Design and Testing of an Intelligent GPS Tracking Loop for Noise Reduction and High Dynamics Applications

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ION Alberta Lunch Meeting
22 OCT 2010

Outline

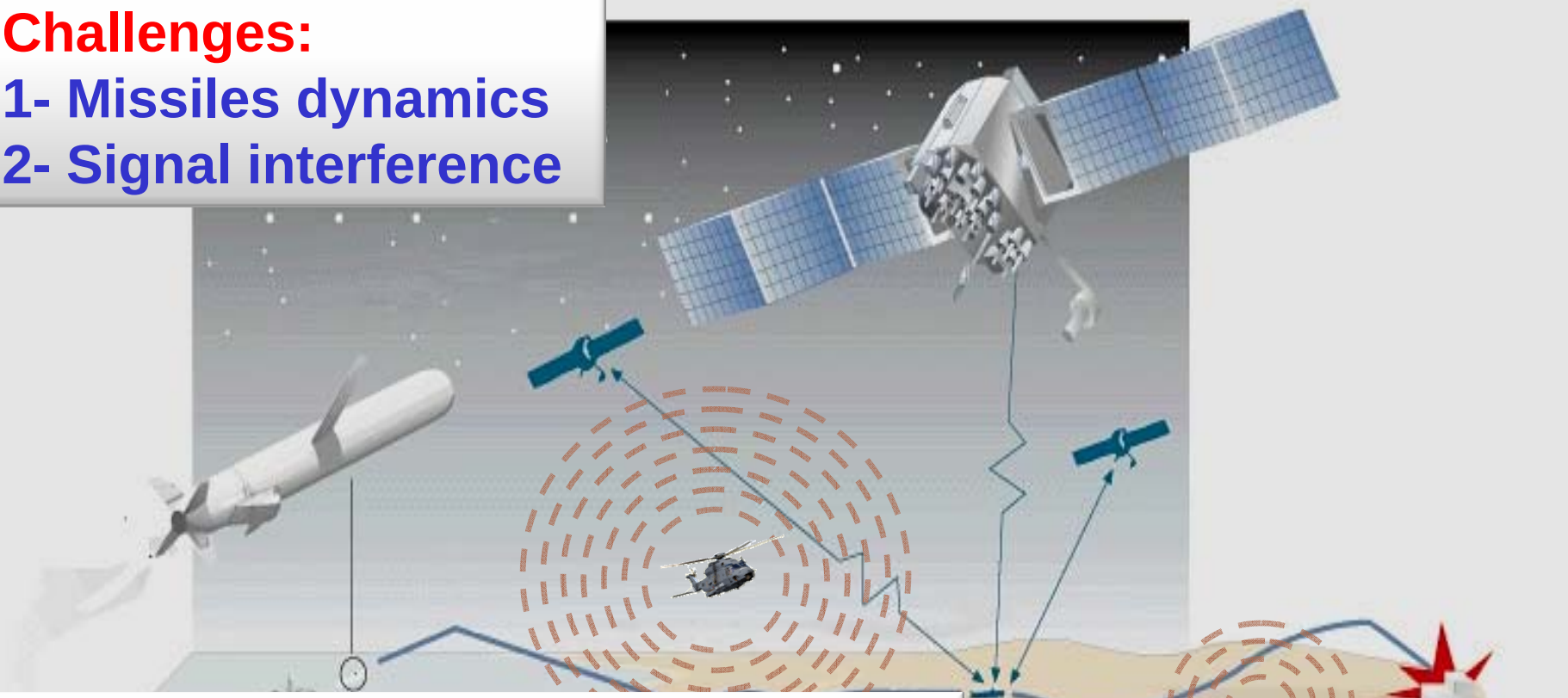
- Motivation
- Background
- Fuzzy logic background
- New design for FLL assisted PLL
- Experimental Setup
- Results
- Conclusions

Motivation

Challenges:

