



# **GNSS Receiver Autonomous Integrity Monitoring Based on Vector Tracking Loop**

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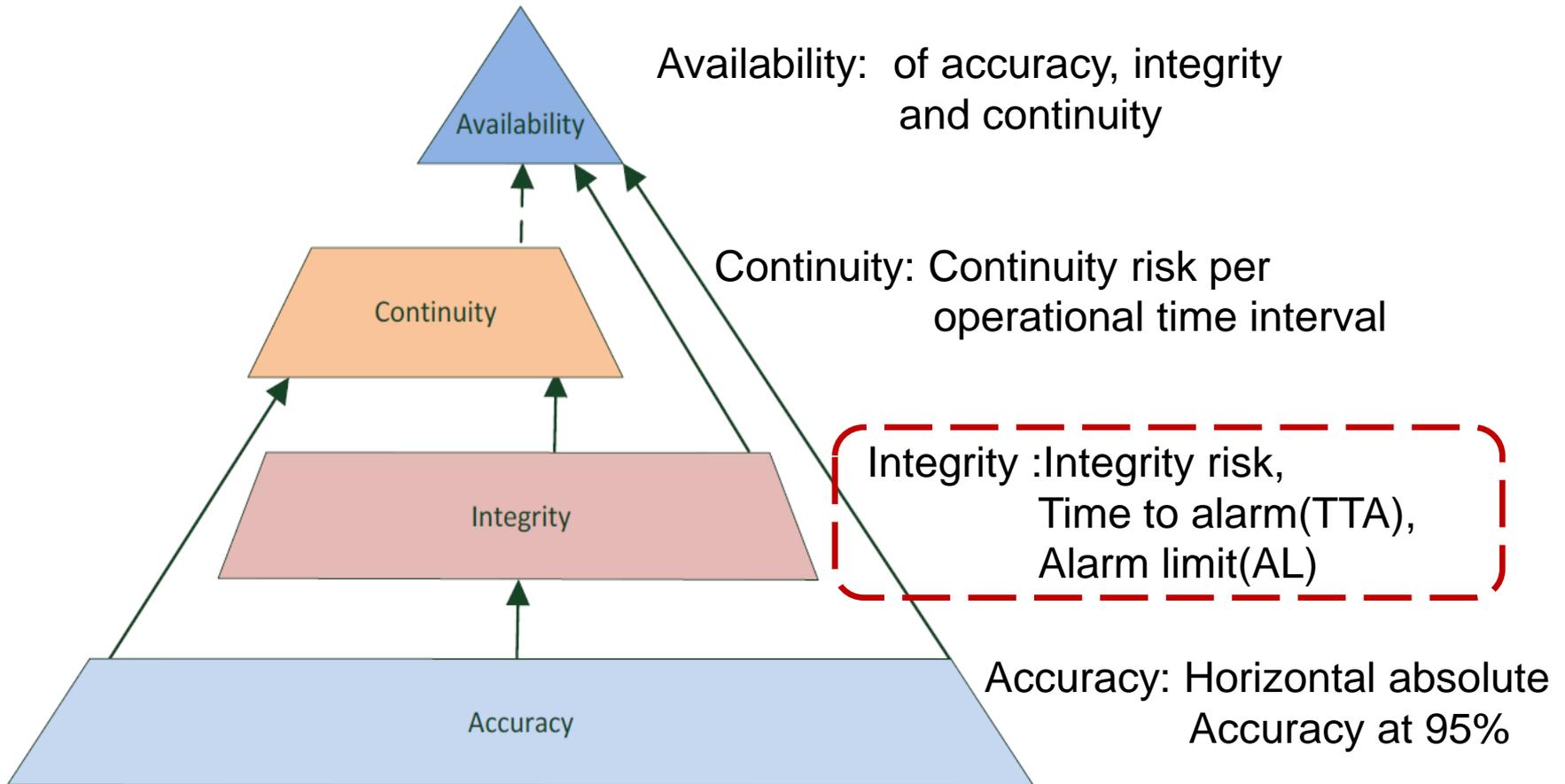
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# INTRODUCTION



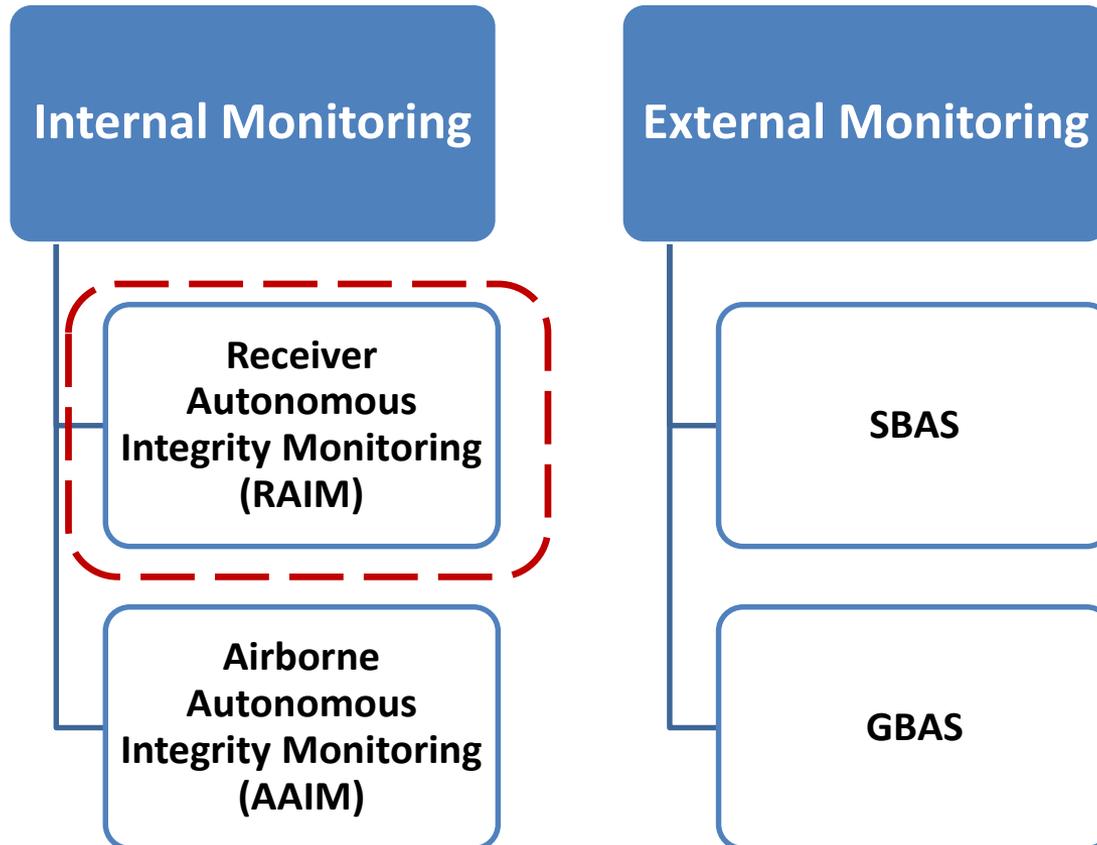
# 1 Introduction

**Accuracy requirement** is crucial for any **GNSS application!!!**





# 1 Introduction





# 1 Introduction

## Receiver Autonomous Integrity Monitoring (RAIM)

- ❖ RAIM compares **redundant pseudo range measurements** against each other to determine **identify and eliminate outlier**.

Redundancy of range measurements

Fault Identification

Fault Exclusion

Precise Position

No.		
1		
2		
3		
4	1.3.4.5	×
5	2.3.4.5	
1.2.4.5		

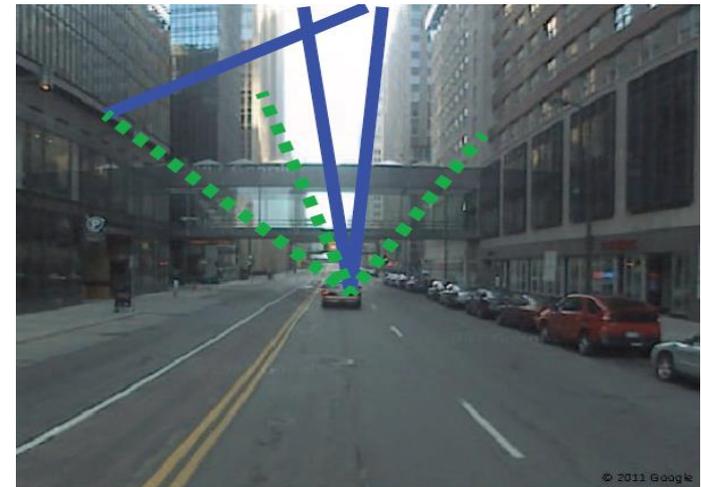
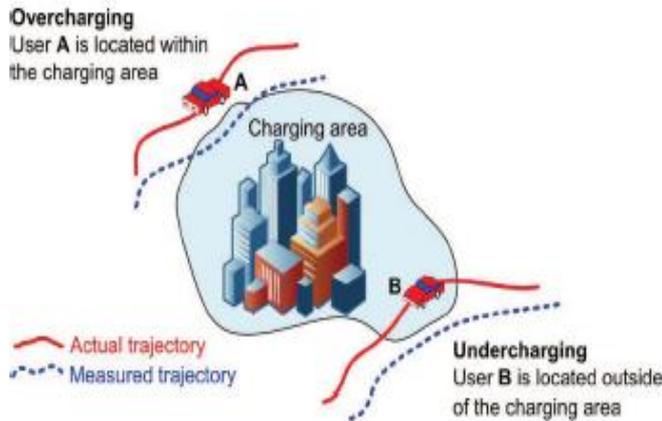
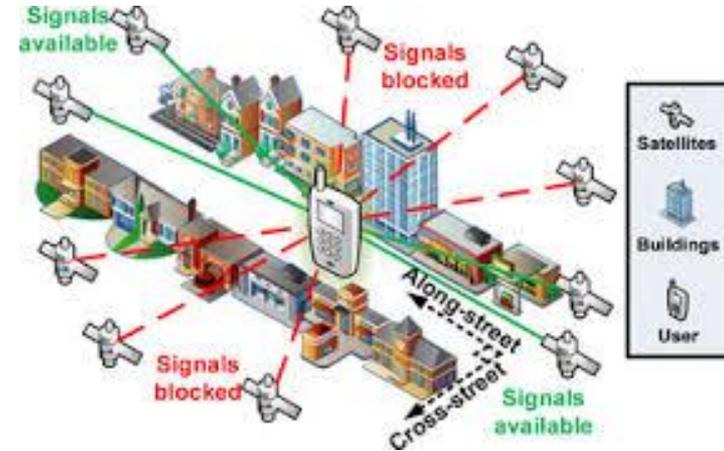
# PROBLEM STATEMENT



