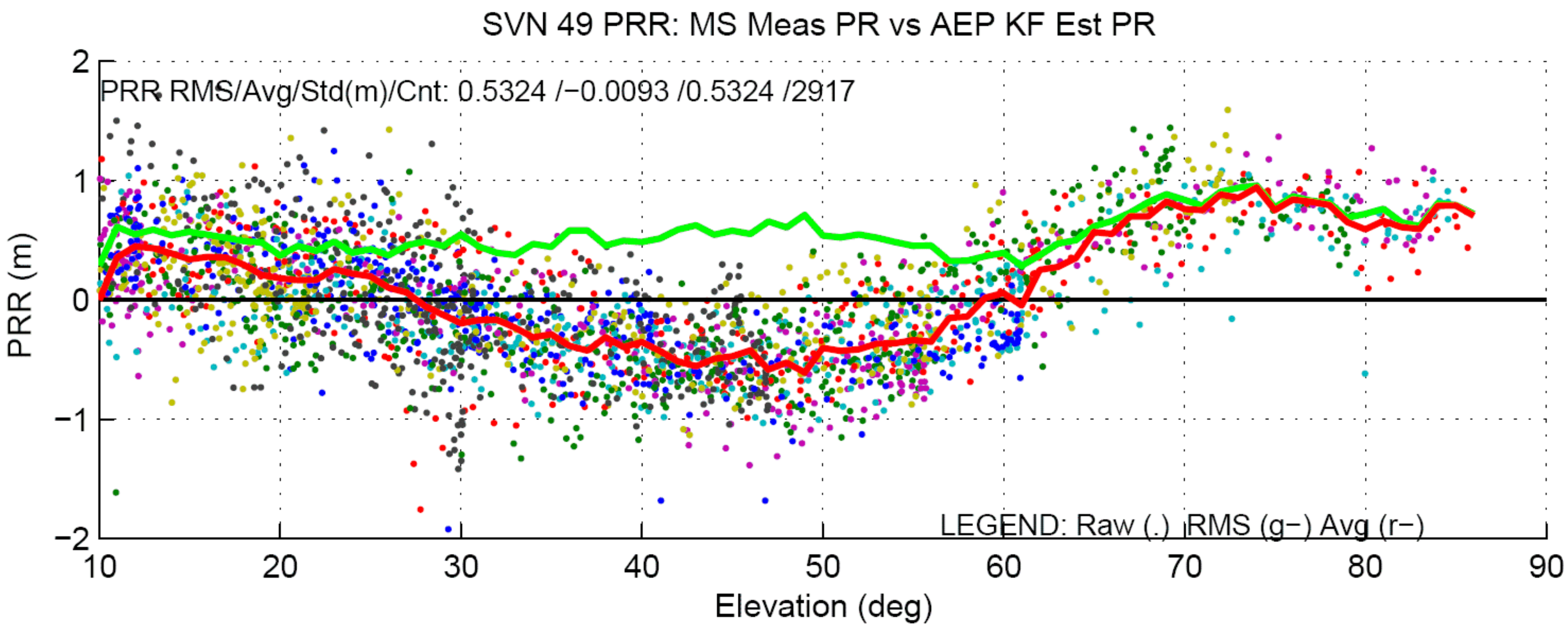
Net Compensation



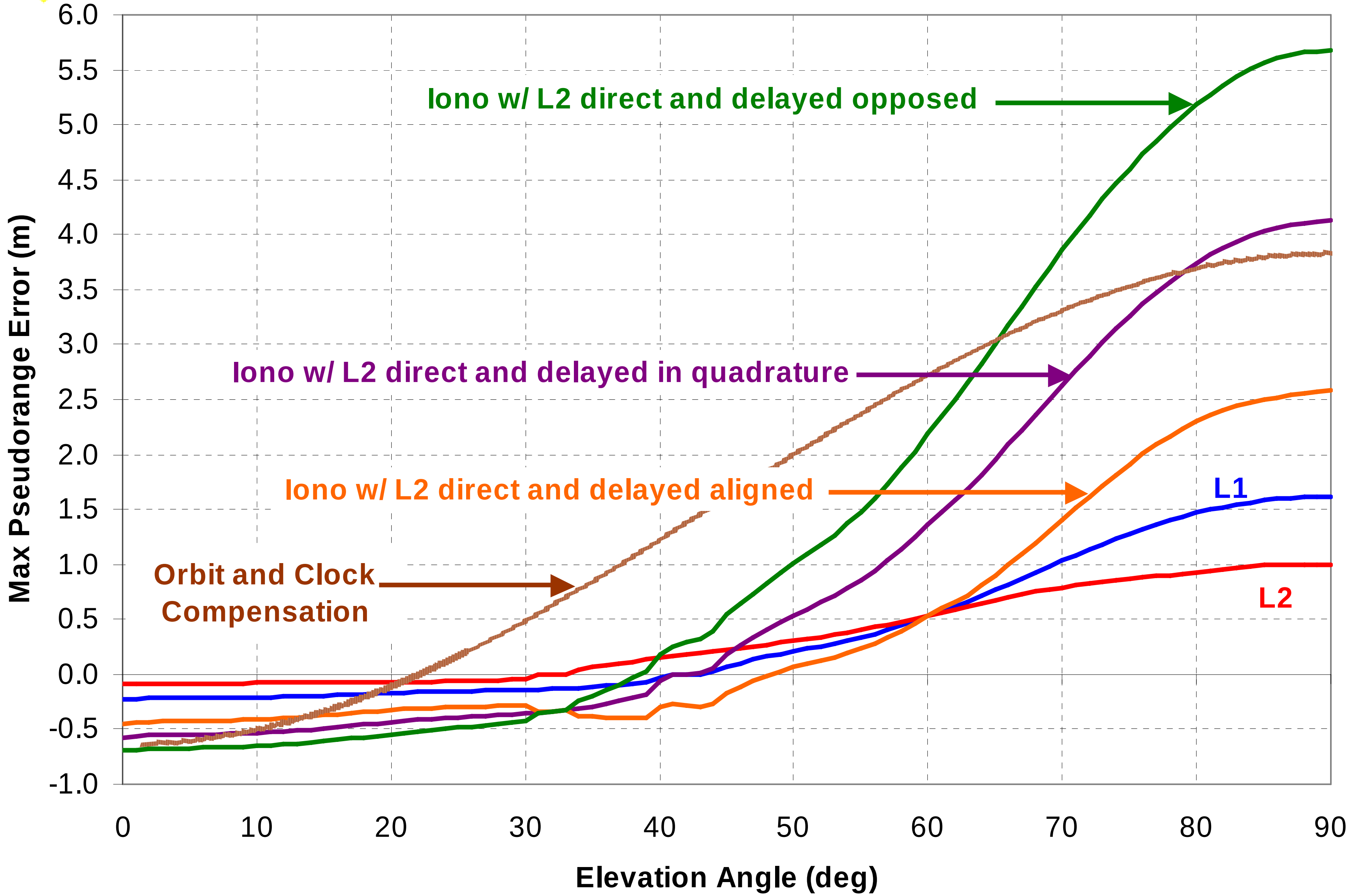
Uncompensated Residuals



Compensated Residuals



Compare Compensation with Error Models



Spirent Simulation

- **Note for organizations with a Spirent simulator**
  - Spirent is preparing a scenario, based on these models, to simulate the SVN-49 problem and enable laboratory testing
  - The scenario provides normal L1 and L2 signals plus a delayed signal with the proper relative amplitude and phase relationships as a function of elevation angle in accordance with these models
  - Several parameters can be modified by the operator
  - The scenario will available directly from Spirent by request