1- Missiles dynamics

2- Signal interference

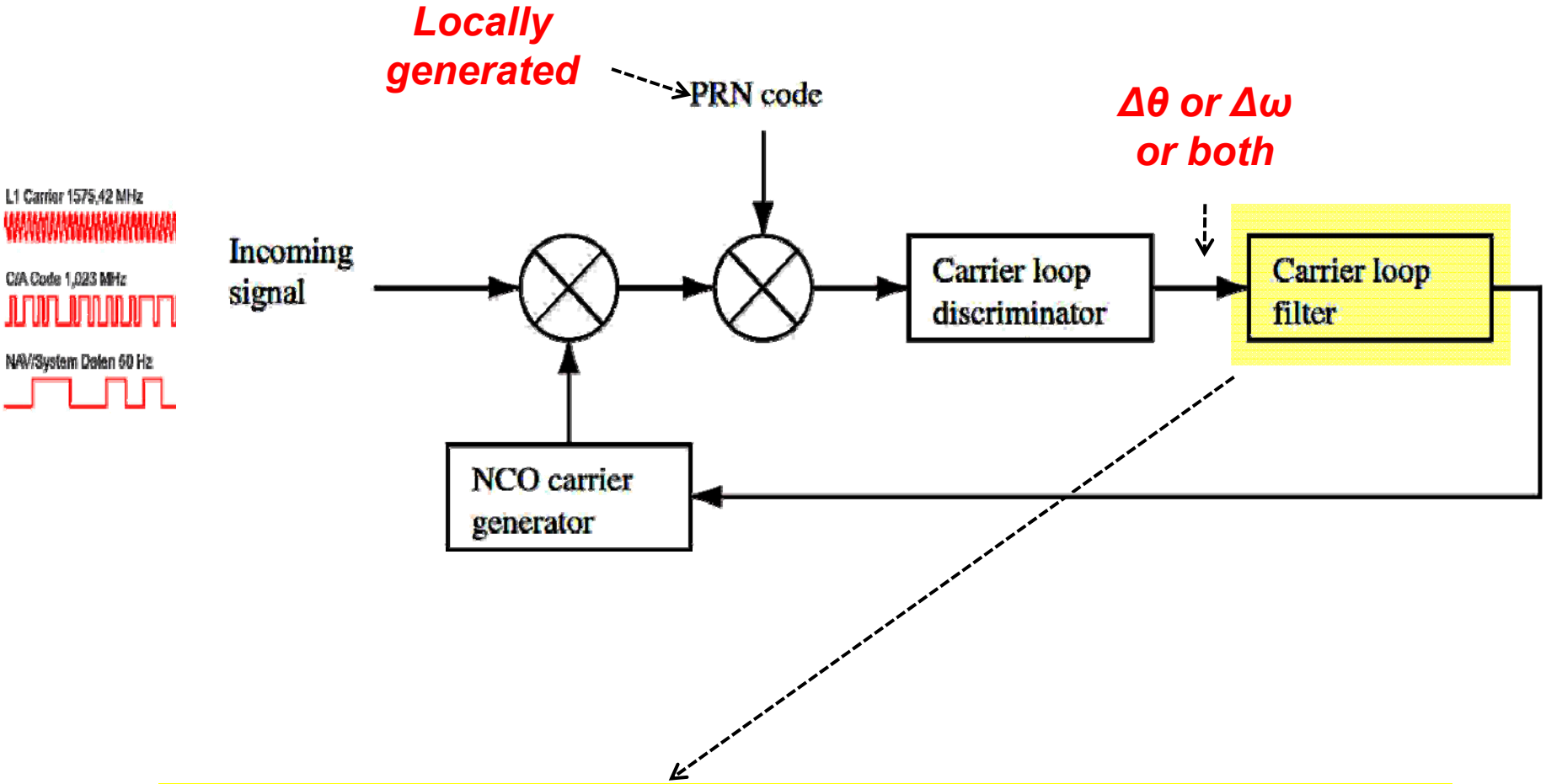


PLL bandwidth (BW) requirements :

1- Missiles dynamics → wide BW

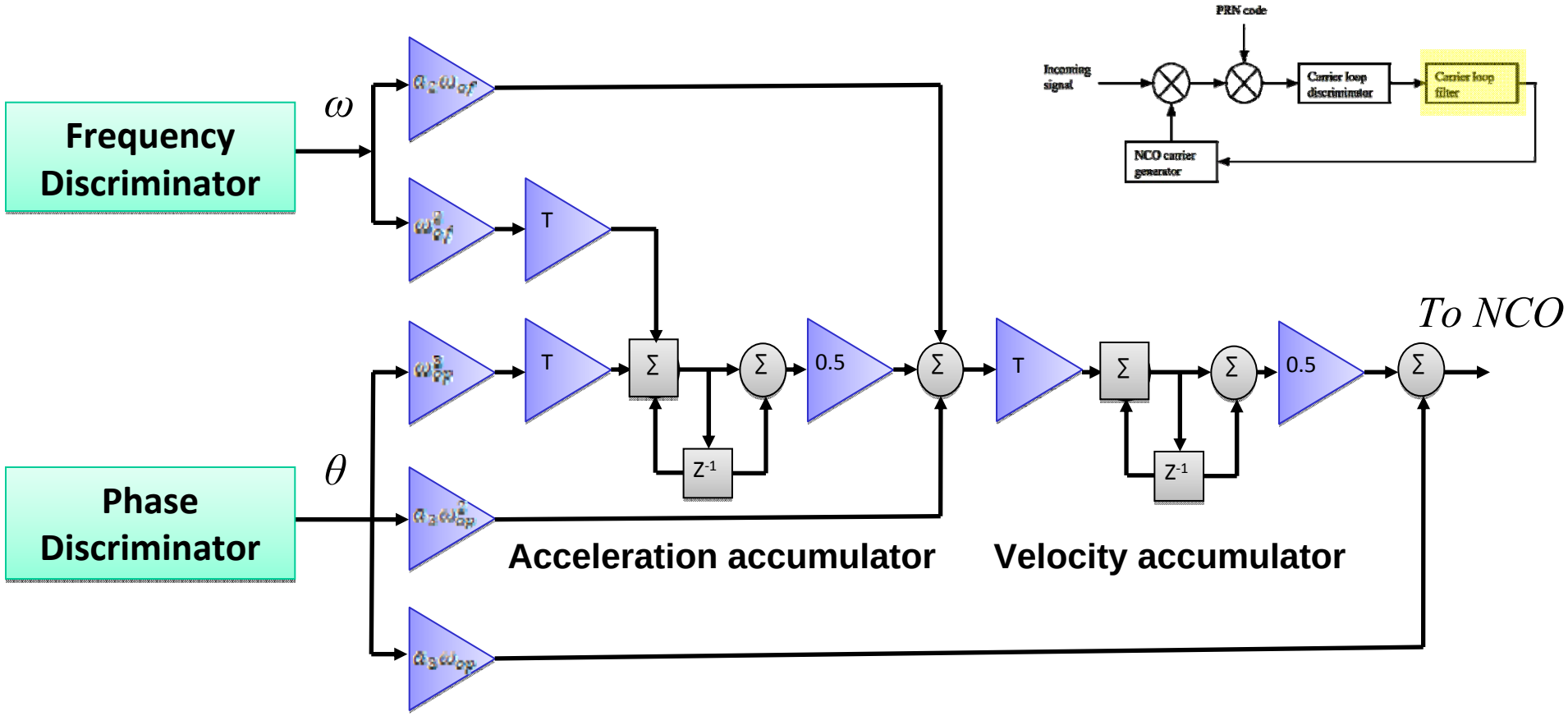
2- Signal interference → narrow BW

Basic PLL block diagram



-Specifies the loop bandwidth
-Can be 1st , 2nd, or 3rd order
-3rd order filter is chosen because it is sensitive to dynamic jerks

