Comparison of Assisted and Stand-Alone Methods for Increasing Coherent Integration Time for Weak GPS Signal Tracking

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Outline

- Introduction
- Increasing Integration Time
- NCO Schemes
- Limitation of Classical Loops
- Loop Filter Design in Z Domain
- Stand-alone Tracking Architecture
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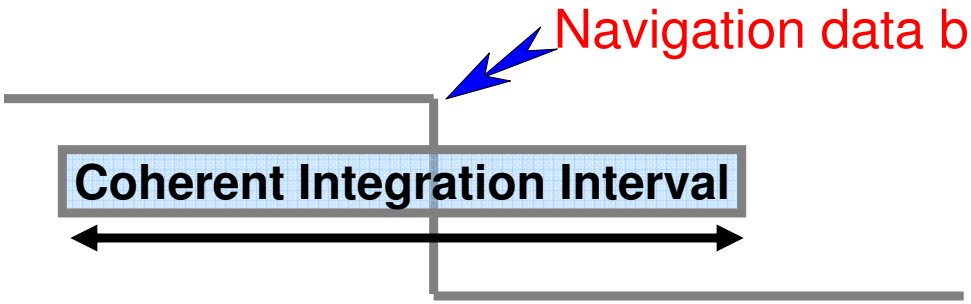
- Tracking Results
- Conclusions

Introduction

- GPS signal is attenuated significantly in an indoor environment, resulting in failure of signal acquisition and tracking by most conventional receivers.
- In order to track weak GPS signals longer coherent integration is required.
- Many factors limit the coherent integration time.
- To overcome these problems several techniques are proposed in this paper.

Increasing Integration Time

- If COH integration periods include a data bit boundary, the possible phase reversal may negate the positive effects of extended integration.



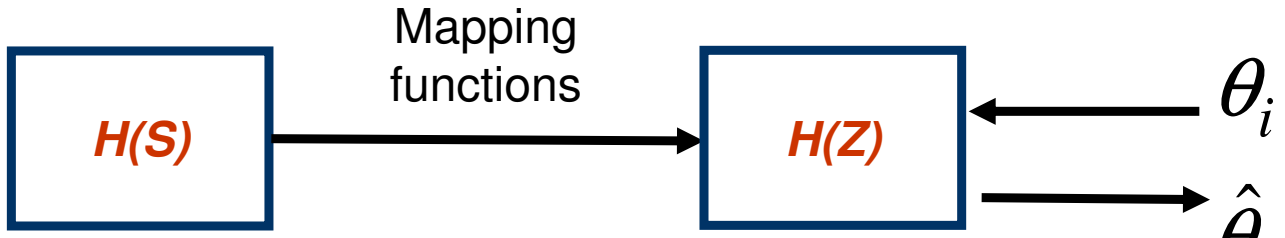
- The extension of COH integration time proportionally reduces the tolerable frequency error due to the sinc pattern in signal after Accumulation and dump process.

$$I_i = \frac{\sin(\pi \Delta f T)}{\pi \Delta f T} \sqrt{2 \frac{S}{N_o} T R(\tau_i) D_i \cos(\Delta \Phi_i) + \eta_{I_i}}$$

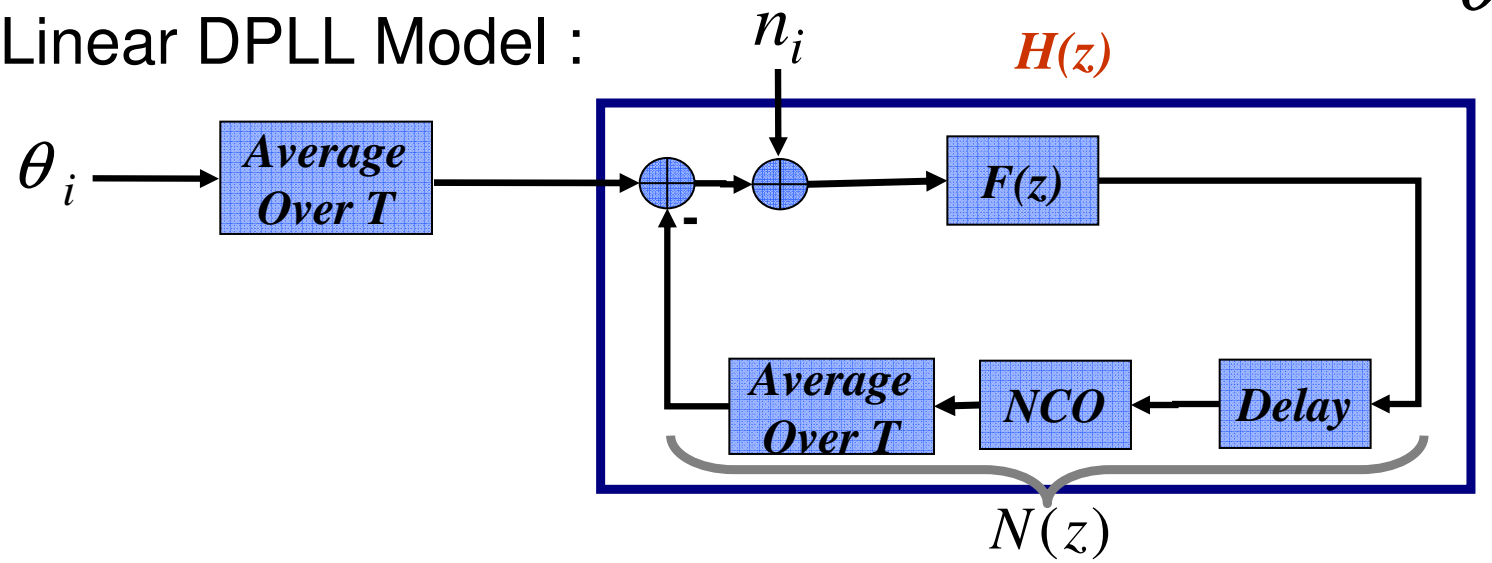
Increasing Integration Time

• Traditional GPS tracking loops are based on digital approximations of analog loops and these approximations break down as integration time increases.