# 2 Problem Statement

## Problem

- ❖ Urban area where GNSS signal is weak
- ❖ Momentarily loss or attenuation of GPS signals
- ❖ Safety-of Life (SoL) applications
- ❖ Scalar loop does not reliable for weak signal

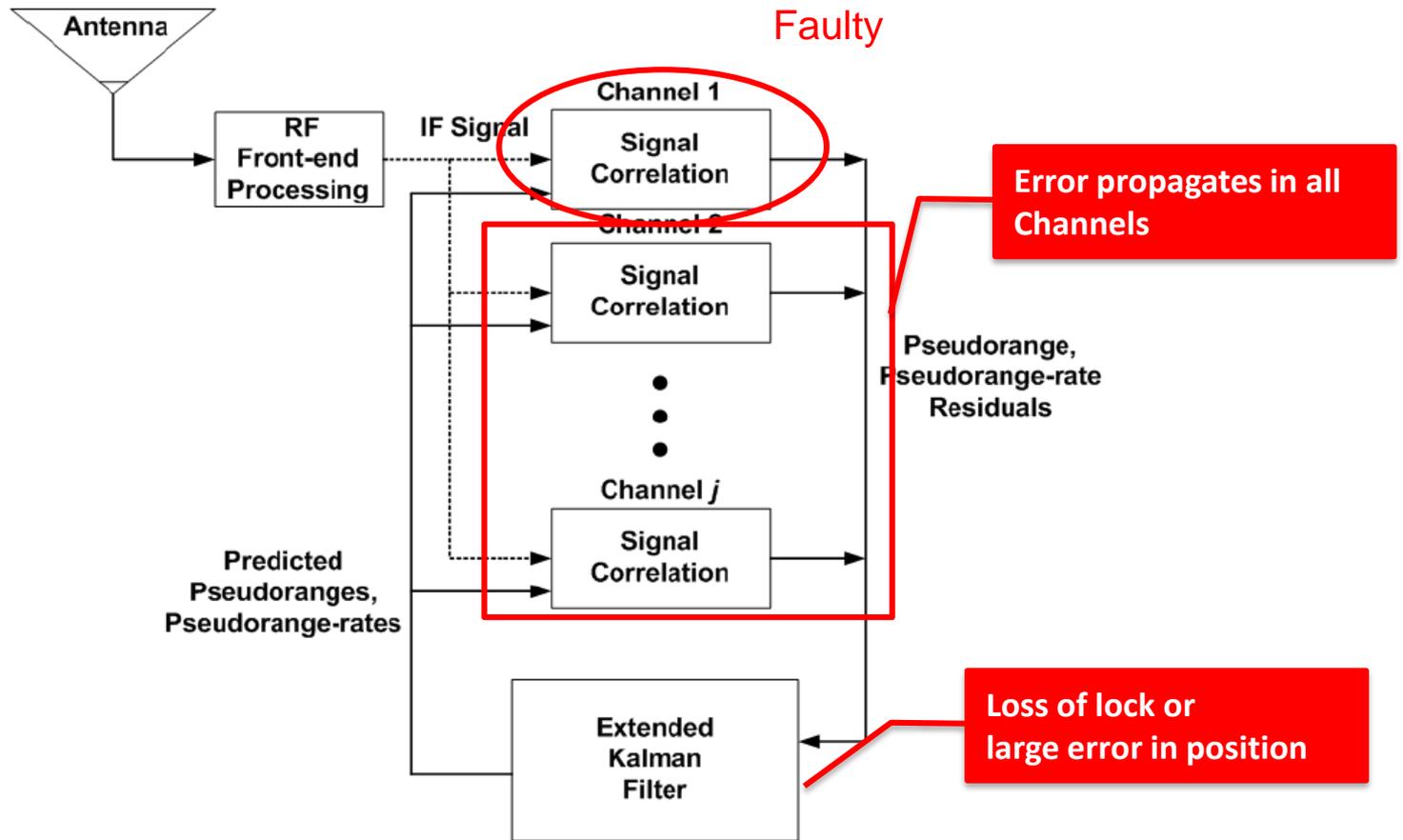




# 2 Problem Statement

## Vector Loop Architecture

Vector-based tracking loops combine the two tasks of signal tracking and position/velocity estimation into one algorithm





## 2 Problem Statement



*'To design **RAIM algorithm** based on **Vector Tracking Loop** and compare performance of **Vector Loop RAIM** with a **Traditional Scalar Loop RAIM**'*

# RESEARCH WORK



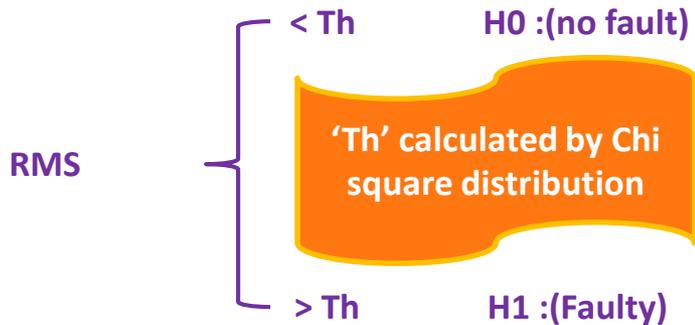
# 3 Scalar Tracking Loop RAIM

**Based on Pseudorange Residual**



Root Mean Square of Pseudorange Residual

$$RMS = \sqrt{\Delta\rho^T \cdot \Delta\rho}$$



Maximum likelihood Method

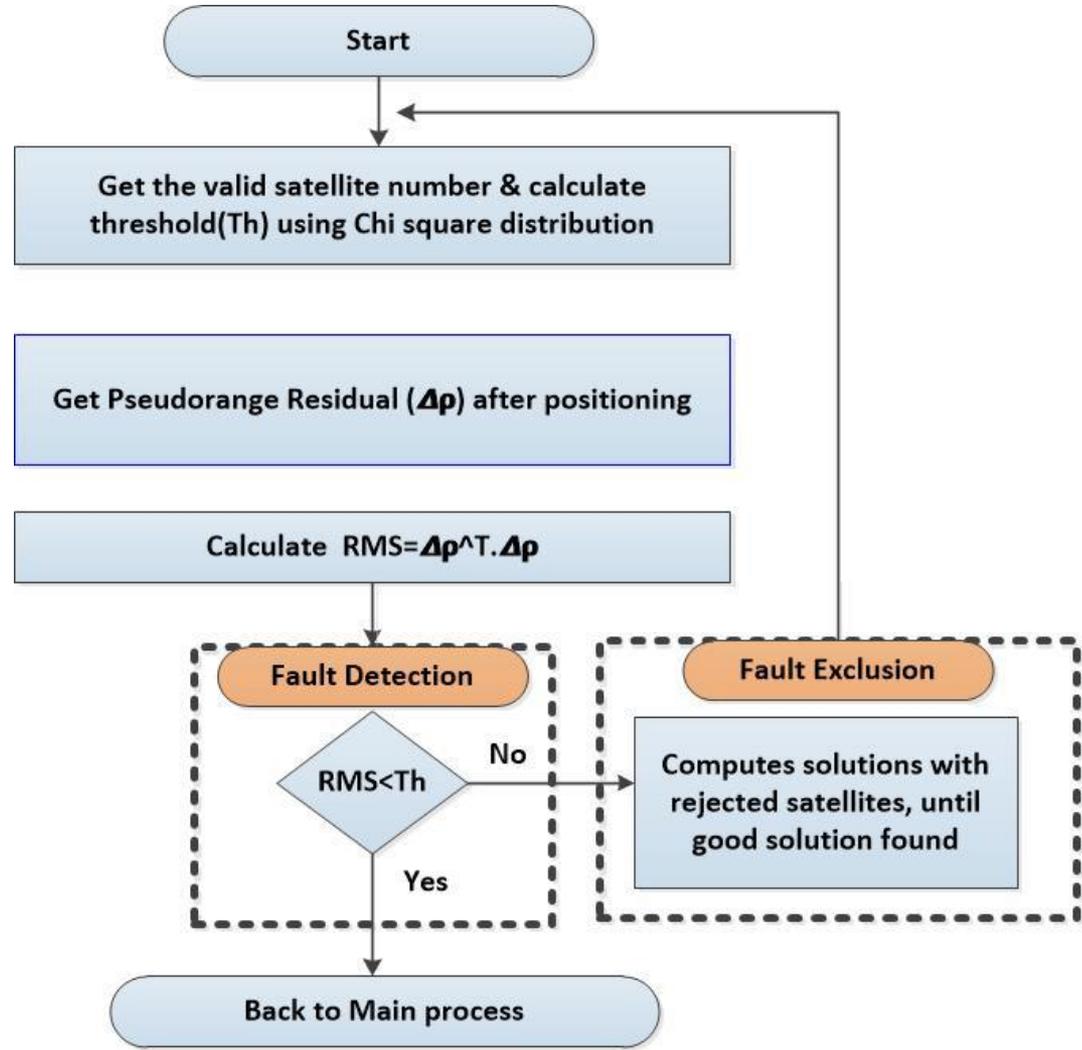
Suppose PRN-1 is Faulty

Subset Index	Subset	Solution
1	1,2,3,4,5	Faulty
2	1,2,3,5,6	Faulty
3	1,2,4,5,6	Faulty
4	1,3,4,5,6	Faulty
5	1,2,,3,4,5	Faulty
6	2,3,4,5,6	Correct

Computes many different solutions with different satellites until a good solution is found.