FLL Assisted PLL Classic Design



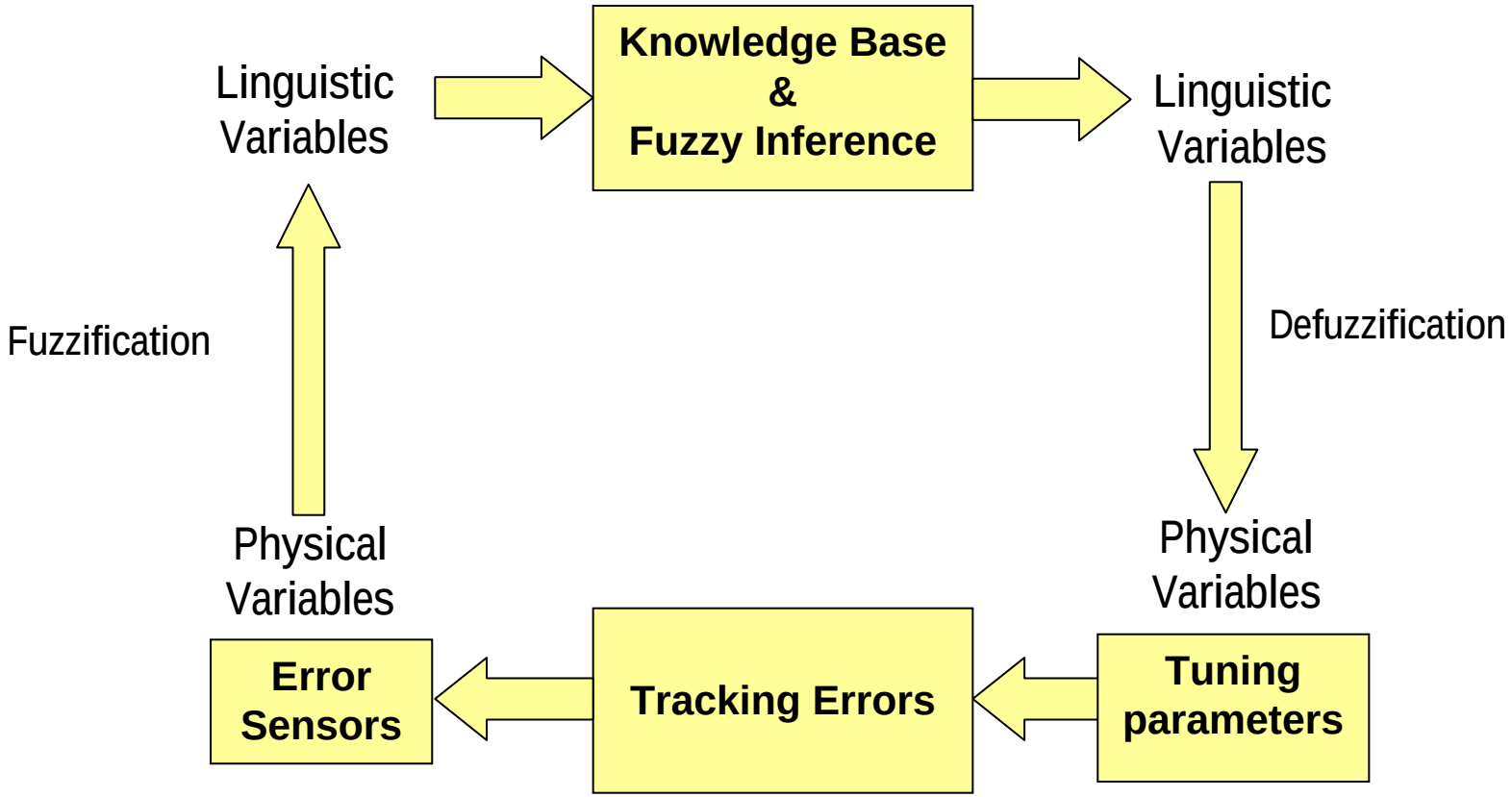
- 3rd order PLL assisted with 2nd order FLL
- All gains are calculated from the loop bandwidth which is a design parameter

Kaplan, E. D. (2006) *Understanding GPS: Principles and Applications, Second Ed., Artech House, INC., Norwood, MA 02062*

