A Revised Model for Coherent GPS Receiver Multipath Performance

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Motivation / Goals

- Previous research has shown disagreement between bench data and predicted results
- Find sources of disparity
- Investigate higher-fidelity model

Further Reasons for Effort

- Greater Accuracy Potential
  - New Civilian Signals
  - Removal of SA

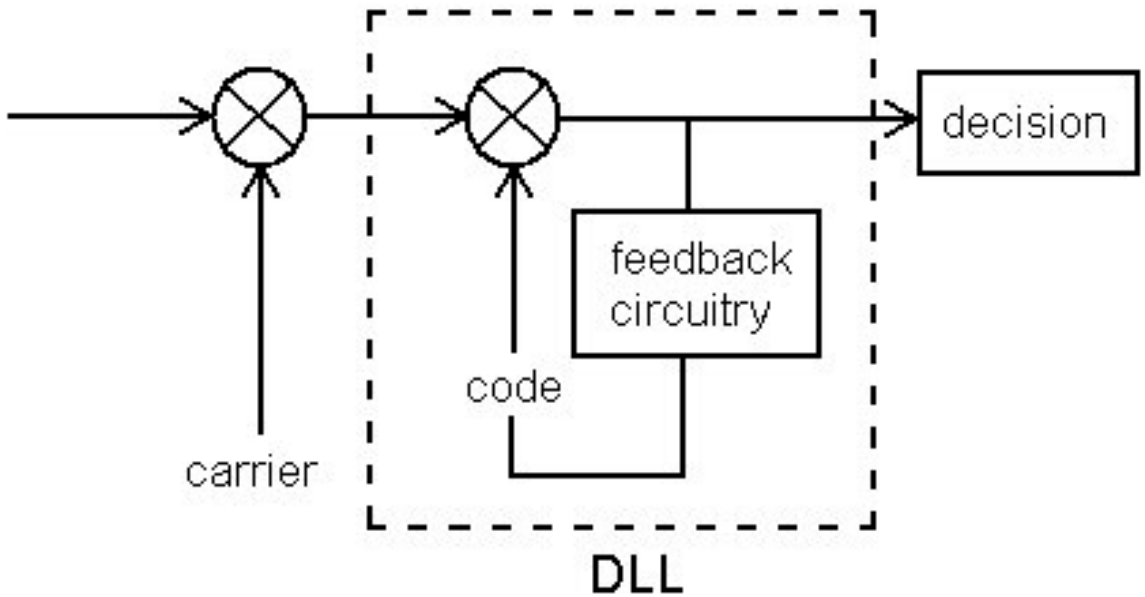
- Bench tests showed 3+ meter biases and external field tests showed 50+ meter errors

Research History

- Study of Environmental Multipath Dynamics
  - » MP Doppler-shift vs. descent rate and ground speed
- DLL Architectures were Analyzed and Simulated
  - » Explored contributions from discriminator type, LF bandwidth, and normalization.
- Focus on Fast-Fading Multipath
  - » Testing range 2-10 Hz for LF bandwidth of .03 Hz