# 3 Scalar Tracking Loop RAIM

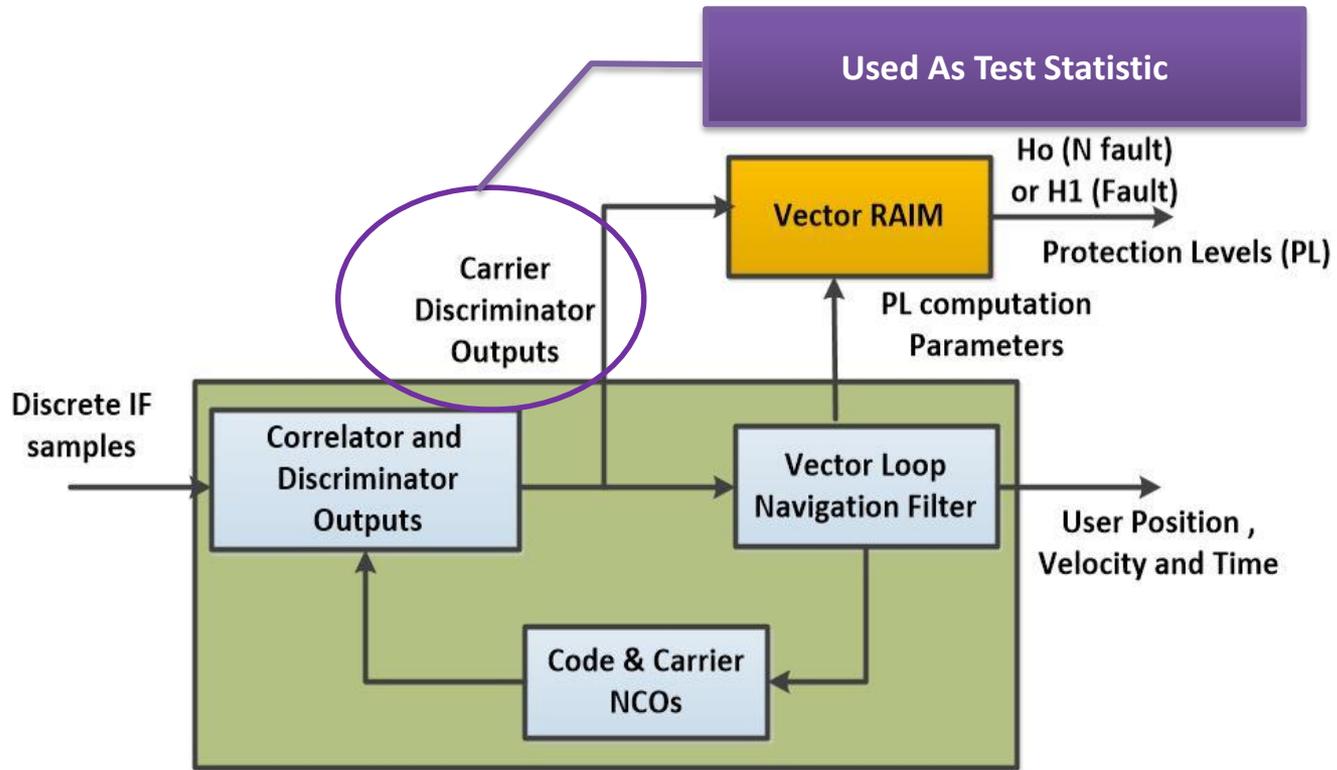




# 3 Vector Tracking Loop RAIM

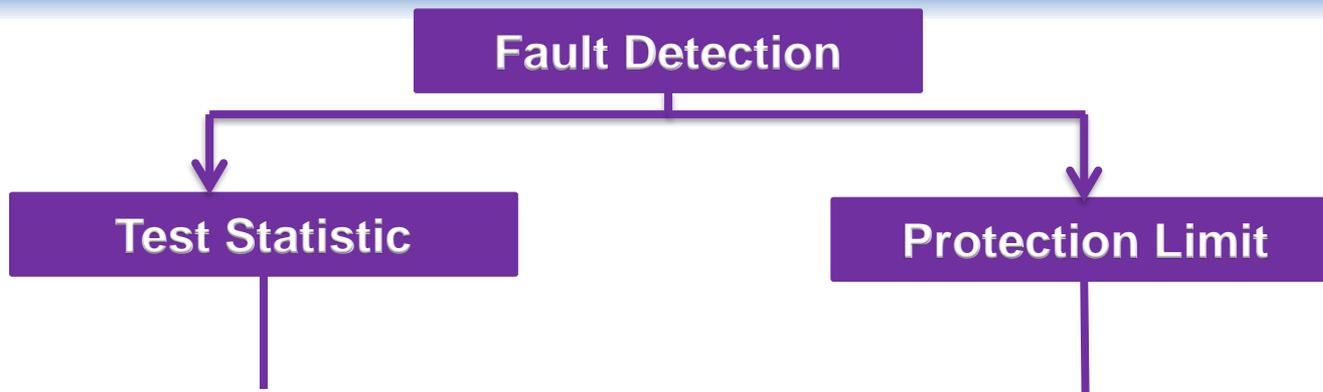
~~Based on Pseudorange Residual~~

Based on Carrier Discriminator Output





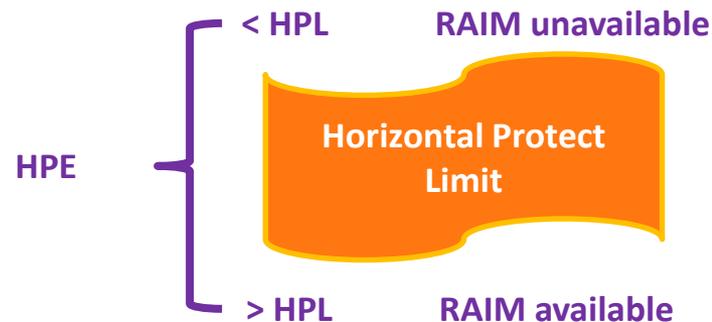
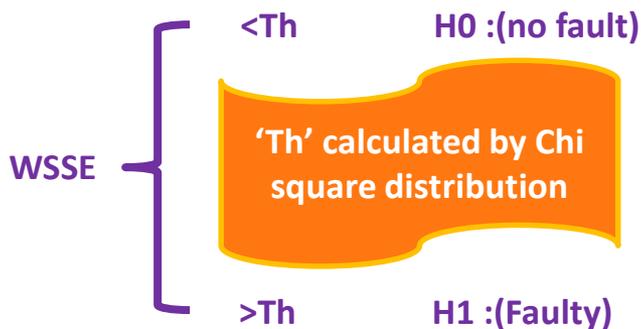
# 3 Vector Tracking Loop RAIM



Weighted Sum of Square Errors  
(WSSE) Using Discriminator Level

$$HPL = Slope_{x,max} \cdot Th_{\chi^2} + K(P_{md}) \cdot \delta_x^0$$

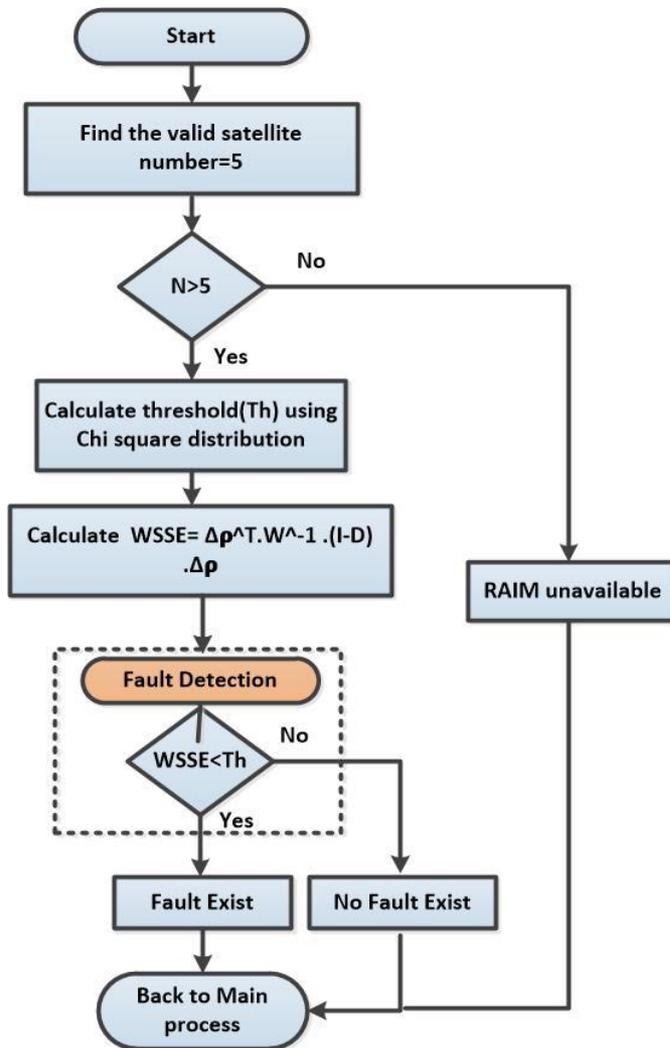
$$WSSE_t = z^2 = \Delta\rho_t^T W_t^{-1} (I - D_t) \Delta\rho_t$$