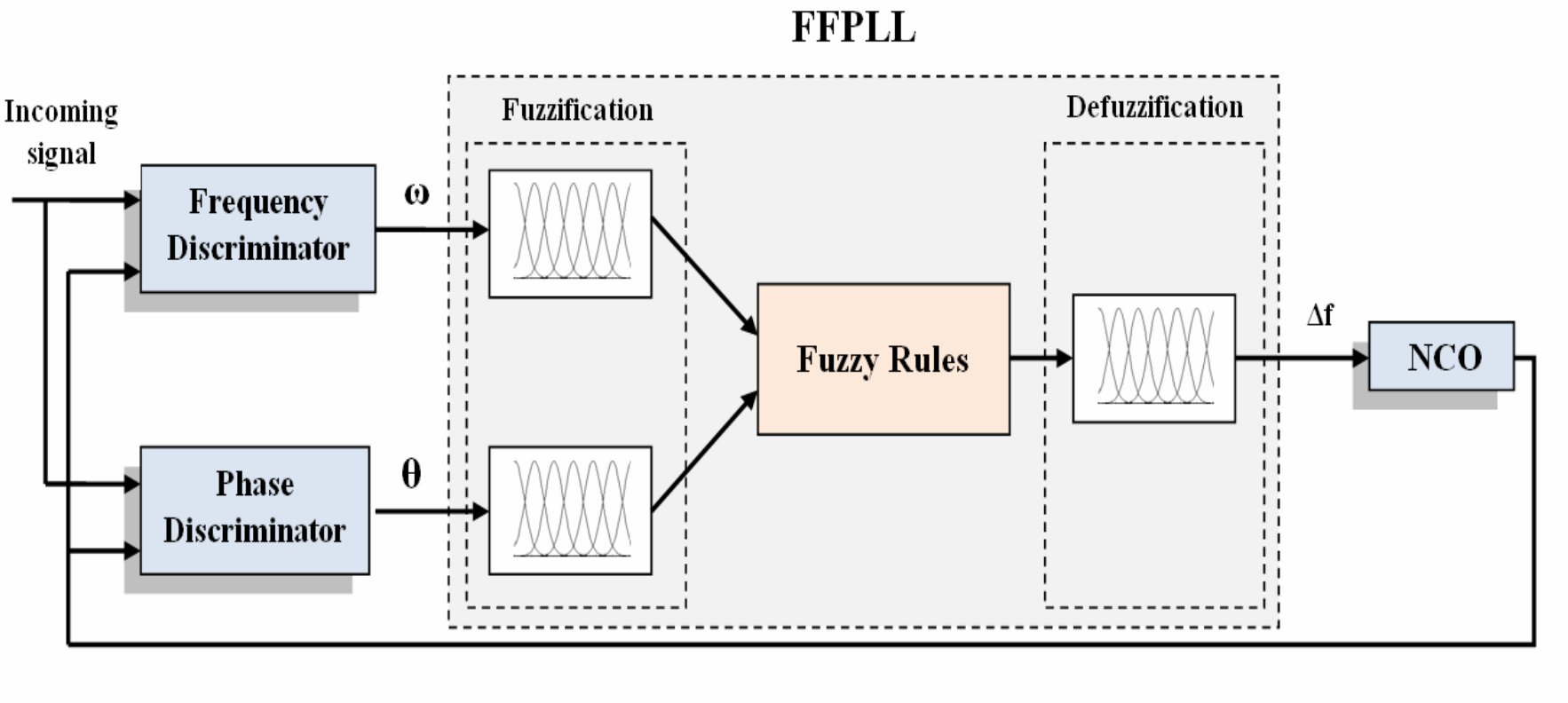
Fuzzy Logic

What Is Fuzzy Logic?

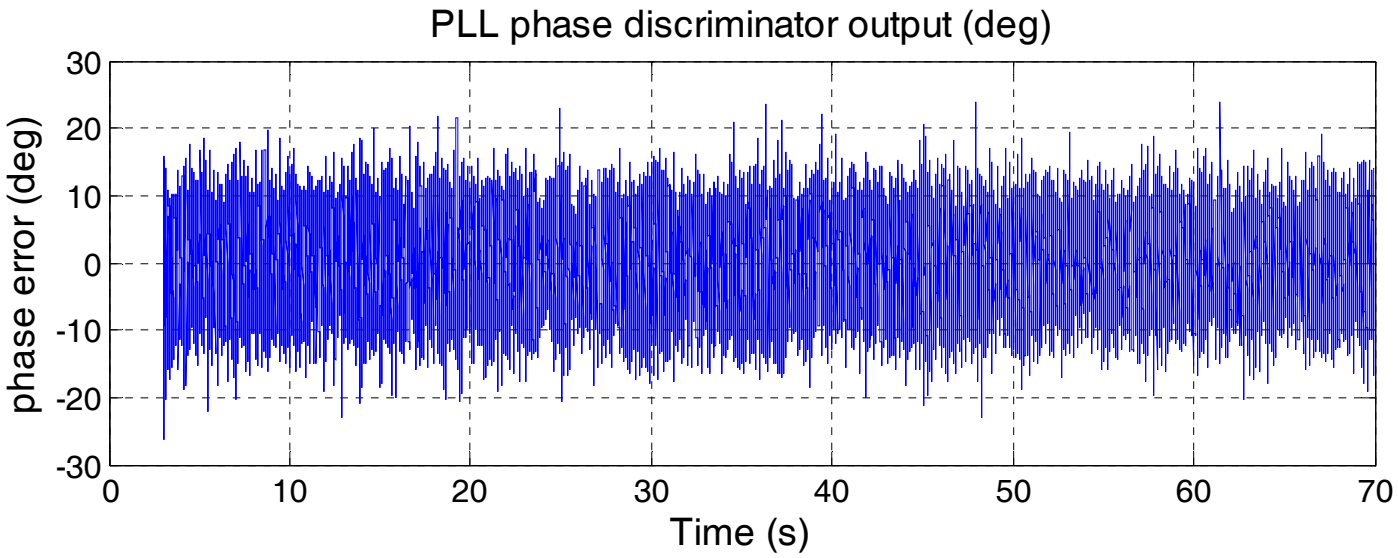
- **Quantification of *linguistic information* while allowing for *imprecision***

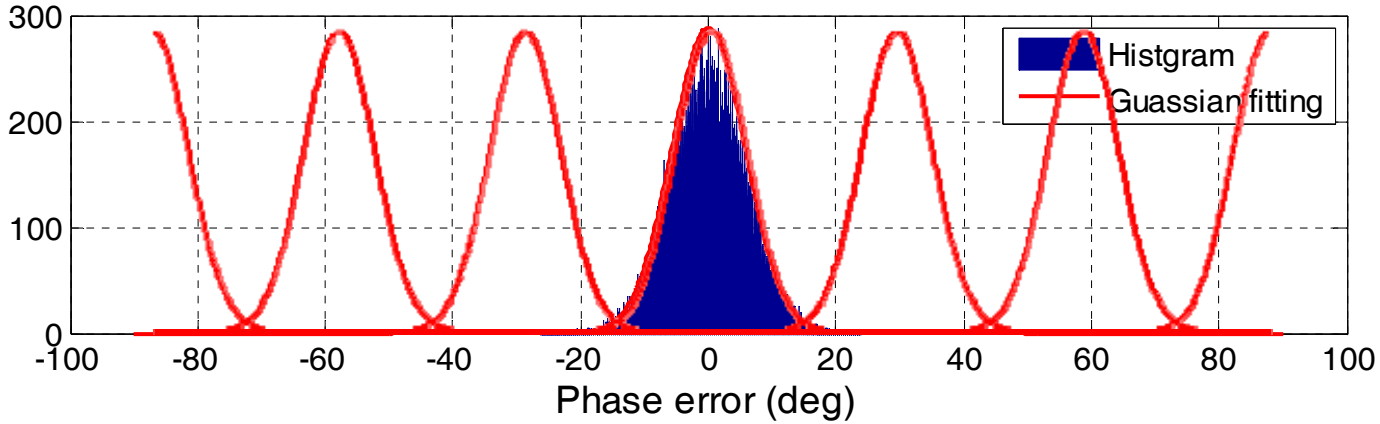


Fuzzy Frequency Phase lock Loop (FFPLL)



Membership Functions Design (1/2)





-BIG -MED -SMALL ZERO +SMALL +MED +BIG

Membership Functions Design (2/2)

Type	Fuzzy Variable	Number of MFs
Input(1)	Phase	9
Input(2)	Frequency	7
output	NCO Tuning frequency	11