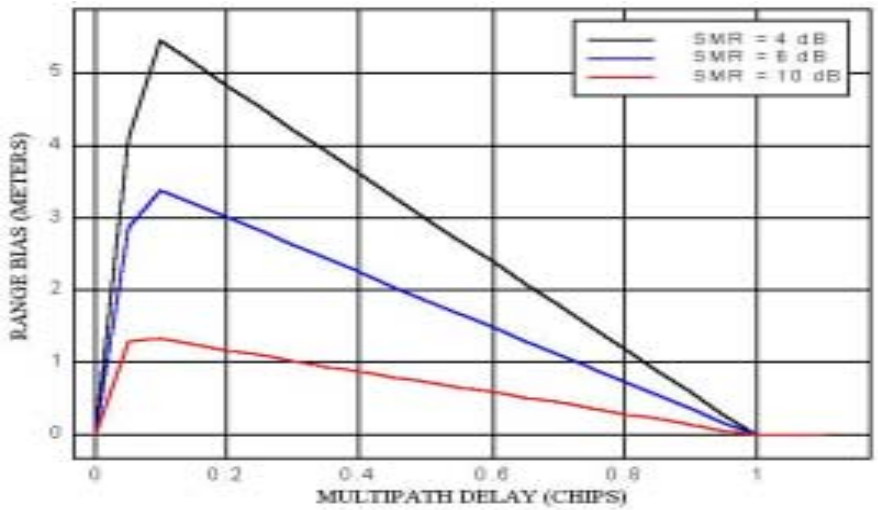
Take a look at code loop architecture

- Current model assumes purely sinusoidal carrier estimate



Expected Results

- Bias in NCDLL code phase estimate

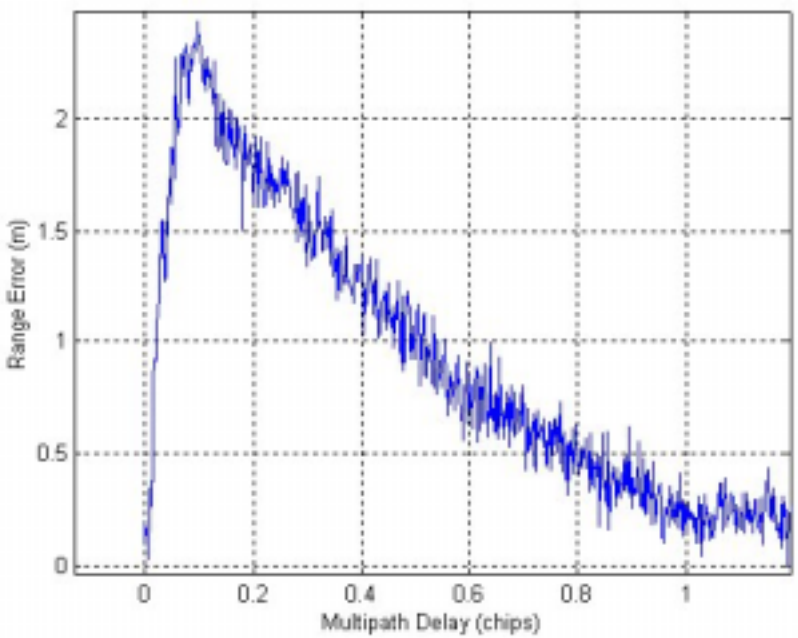


- Unbiased estimate from CDLL
- Fast fading is fast fading, bias is frequency independent