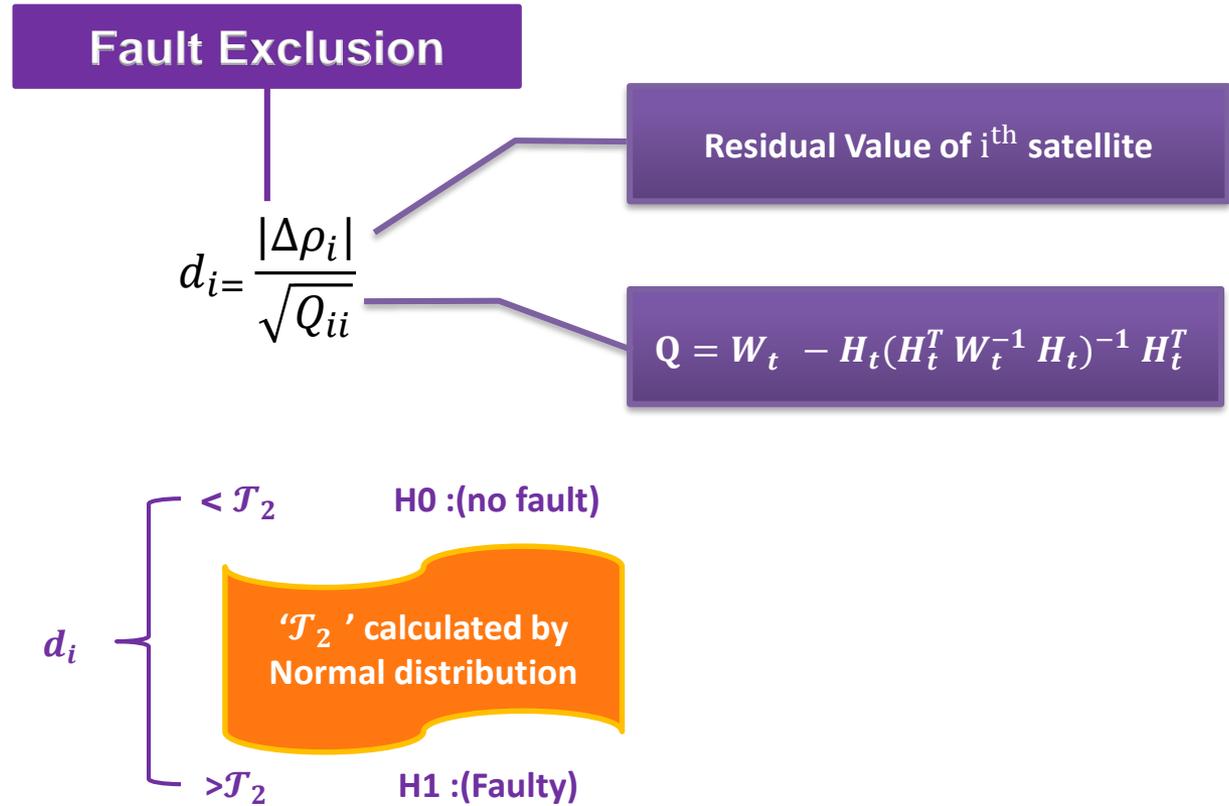
# 3 Vector Tracking Loop RAIM

## Fault Detection Flow chart





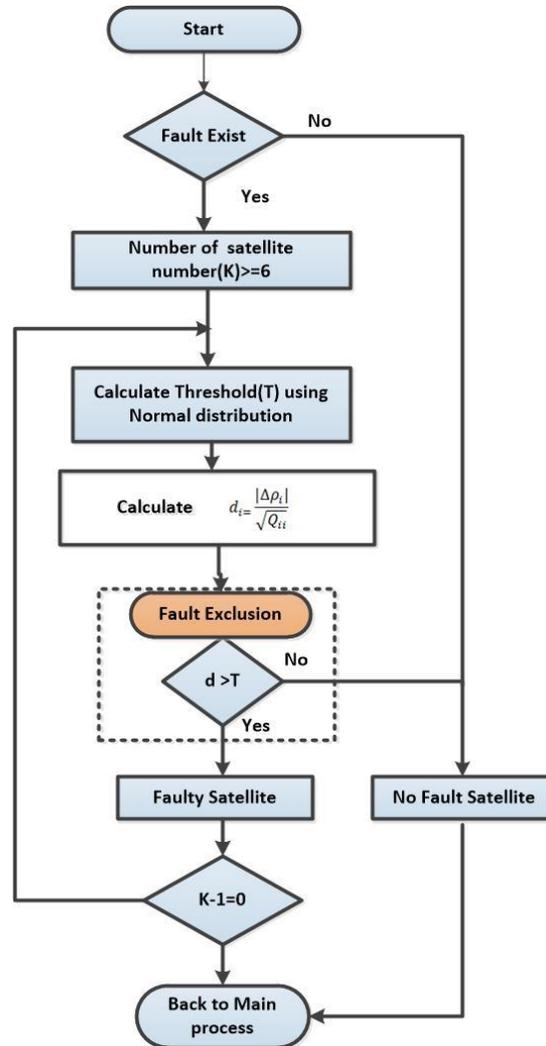
# 3 Vector Tracking Loop RAIM





# 3 Vector Tracking Loop RAIM

## Fault Exclusion Flow chart

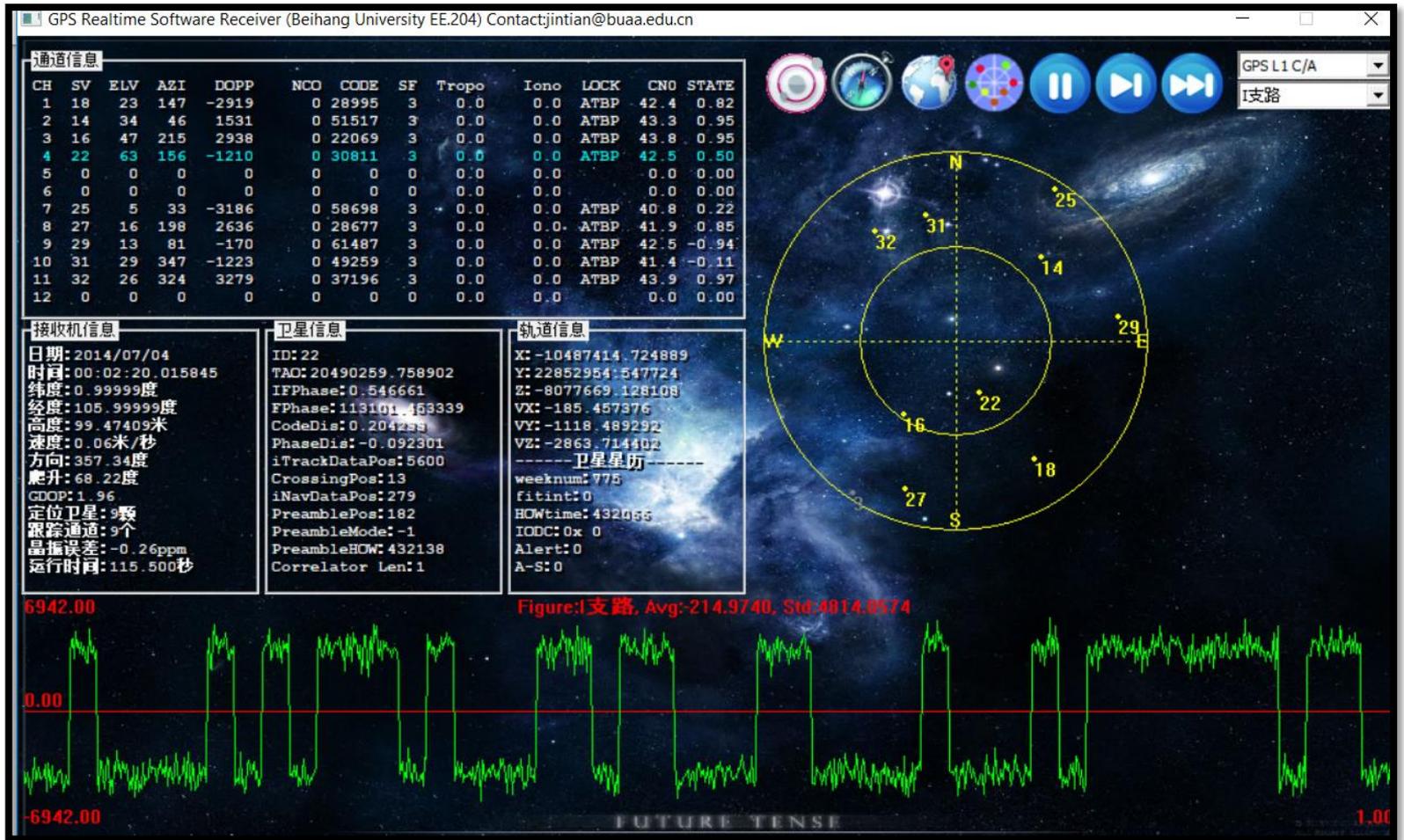


# RESULTS



# 4 Results

Developed on Visual C 2008

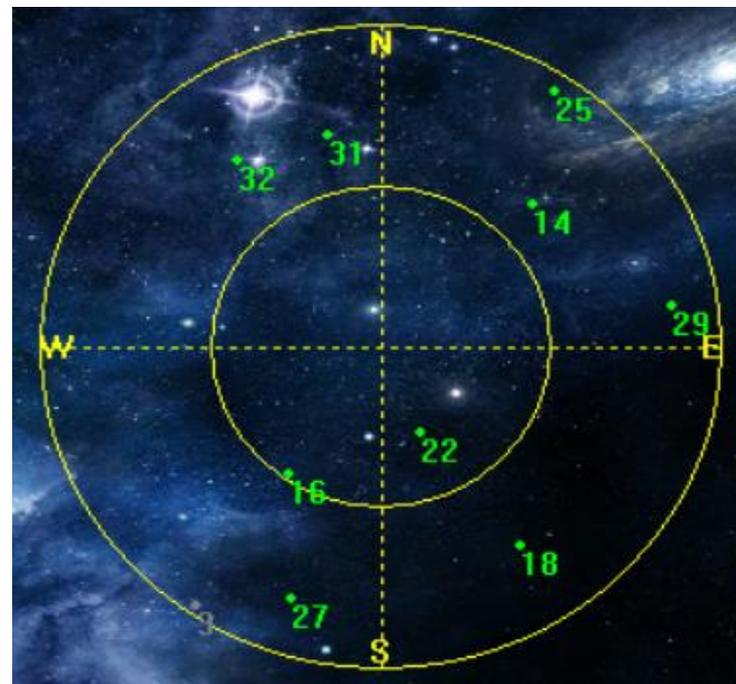




# 4 Results

- ❖ All data is collected at GPS L1 from a simulator (Spirent GSS8000, 12-channel)