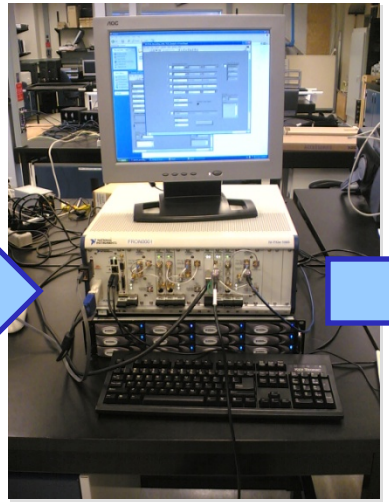
Coarse Tuning ⟵ *Fine Tuning* ⟶ *Coarse Tuning*

θ↓ ω→	-B	-M	-S	Ze	+S	+M	+B
-B	+B	+MB	-M	-M	-M	-MB	-B
-MB	+B	+MB	-SM	-M	-M	-MB	-B
-M	+B	+MB	-S	-SM	-M	-MB	-B
-S	+B	+MB	Ze	-S	-SM	-MB	-B
Ze	+B	+MB	+S	Ze	-S	-MB	-B
+S	+B	+MB	+SM	+S	Ze	-MB	-B
+M	+B	+MB	+M	+SM	+S	-MB	-B
+MB	+B	+MB	+M	+M	+SM	-MB	-B
+B	+B	+MB	+M	+M	+M	-MB	-B

B: Big, MB: Medium Big, M: Medium, SM: Small Medium, S: Small, Ze: Zero.

Experiment Setup (1/2)

Parameters	Value
Sampling frequency	f_s = 10 MHz
Intermediate frequency	f_{IF} = 0.42 MHz
Sampling	Complex

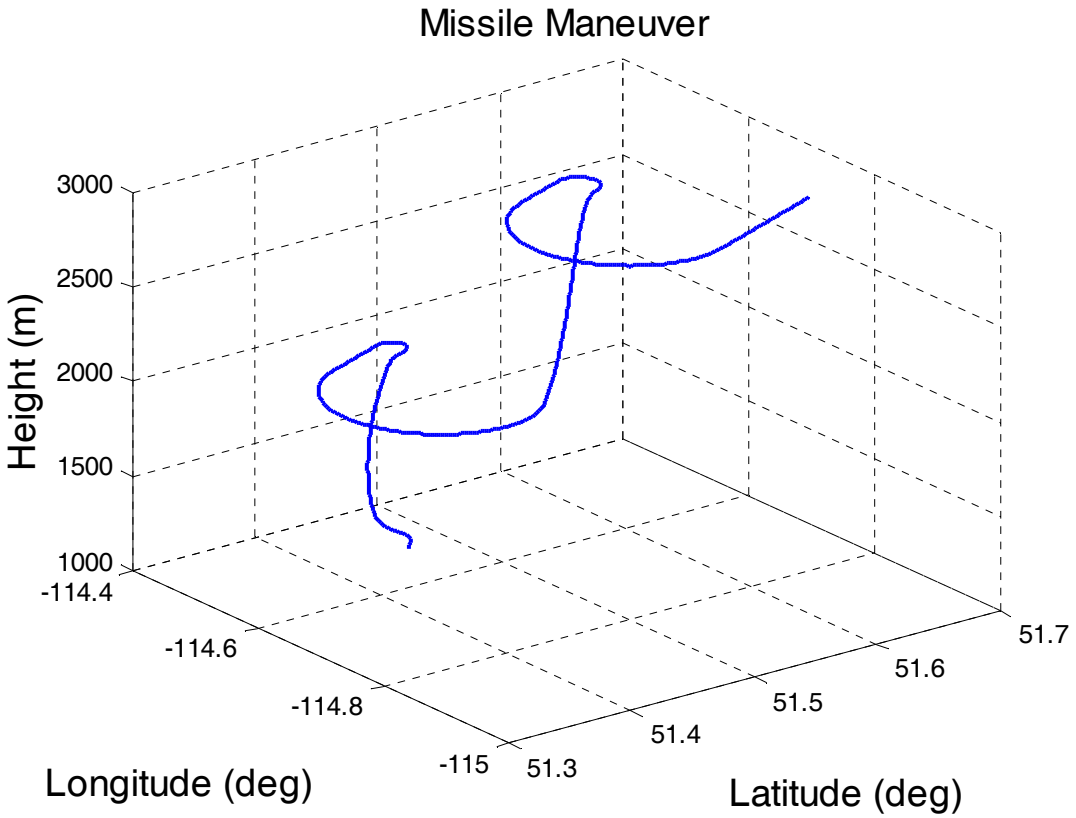


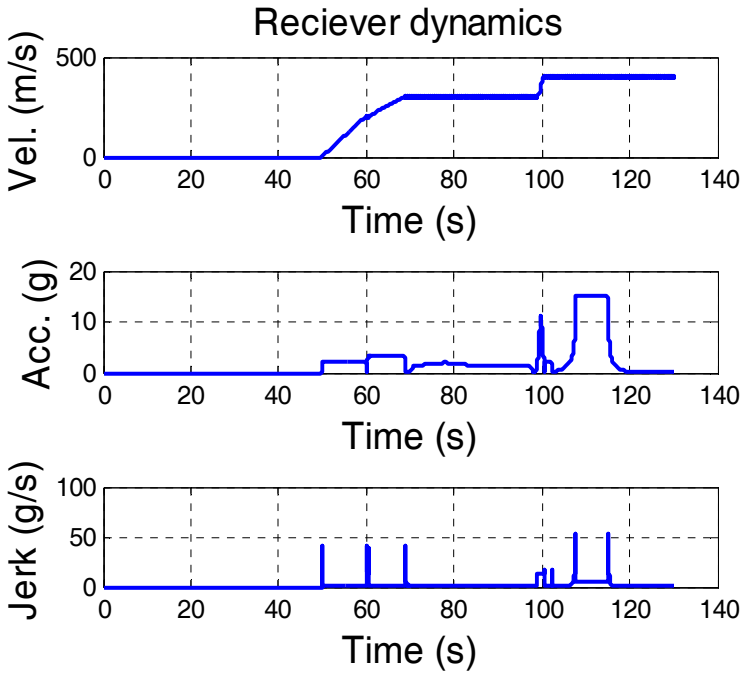
Post processing

GPS H/W simulator
Spirent GSS7700

National Instrument
RF Front End

Experiment Setup (2/2)