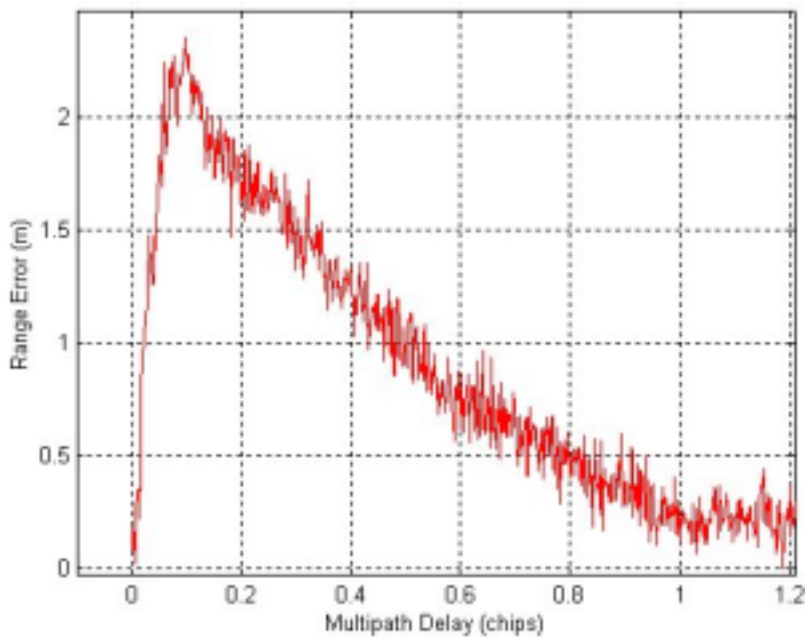
Bench Observations

- CDLL not much better than NCDLL

NCDLL



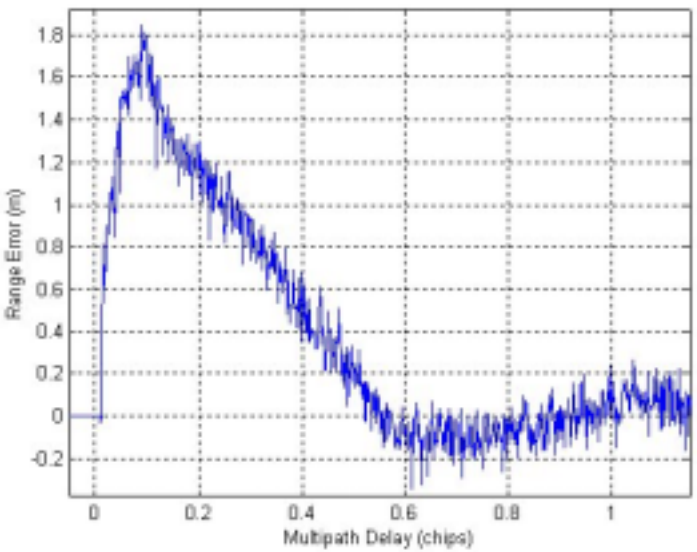
CDLL

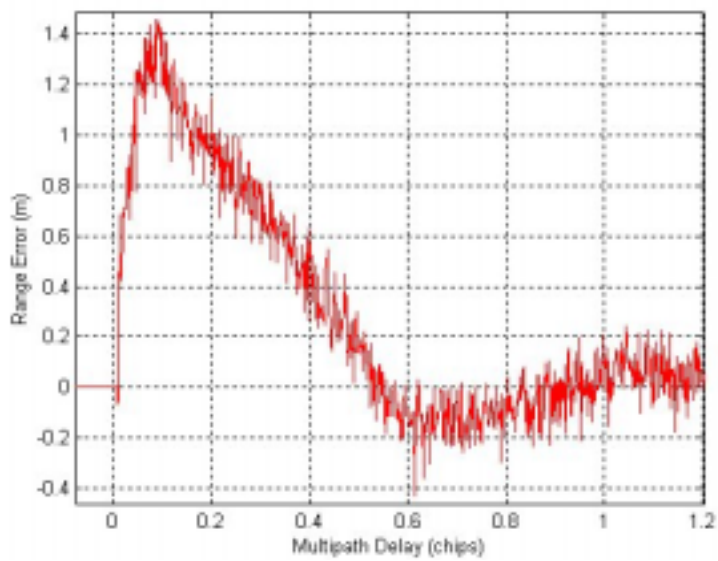


SMR = 6dB, 5 Hz FF

Bench Observations (Cont')