- ❖ Total number of satellites =9 at epoch 115

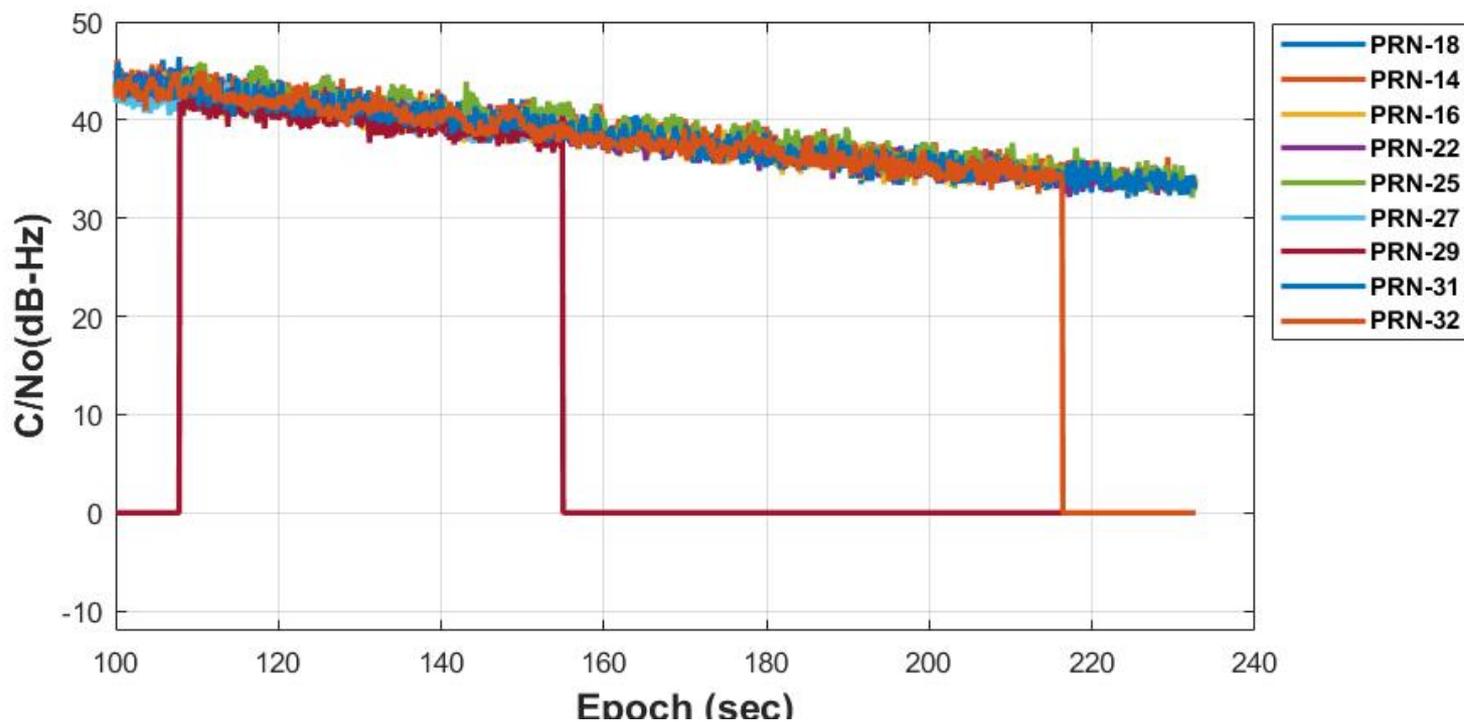
Sampling Frequency	62.000 MHz
Intermediate Frequency	4.17 MHz
Attenuation C/No	1 dB
Attenuation period	10 seconds
C/No Threshold	29 dB-Hz
Number of Visible Satellite	9
Constellation	GPS L1
Probability of False detection	0.05
Degree of Freedom	Total Satellites -4
Threshold Calculation	Chi square distribution