• The **product between loop noise bandwidth and integration time (BT)** should remain near **zero**.

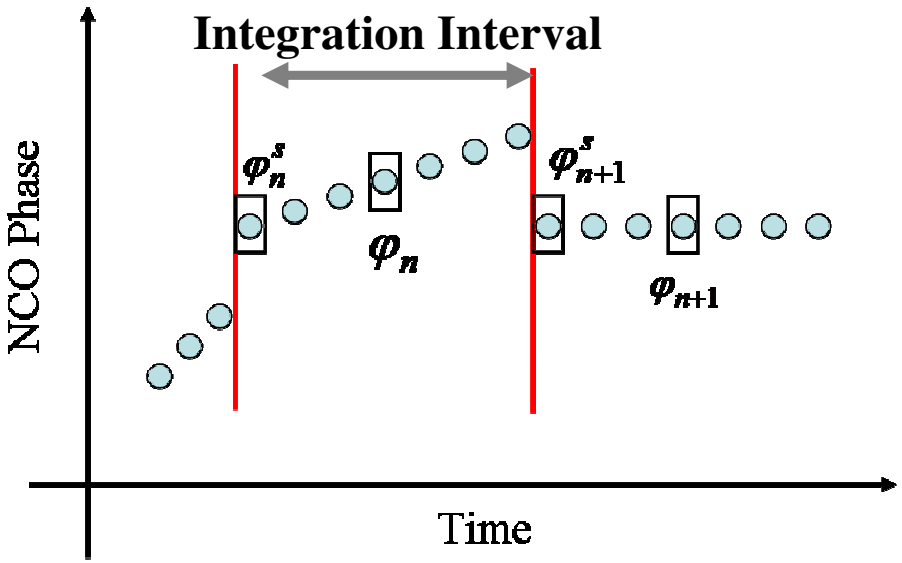


- Linear DPLL Model :