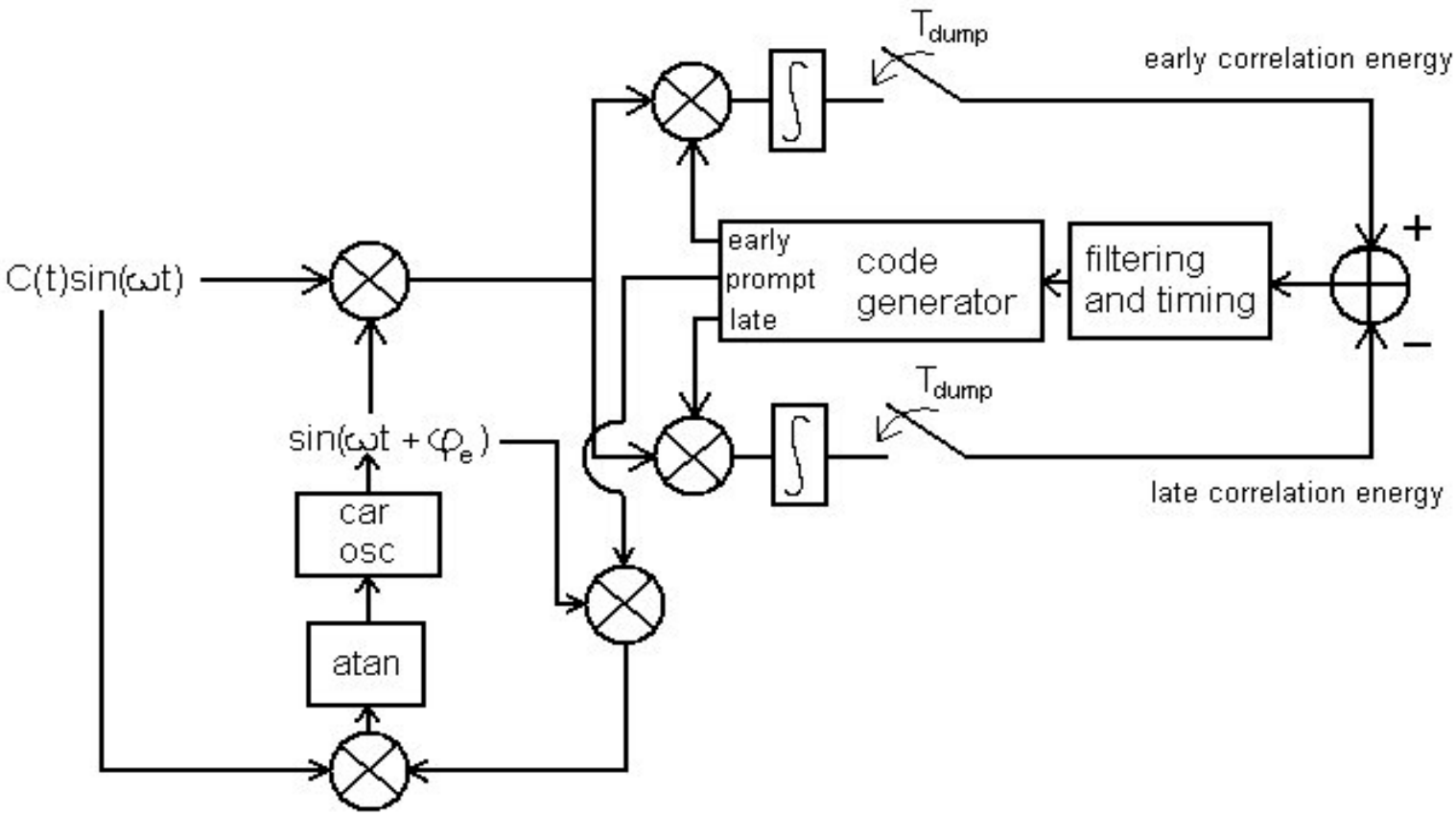
- performance of both improved at higher frequencies
- slightly greater advantage in CDLL toward upper part of tested frequency band





SMR = 6dB, 10 Hz FF

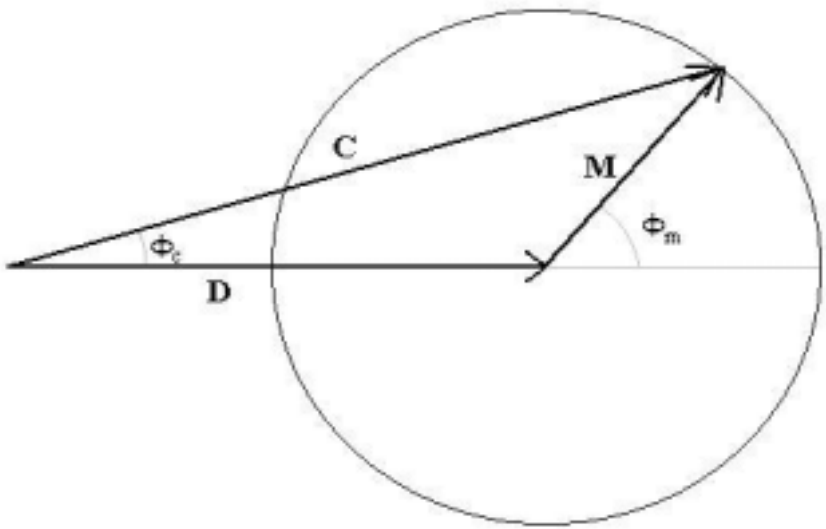
Let's reexamine the tracking loop



Demodulating sinusoid is determined in separate PLL

- Carrier loop tracks phase of incoming signal
- This phase is assumed constant in previous model
- Effect of any zero-mean tracking errors also assumed to be zero-mean