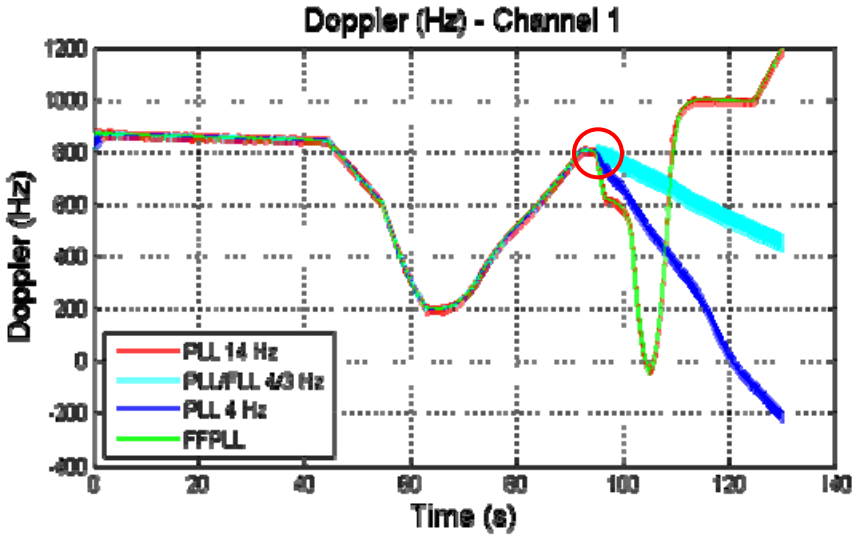


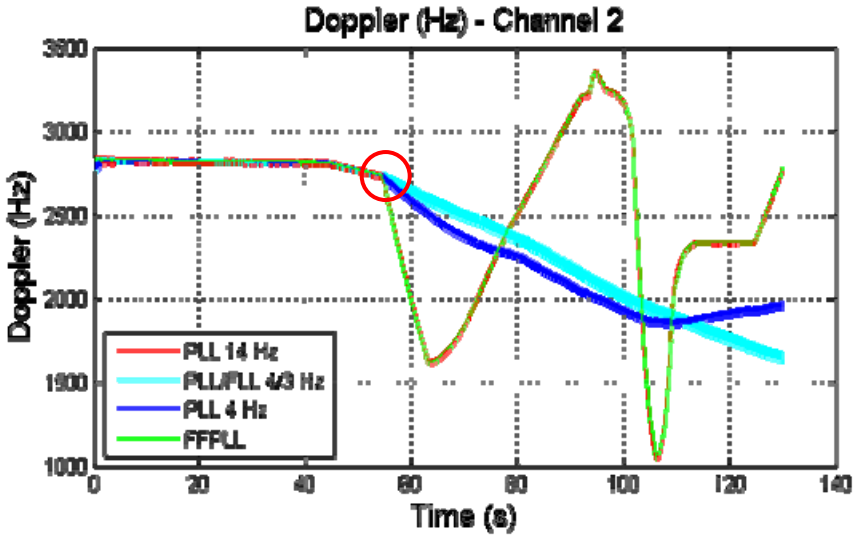


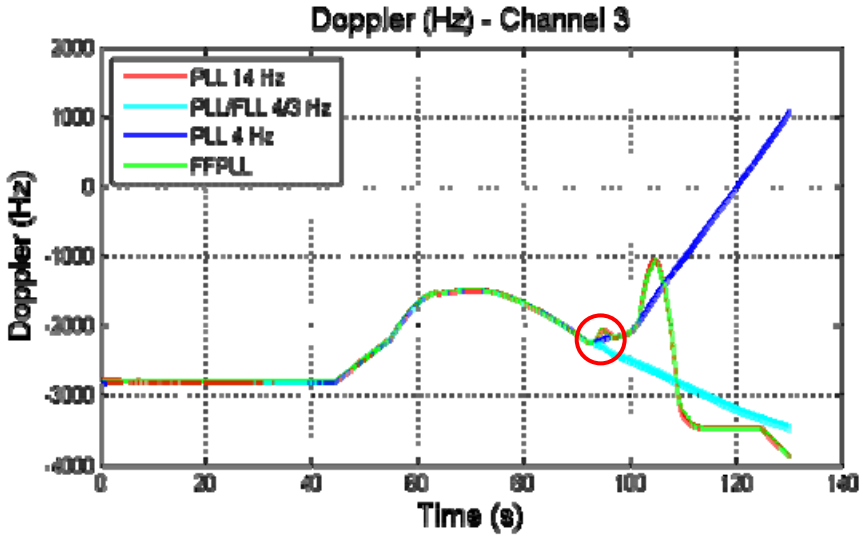
Scenario: Highly dynamic- Velocity: 400 m/s- Acceleration: up to 15 g
Jerk: up to 50 g/s

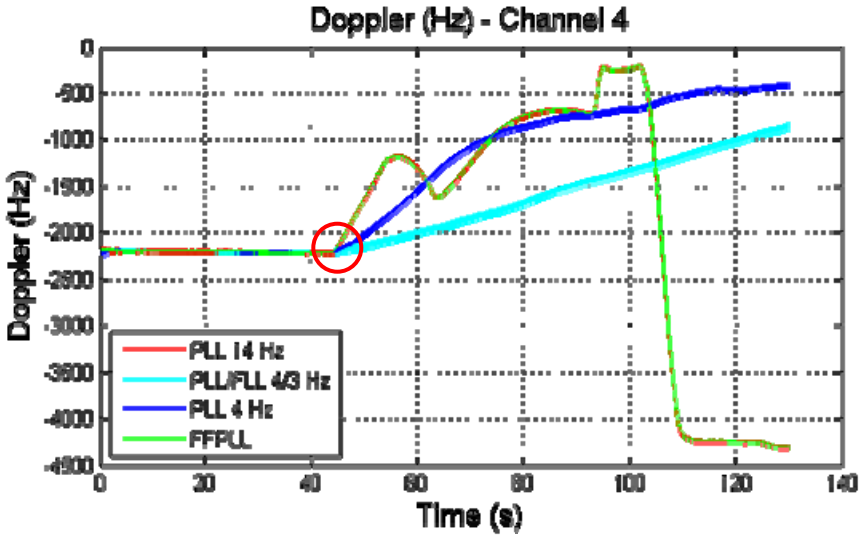
Results (1/3)