# 4 Result

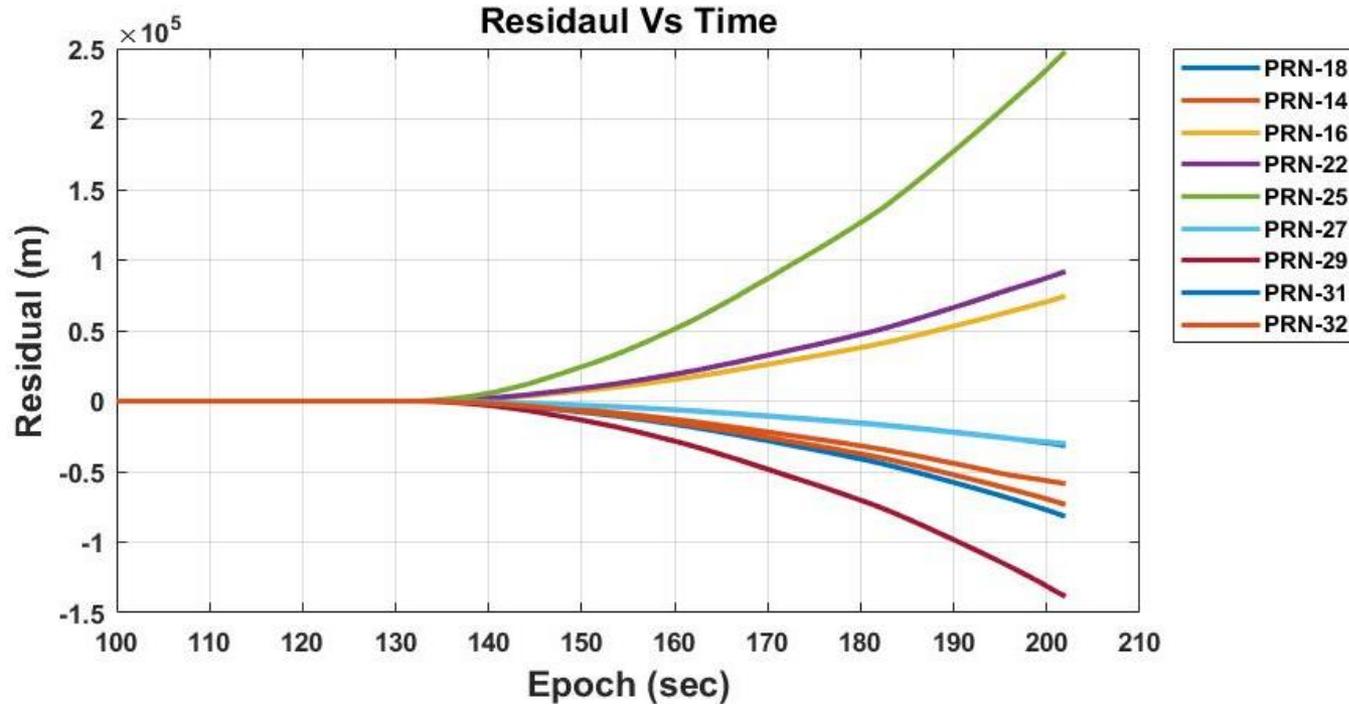
## C/No Vs. Time





# 4 Scalar Tracking Loop RAIM Result

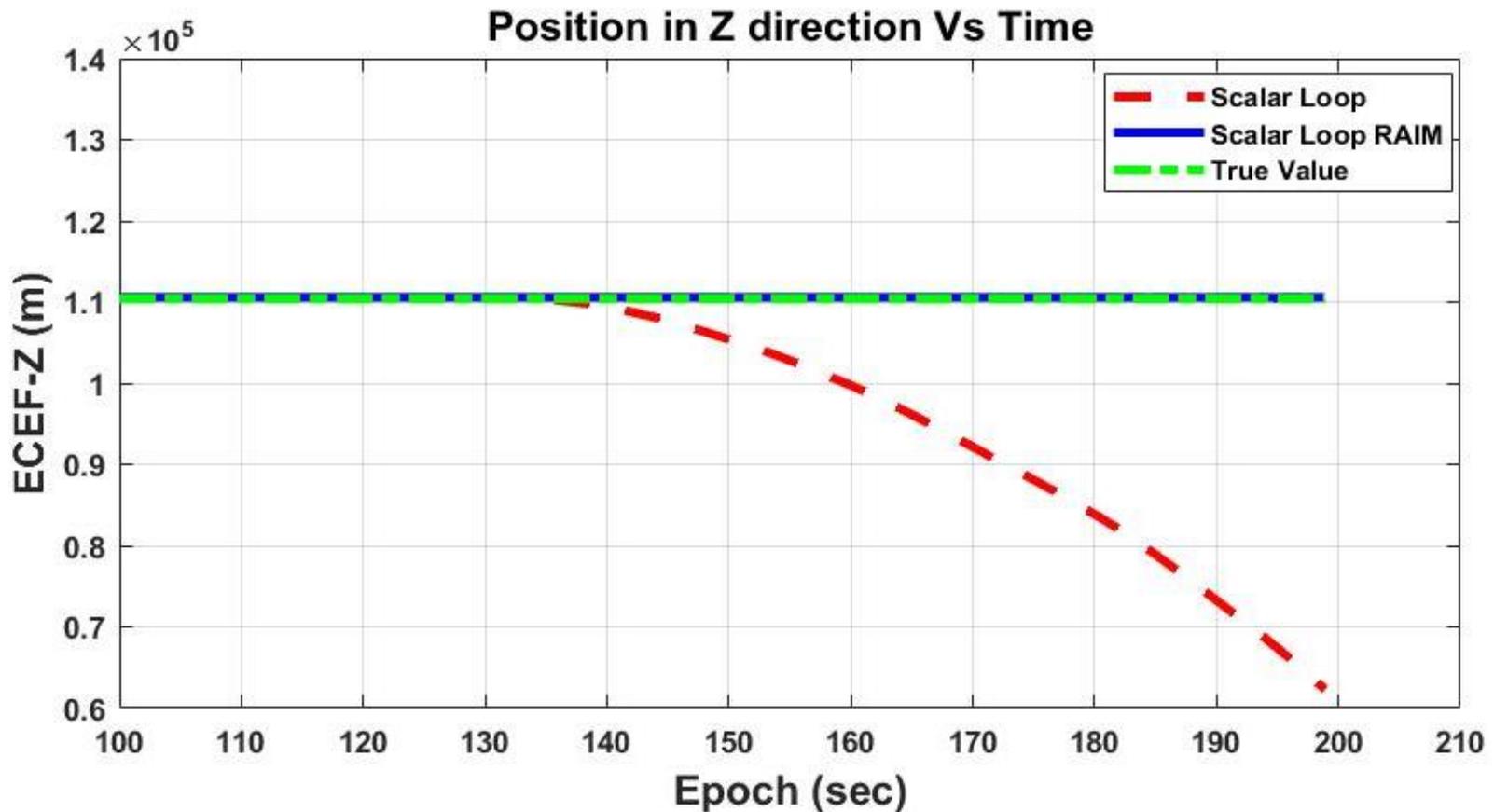
## Residual Graph





# 4 Scalar Tracking Loop RAIM Result

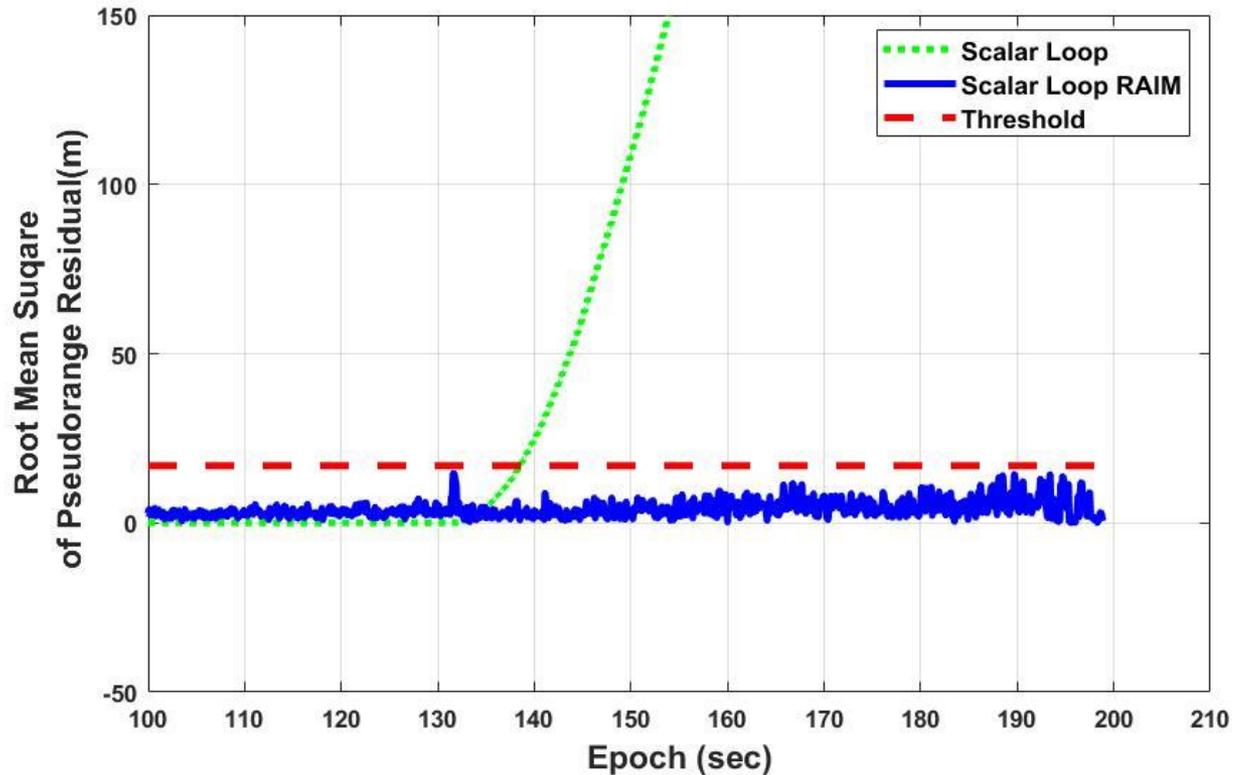
## Deviation in X, Y, Z coordinates





# 4 Scalar Tracking Loop RAIM Result

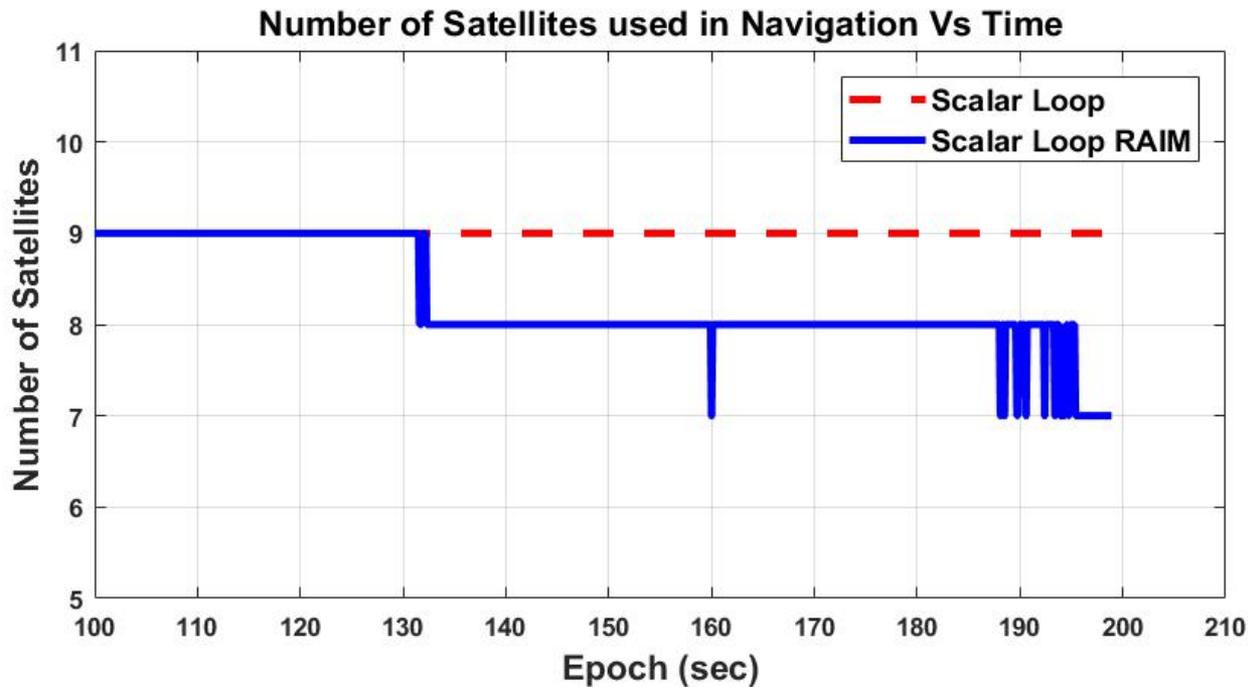
## Root Mean Square of Pseudorange Residual