A classical look at multipath in a PLL

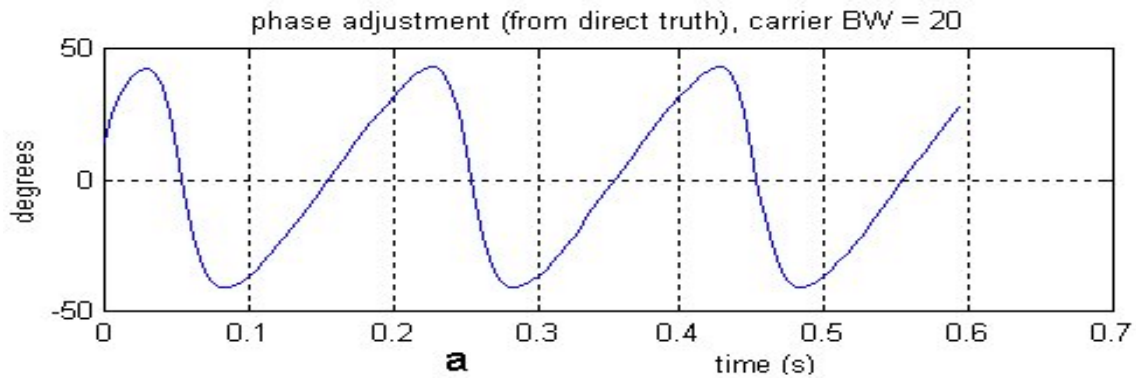


$$\phi_c = \tan^{-1}\left(\frac{\sin\phi_m}{SMR + \cos\phi_m}\right)$$

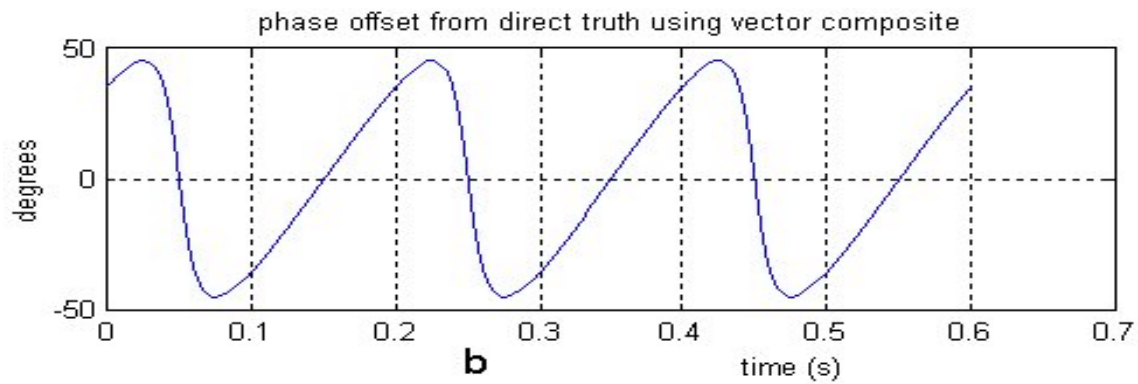
SMR is post-correlation signal-to-multipath strength ratio