Different NCO Schemes

Phase rate and Phase feedback

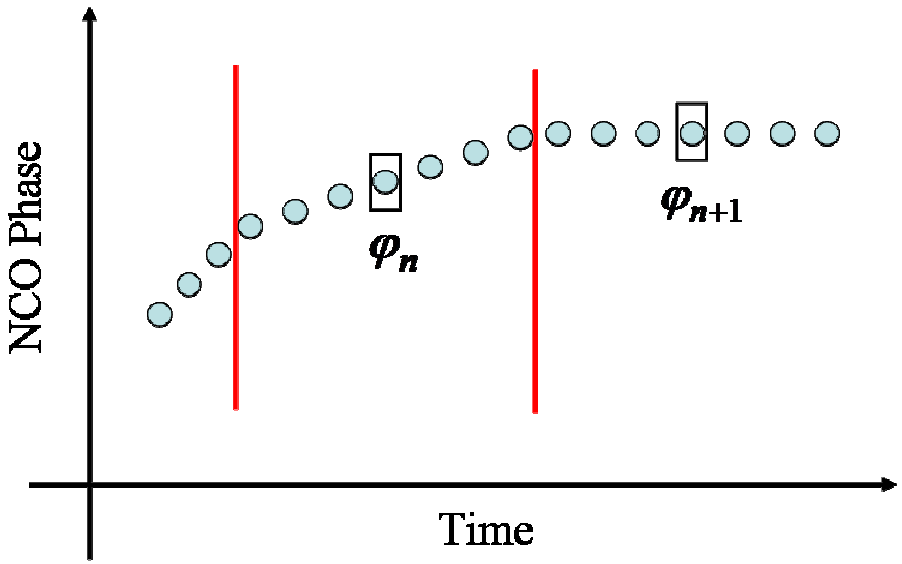


$$\varphi_{n+1} = \varphi_n + Tf_{n+1}$$

$$\varphi_{n+1}^s = Frac\,(\varphi_{n+1} - \frac{T}{2} f_{n+1})$$

$$N(z) = \frac{T}{(z-1)}$$

Phase rate feedback



$$\varphi_{n+1} = \varphi_n + \frac{T}{2}(f_n + f_{n+1})$$

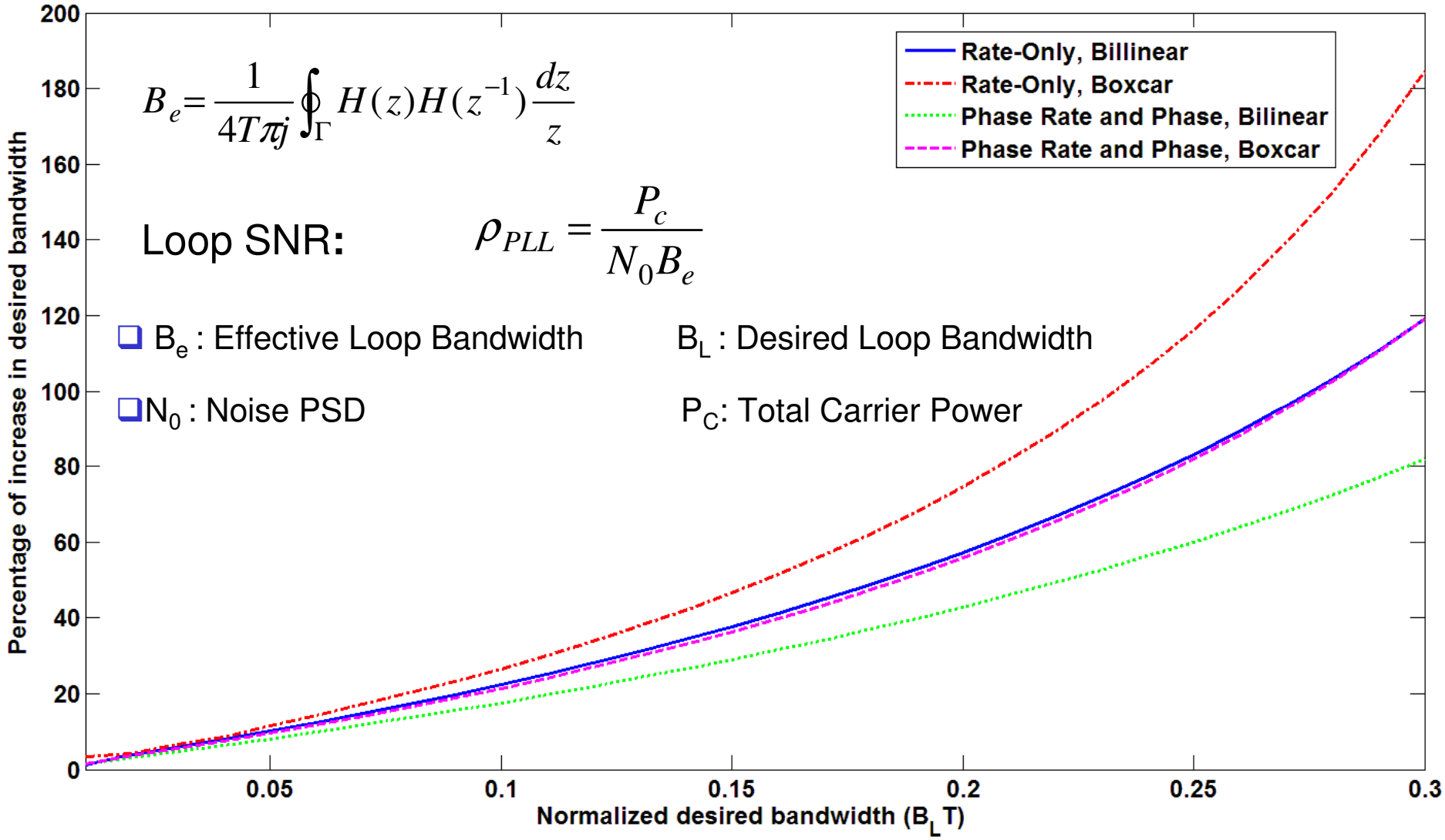
$$N(z) = \frac{T(z+1)}{2(z-1)z}$$

Limitations of Classical Loops

$$B_e = \frac{1}{4T\pi j}\oint_{\Gamma} H(z)H(z^{-1})\frac{dz}{z}$$

Loop SNR: $$\rho_{PLL} = \frac{P_c}{N_0 B_e}$$

- B_e : Effective Loop Bandwidth
- N_0 : Noise PSD
- B_L : Desired Loop Bandwidth
- P_C: Total Carrier Power



Limitations of Classical Loops

For a fixed given bandwidth how much could we increase the integration time?