# 4 Scalar Tracking Loop RAIM Result

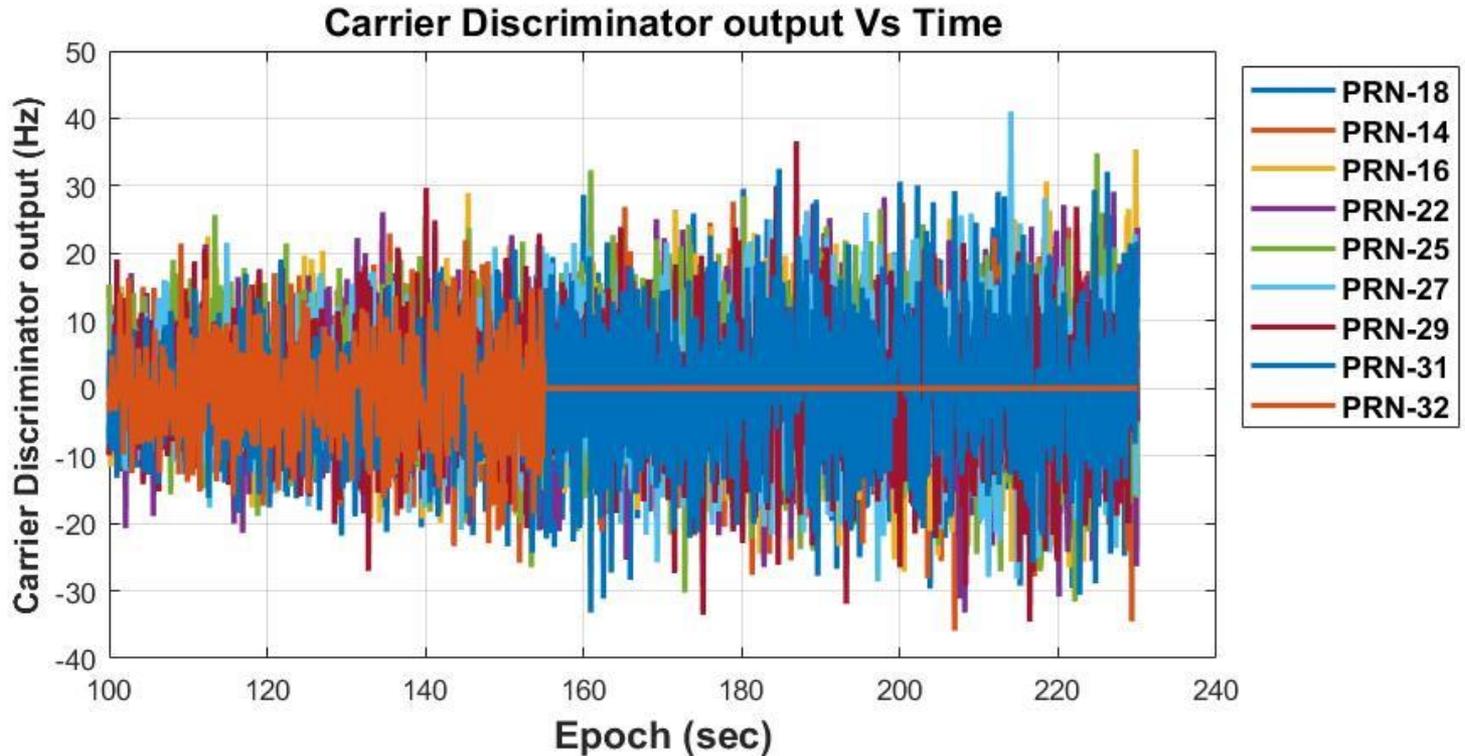
## Number of satellite used in Solution





# 4 Vector Tracking Loop RAIM Result

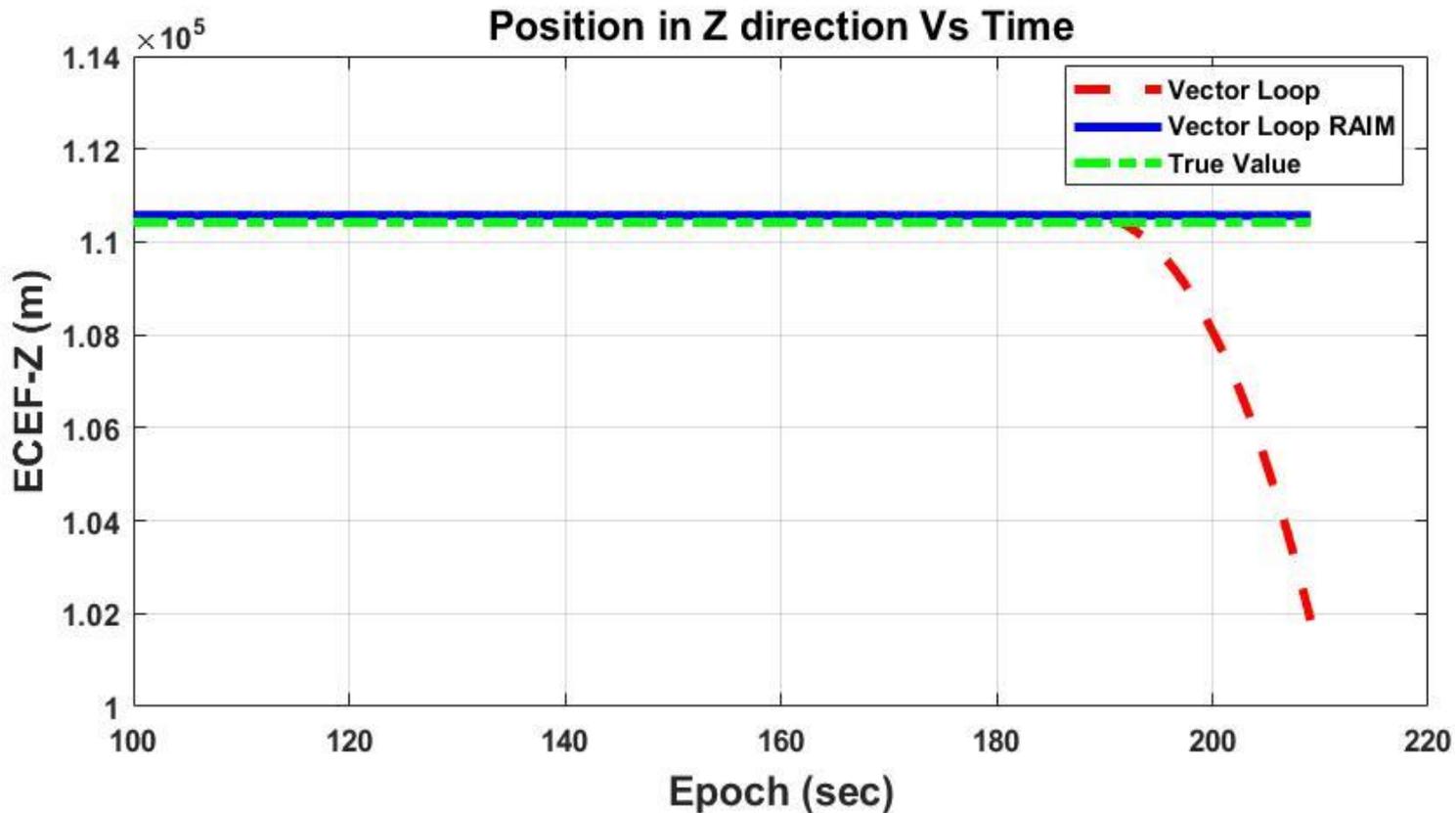
## Carrier Discriminator output





# 4 Vector Tracking Loop RAIM Result

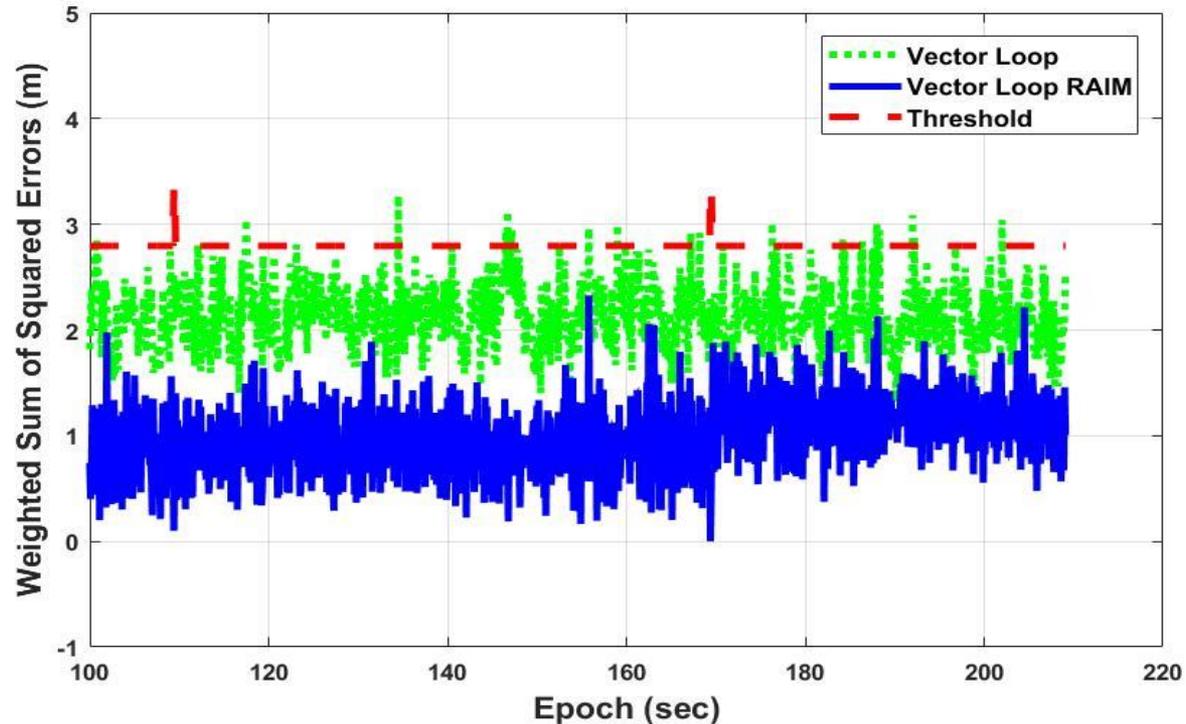
## Deviation in X, Y, Z coordinates





# 4 Vector Tracking Loop RAIM Result

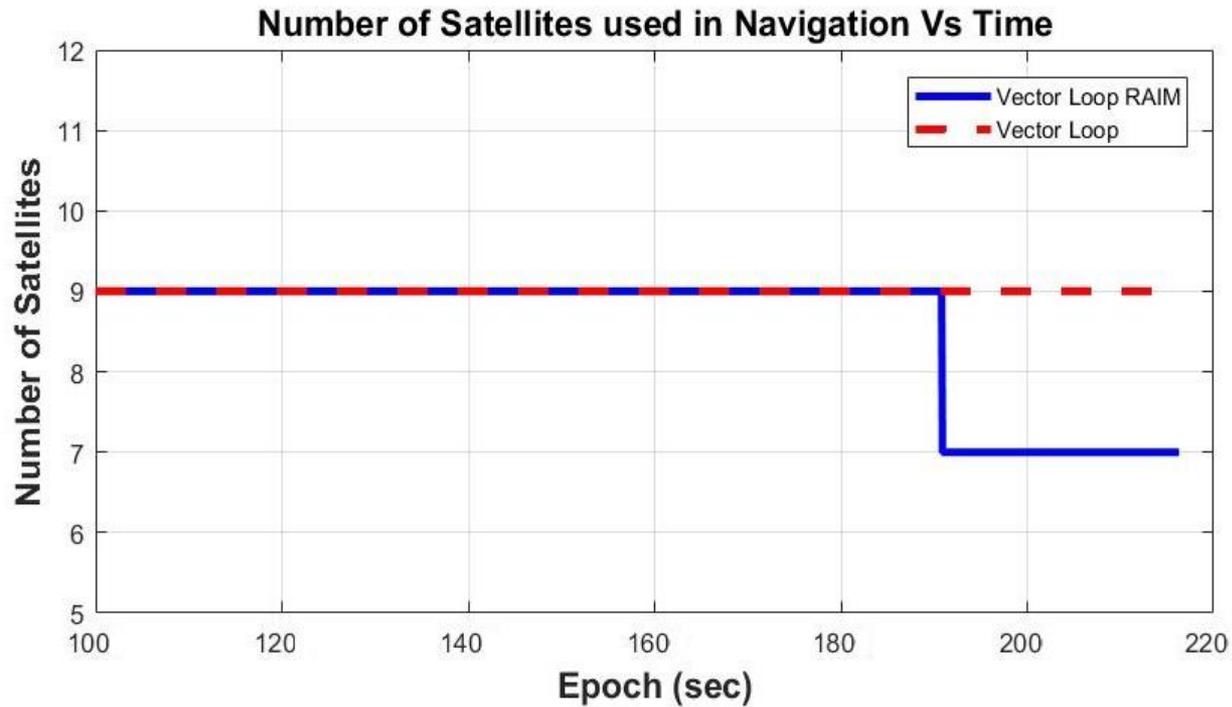
## Weighted Sum of Squared Errors





# 4 Vector Tracking Loop RAIM Result

## Number of satellite used in Solution





# 4 Comparison

## Scalar Tracking Loop RAIM

## Vector Tracking Loop RAIM

Pseudorange Residual



Test statistic derived from

Carrier/Code discriminator output

Weighted Least square solution



Test Statistic Approach

Weighted Sum of the Squared errors