Carrier-phase multipath distorts reference sinusoid in code loop

PLL estimate



Vector sum



Impact on NCDLL

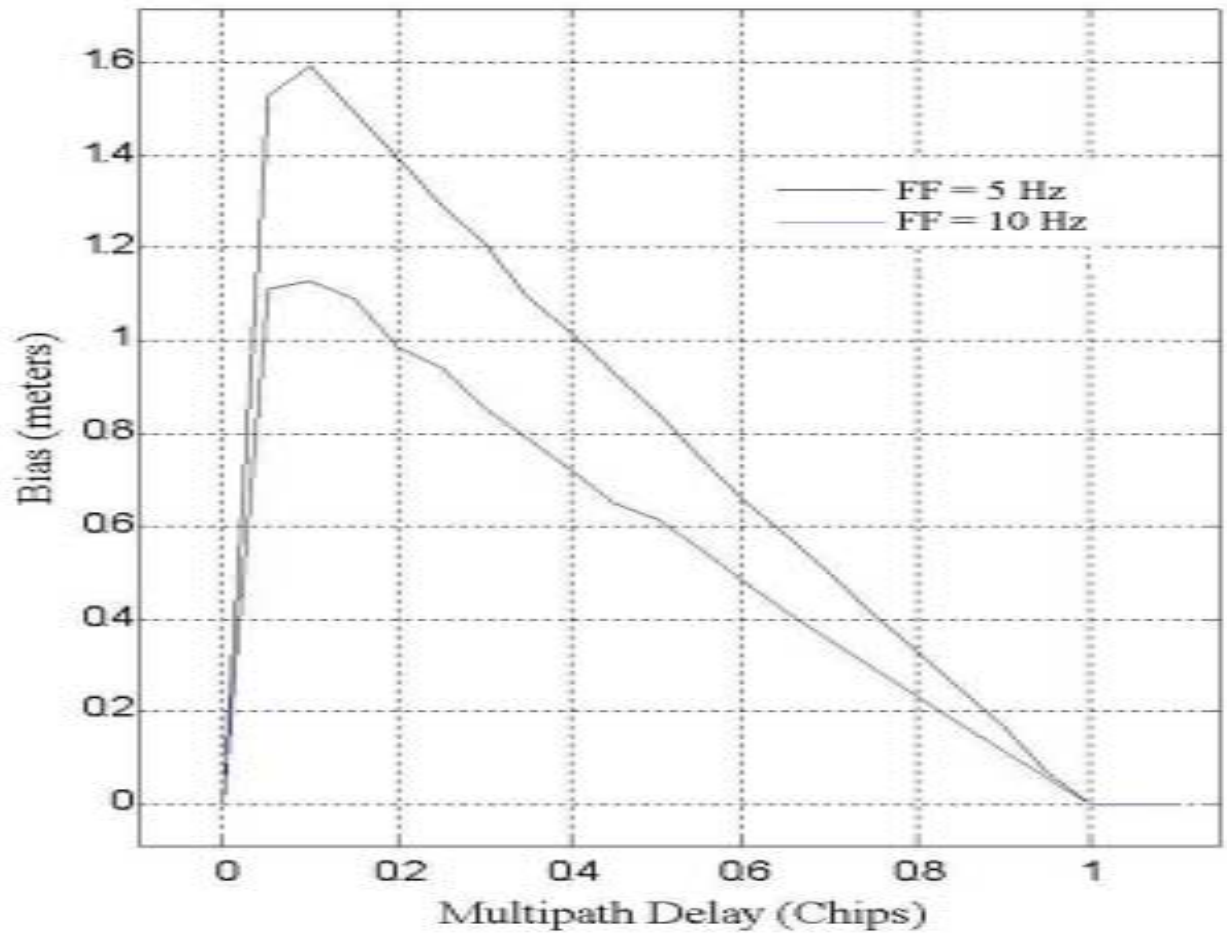
- Discriminator: $I_E^2 + Q_E^2 - I_L^2 - Q_L^2$
- Geometric sum of orthogonal components makes it phase-independent
- This makes NCDLL more robust for tracking

Impact on CDLL

- Discriminator: $I_E - I_L$
- Only in-phase components are used for tracking
- Time-varying reference phase causes loss of symmetry in discriminator output
- Code tracking bias results
- Carrier loop bandwidth becomes significant

New model explains bench data

CDLL Bias, SMR = 6dB



Additional Considerations

- NovAtel Beeline RX code loop feeds back at only 5 Hz.
- Classical models assume 50 - 1000 Hz
- Result is multipath greater than 5 Hz begins to average out in accumulated discriminator.

Conclusions

- Existing Model of Fading Multipath Effects not sufficient to explain bench results.
- Minor modification in carrier loop coupling gives insight to most significant result.
- Other observations explained by manufacturer-specific processing methods

Future Work (Proposed)

- Explore various feedback rates and functions
- Investigate whether new signal structures and antenna designs will reduce the problem
- Expand test space to ensure that this new model is adequate