Continuity



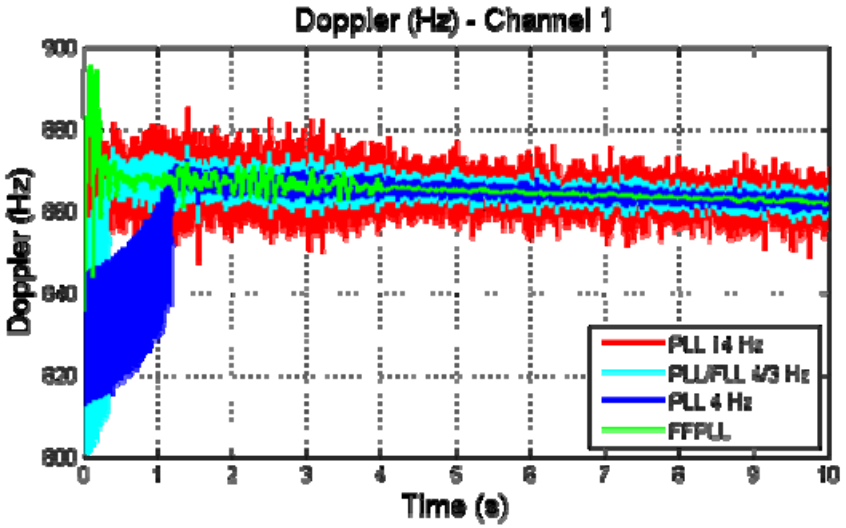


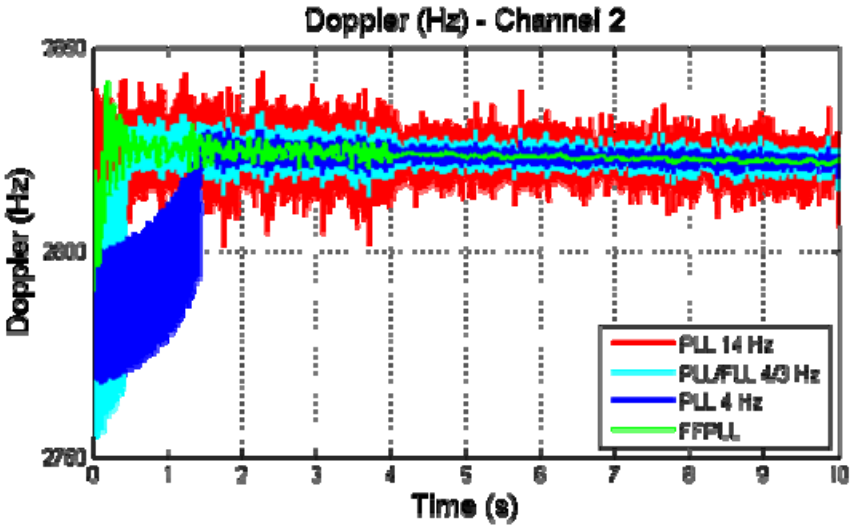


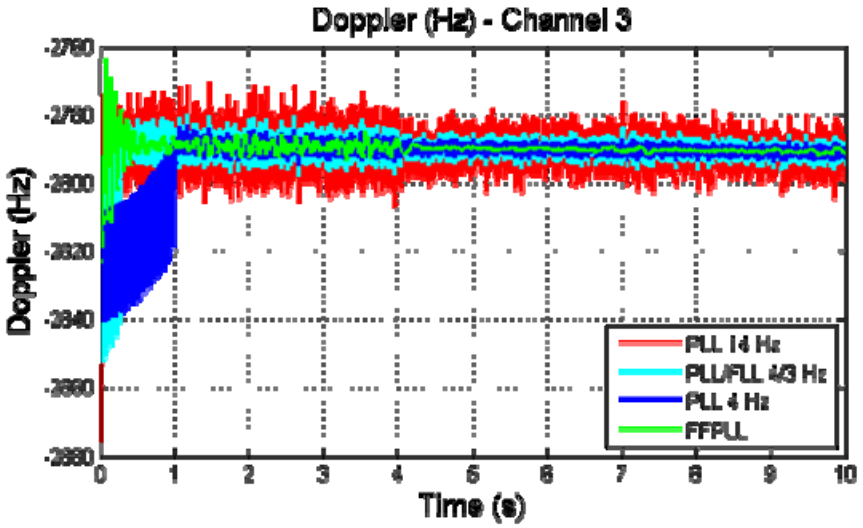


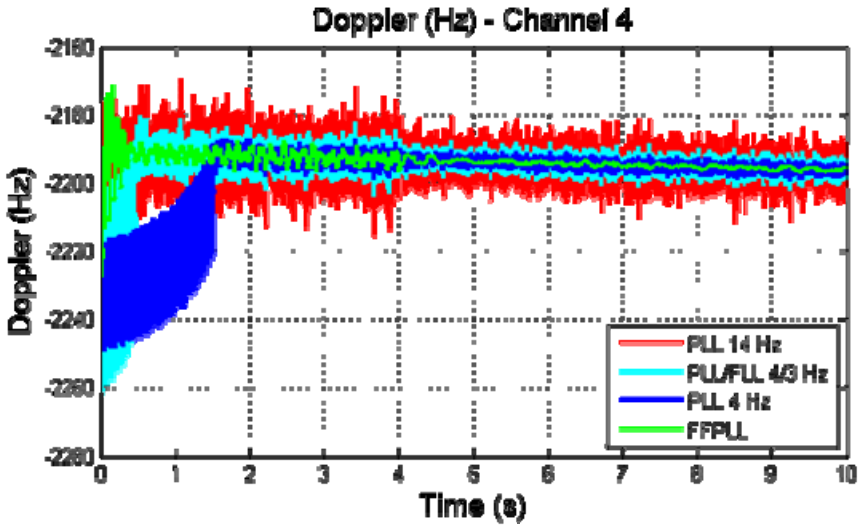
Results (2/3)