One or two using Maximum likelihood Method



Fault Exclusion

Single

Does not work in weak signals



Environment

Work in weak signals environment

Easy, simple, less computations



Complexity

Complex



# Conclusion

*To design vector tracking loop RAIM in a weak GPS signals environment, Carrier /code discriminator output is the preferable approach because it is uncorrelated with channel noise*

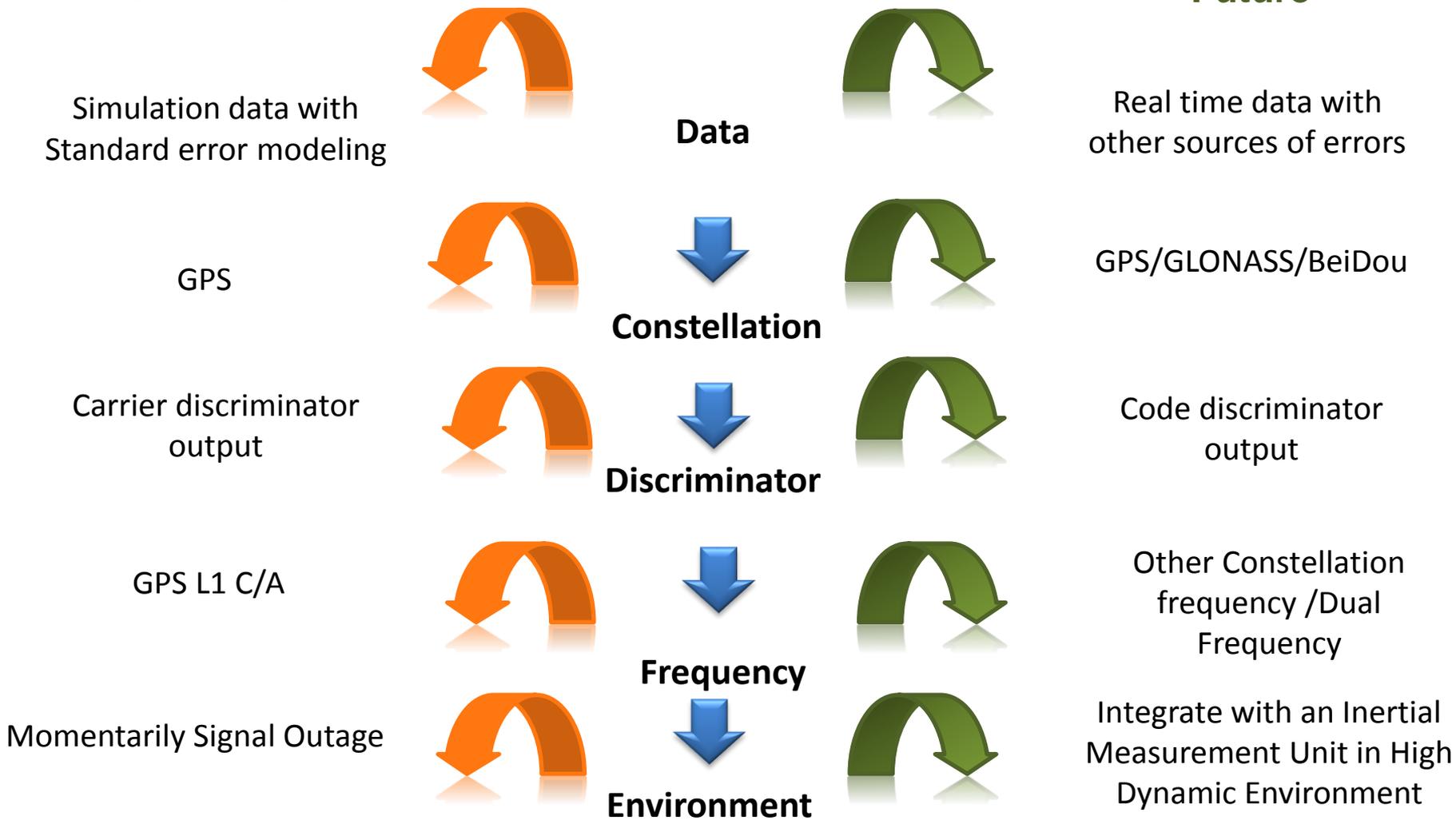
# FUTURE PROSPECTS



# 5 Future Prospects

## Research

## Future



**THANK YOU**



# References

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- 3) Zhaoyan Sun<sup>1</sup>, Xinlong Wang: Design of an adaptive GPS vector tracking loop with the detection and isolation of contaminated channels. In: Springer-Verlag Berlin Heidelberg 2016
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