Impossible

T=400 ms, B=3 Hz

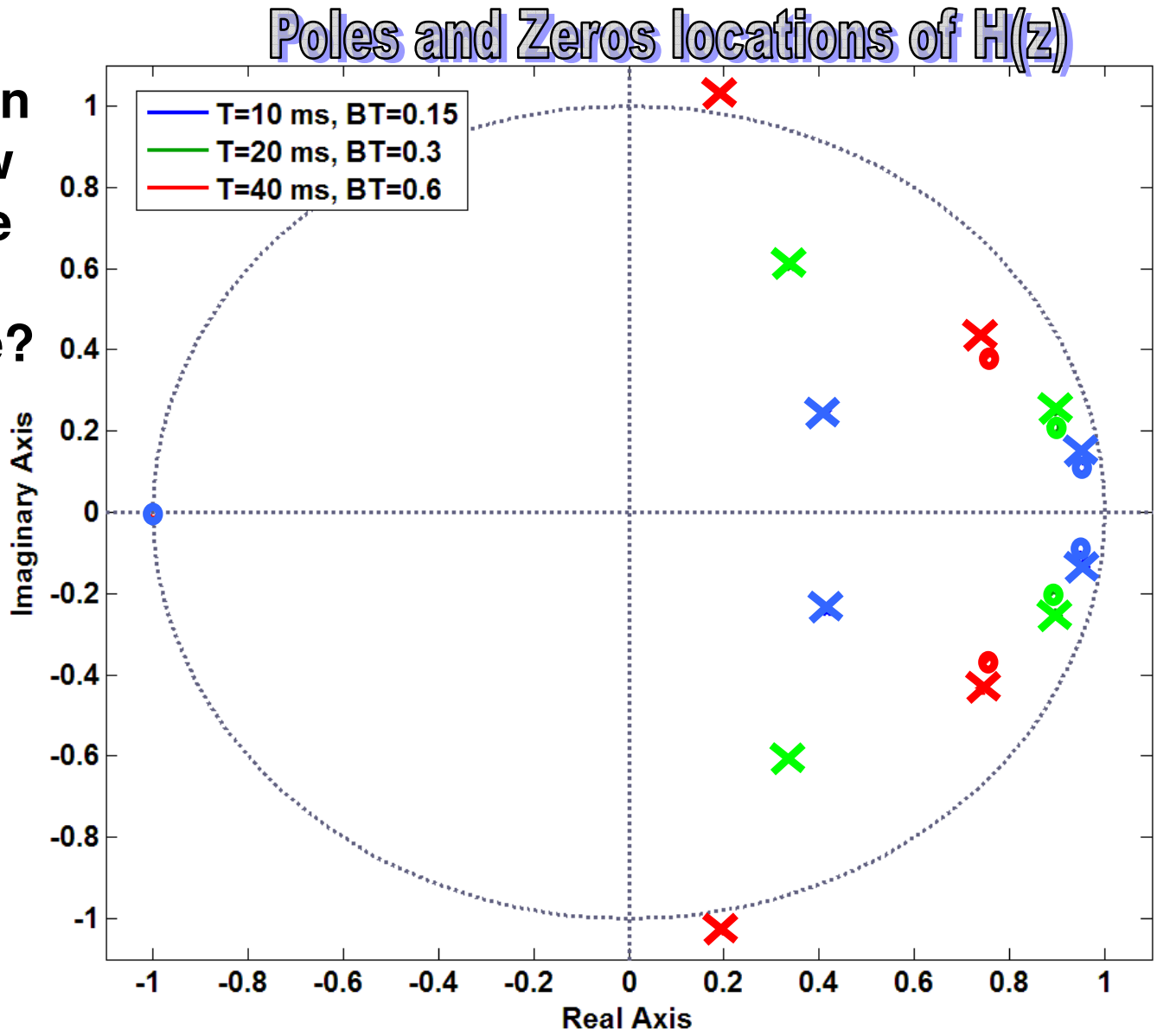
⇓

BT=1.2

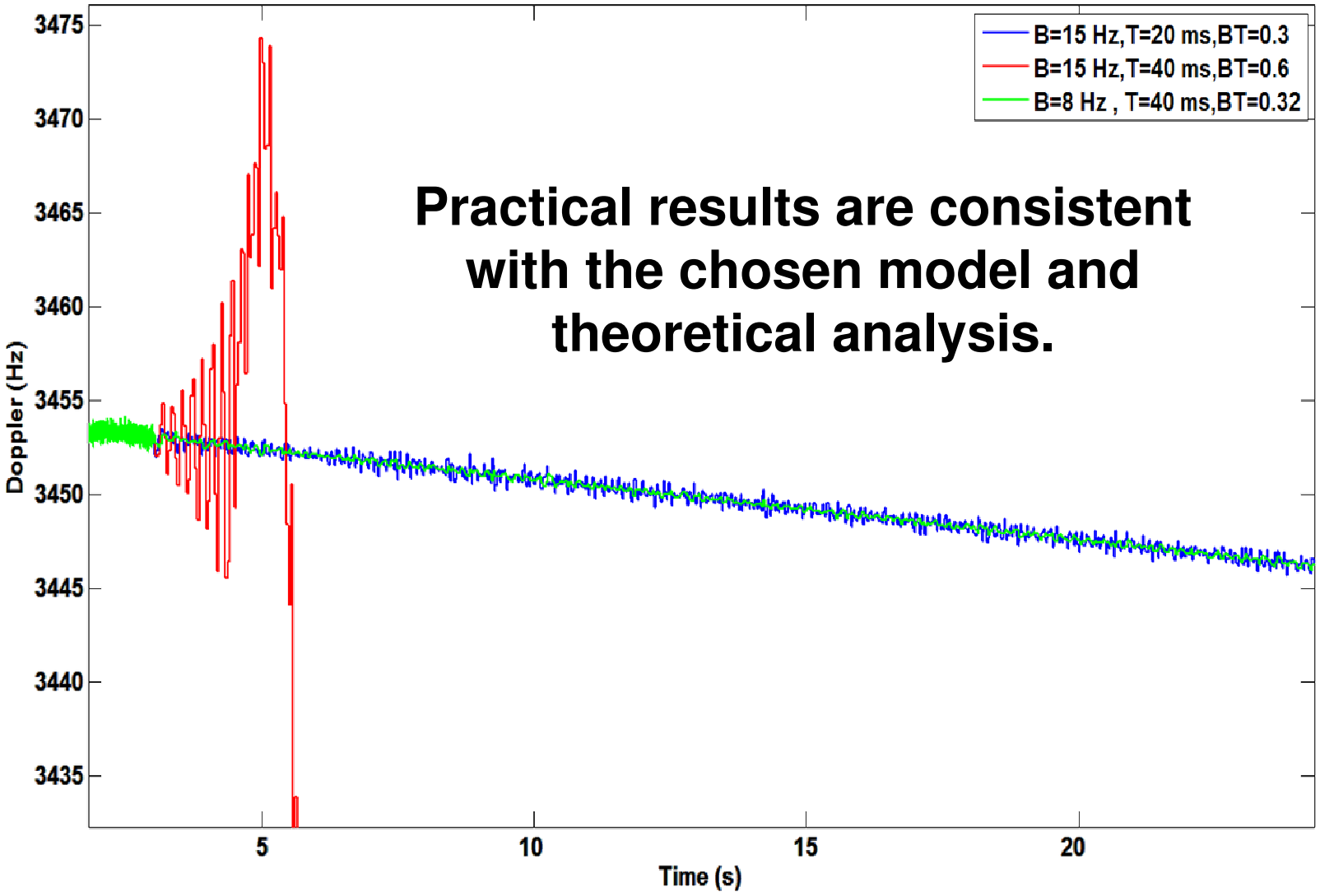
T=20 ms, B=35 Hz

⇓

BT=0.7



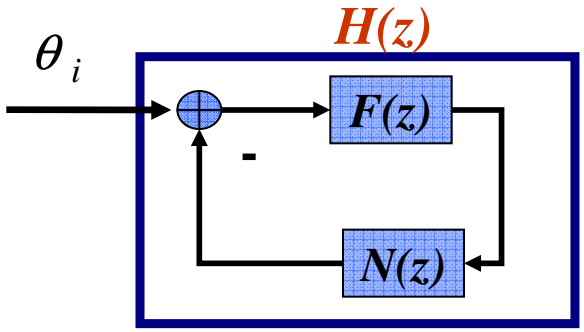
Limitations of Classical Loops



Loop Design in Digital Domain

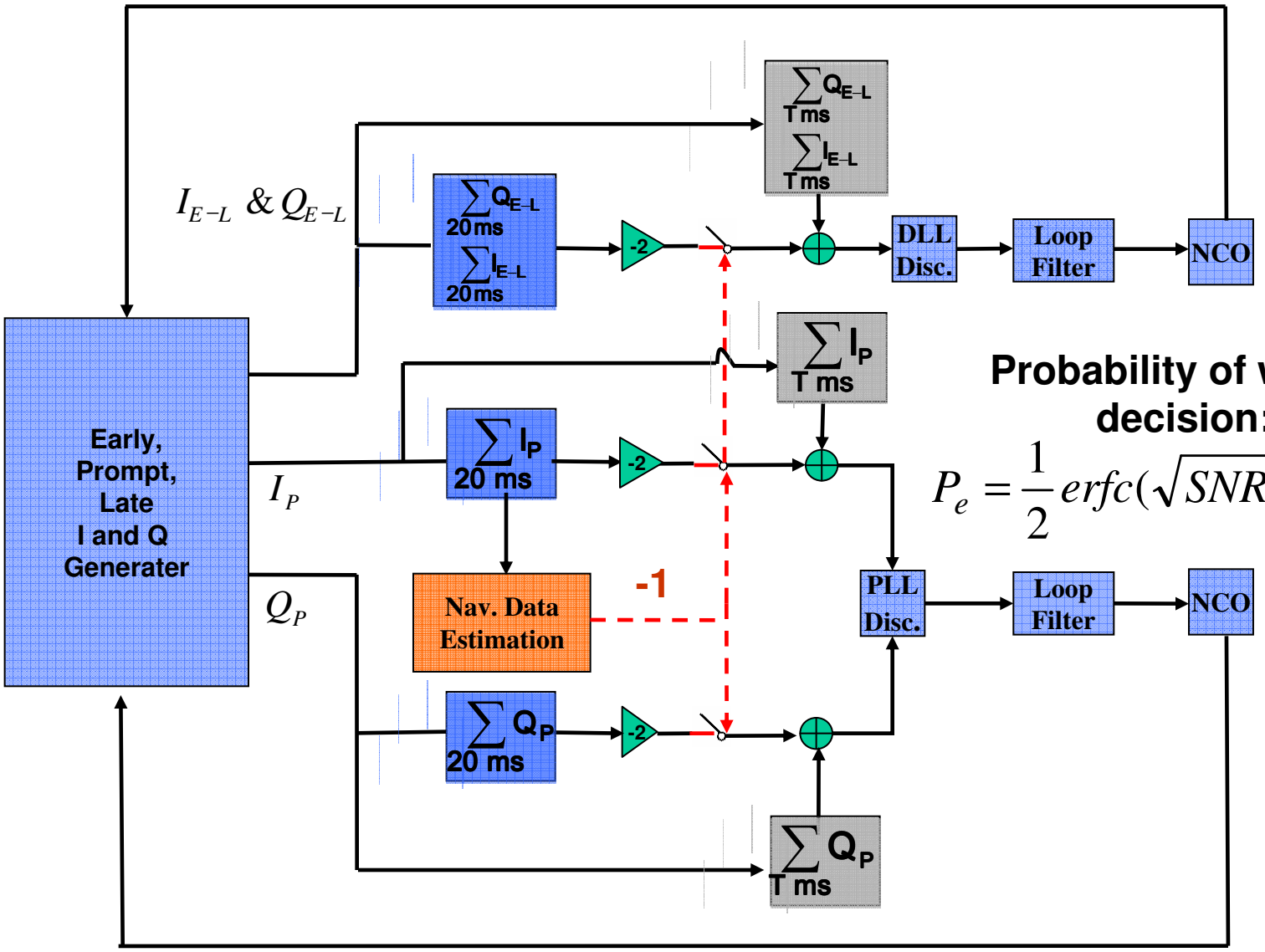
- Other techniques which are more versatile against low update rate (long integration time) should be used.
- *H(z) can be designed completely in Z-domain.*
  - For a given NCO type and its transfer function, what is the optimum filter to minimize the noise at the output of the NCO?

$$H(z) = \frac{F(z)N(z)}{1 + F(z)N(z)}$$



- The desired (target) bandwidth will be equal to the effective bandwidth.
- The loop remains stable for very long integration times (up to BT=3) .
- As it is shown in paper even in this case the usage of the phase and phase rate feedback NCO is preferable.

Stand-alone Tracking Architecture



Probability of wrong decision:

$$P_e = \frac{1}{2} erfc(\sqrt{SNR}\cos(\varphi_e))$$

Test Setup

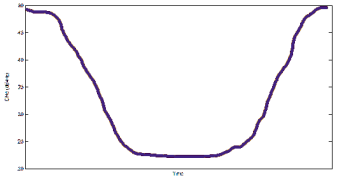
Static

Novatel
OEM4

Decoder

Navigation
Data

Variable
Attenuator



Splitter

U-blox
HS receiver

LNA

NI
Front-end

Software Receiver

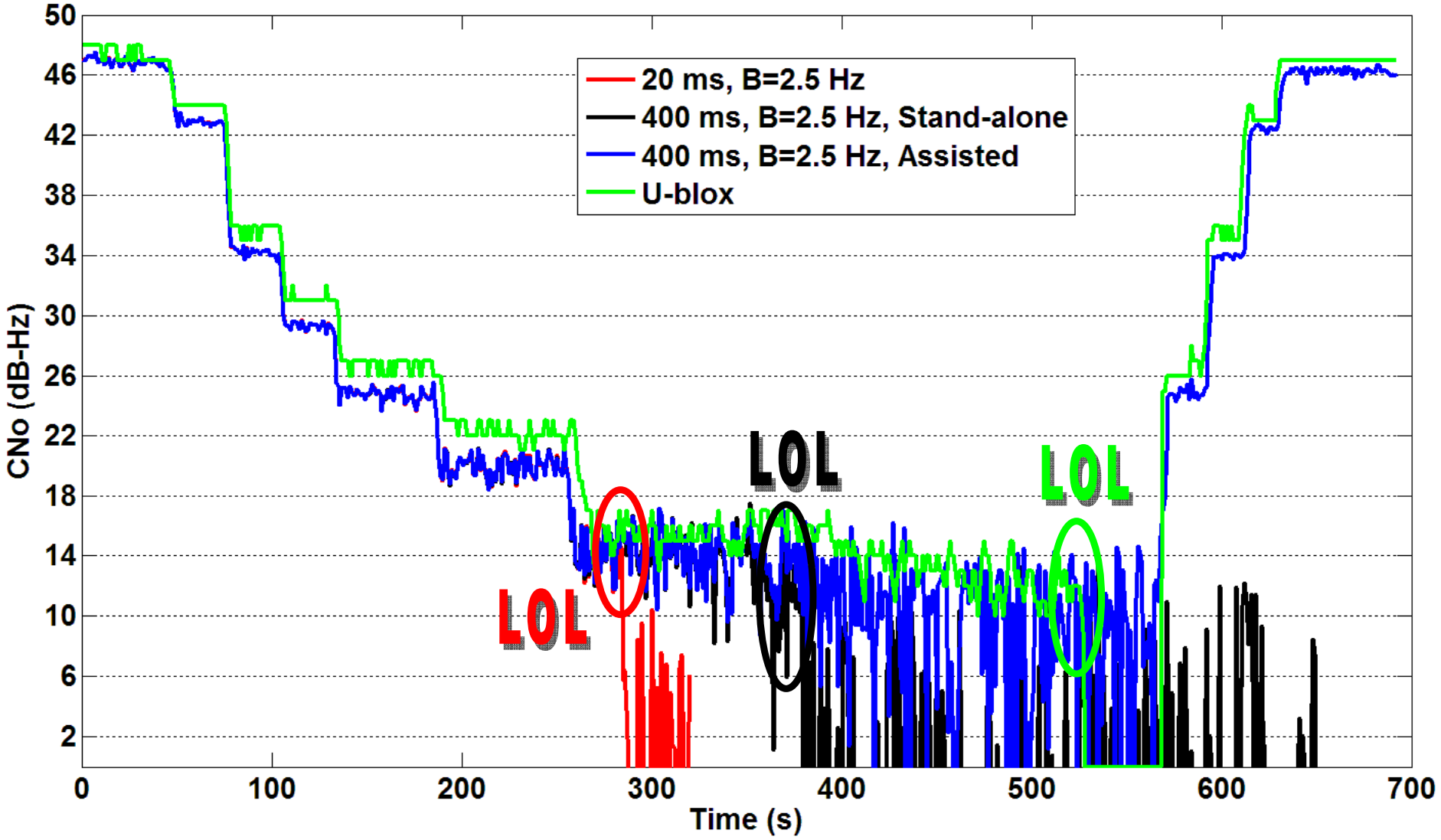