Speed and Accuracy



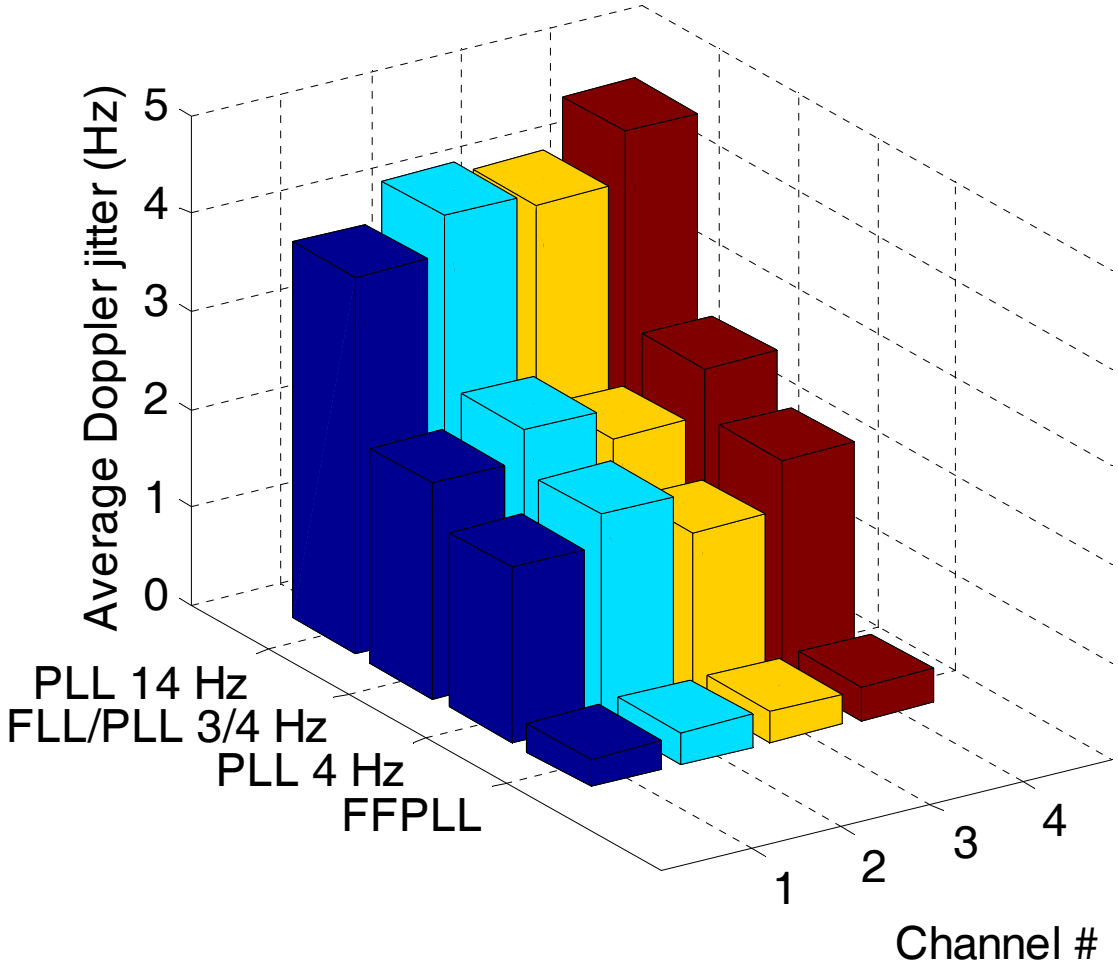






Results (3/3)

Doppler Tracking Jitter (average)



Conclusions

- It is difficult to solve for dynamic robustness and noise rejection at the same time using classic PLL or FLL assisted PLL

- Fuzzy systems can be used to replace the classic FLL assisted PLL noise filter and provide better dynamic performance and better noise rejection level

- The proposed FFPLL performs as if it is a very narrow noise bandwidth PLL, in terms of noise level, and its dynamic performance is as fast as a wide PLL performance

- Future work: Adaptive shaping of the input MFs to accommodate C/No variations due to signal interference

Questions????

References

- Bogatin, E. (2003) Signal Integrity - Simplified, Prentice Hall PTR
- Kaplan, E. D. (2006) *Understanding GPS: Principles and Applications, Second Ed., Artech House, INC., Norwood, MA 02062*
- Mao, W. L., H. W. Tsao, and F. R. Chang (2004) "Intelligent GPS receiver for robust carrier phase tracking in kinematic environments," *IEE proceedings. Radar, sonar and navigation, vol. 151, (no3), pp. 171-180*
- Mao, W. L. (2007) "Applications of New Fuzzy Inference-Based Tracking Loops for Kinematic GPS Receiver," *Circuits, Systems, and Signal Processing, Volume 26, (Number 1), February, 2007, 91-113*
- Ross, T. J., J. M. Booker, and W. J. Parkinson (2002) *Fuzzy Logic and Probability Applications, American Statistical Association Society for Industrial and Applied Mathematics, Alexandria, Virginia*
- Sadati, N., and A. T. Balaei (2006) "Fuzzy goal coordination of large-scale systems using Tamura's method," Vancouver, BC, Canada, 1355-1361, Institute of Electrical and Electronics Engineers Inc.
- Simon, D., and H. El-Sherief (1994) "Fuzzy phase-locked loops," Las Vegas, NV, USA, 252-259, Publ by IEEE
- Unglaub, R. A. G., and D. Chit-Sang Tsang (1999) "Phase tracking by fuzzy control loop," *Aerospace Conference, 1999. Proceedings. 1999 IEEE, 57-66 vol.55,*
- Zadeh, L. A. (1965) "Fuzzy Sets," *Information and Control, Volume 8, 338-353*