Assisted
Tracking
Loop

GSNRx™

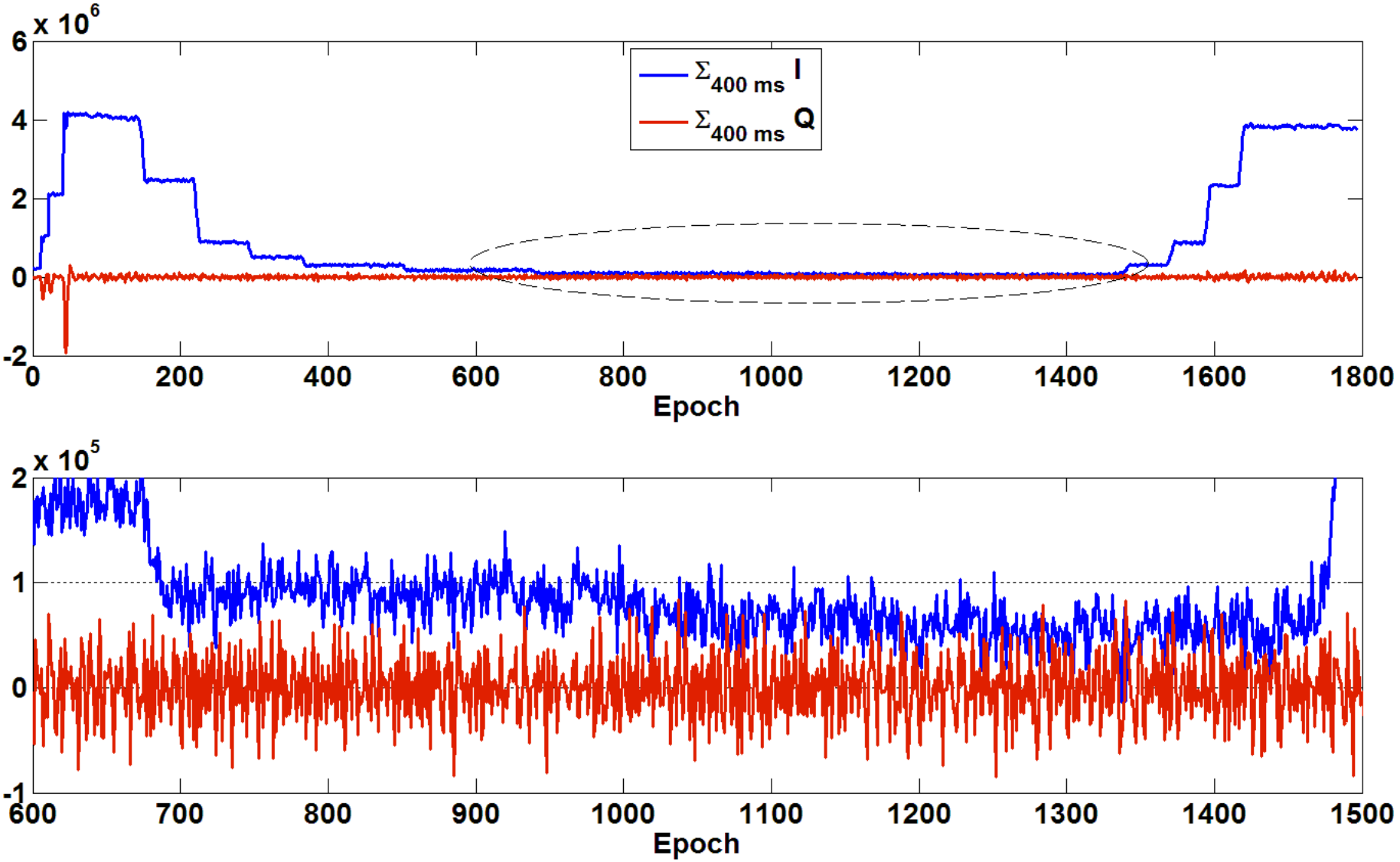
Stand Alone
Tracking
Loop

Tracking
Parameters

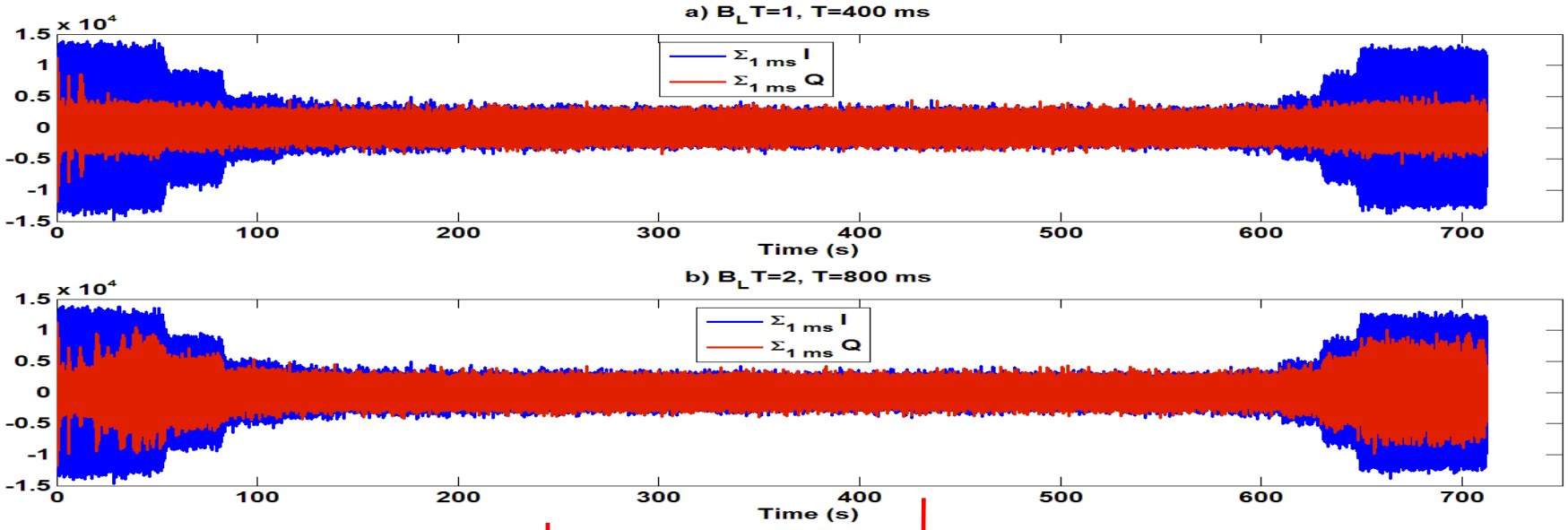
Tracking Results (1/4)

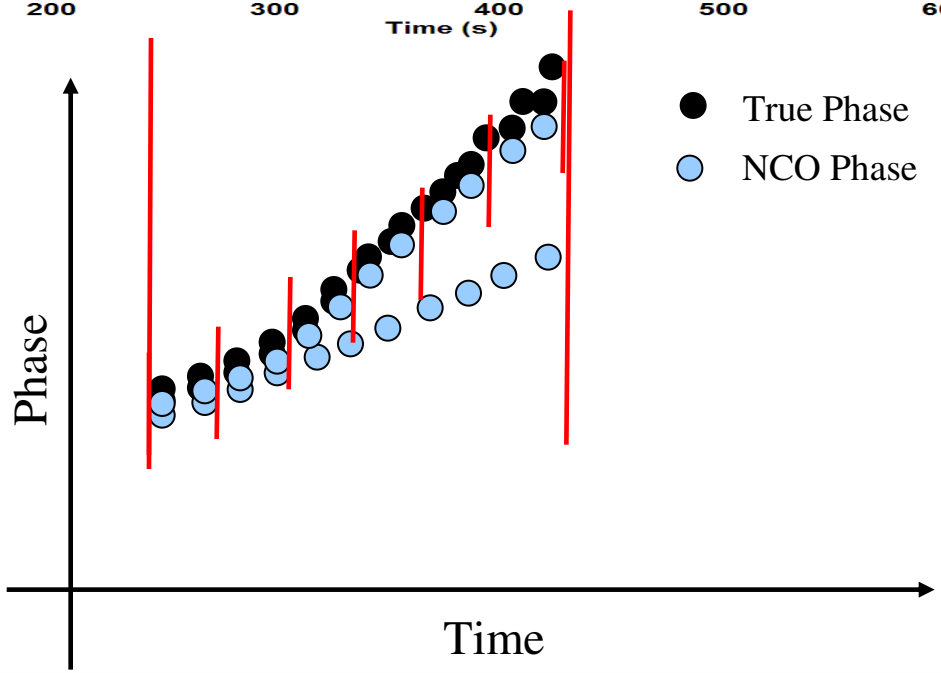


Tracking Results (2/4)

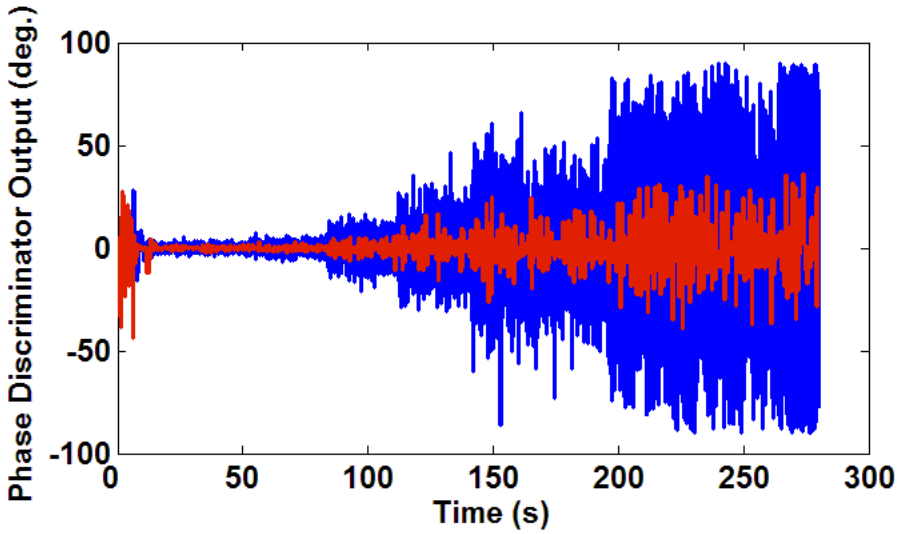


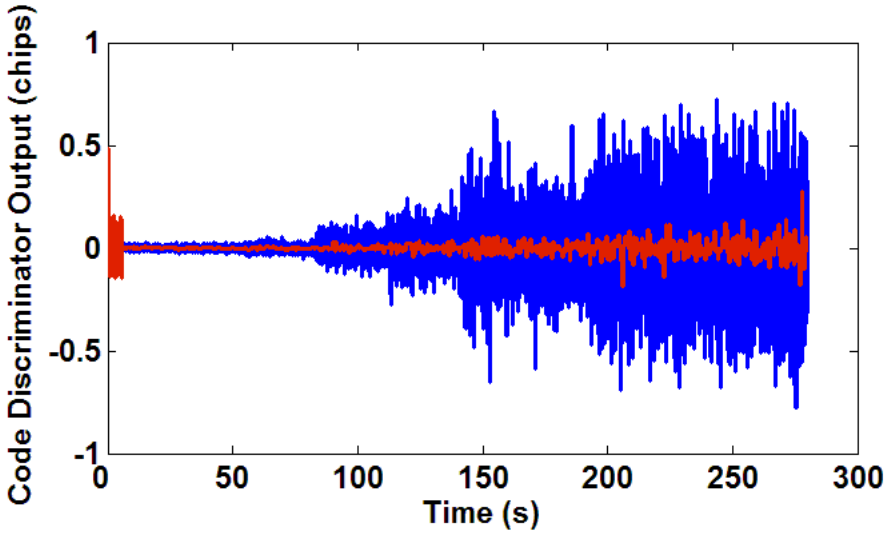
Tracking Results (3/4)

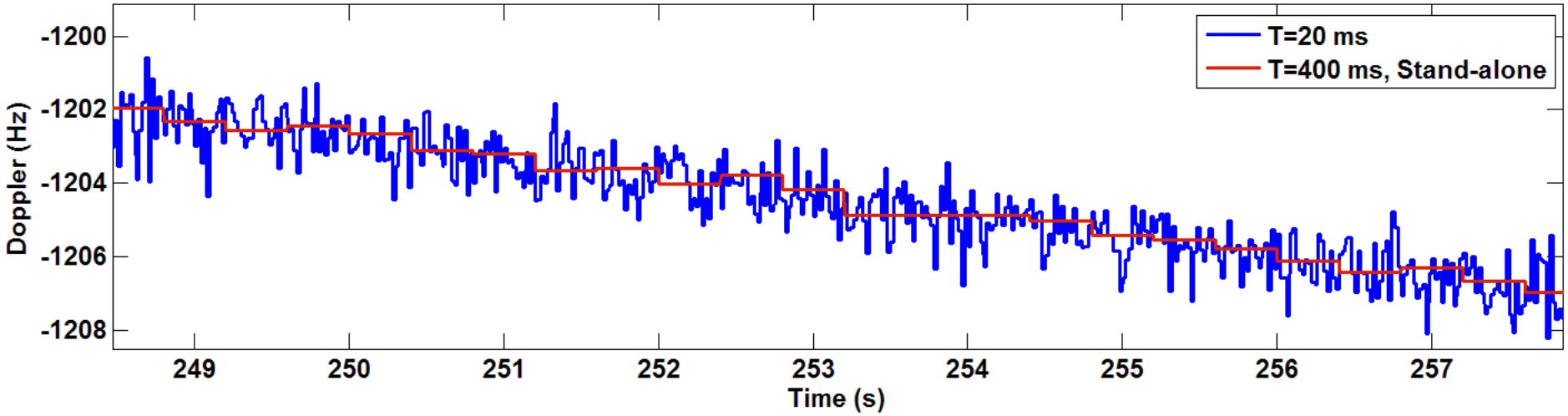




Tracking Results (4/4)







Conclusions and Future Work

- This paper for the first time presents performance of a DPLL in very long integration times.
- Phase and Phase-rate feedback NCO is introduced for GNSS applications and some of its advantageous are discussed.
- Assisted and stand-alone schemes are considered and it is shown that in assisted scheme the phase lock can be achieved down to the 10 dB-Hz for static scenarios.
- Optimum tracking loops in Z-domain, show about 5 dB improvements in comparison with conventional techniques.
- Addition of frequency rate to the DPLL architecture will be considered