#2201

CHARACTERISTICS OF DEEP GPS SIGNAL FADING DUE TO IONOSPHERIC SCINTILLATION ANALYZED USING A SOFTWARE RECEIVER

Jiwon Seo, Todd Walter, Tsung-Yu Chiou, and Per Enge

Department of Aeronautics and Astronautics, Stanford University, Stanford, CA 94305, United States

1 Abstract

This paper analyzes raw GPS (Global Positioning System) data collected at Ascension Island in March 2001 in order to characterize statistics of deep signal fading due to ionospheric scintillation. Strong scintillation period based on S4 index during the eight days' campaign was chosen and the data was processed in 50 Hz rate using a commercial software receiver. Statistics of fading duration according to carrier to noise density ratio (C/No) are presented and time between deep fades are also analyzed. Importance of these characteristics for an operational aircraft navigation system using GPS and WAAS (Wide Area Augmentation System) is discussed.

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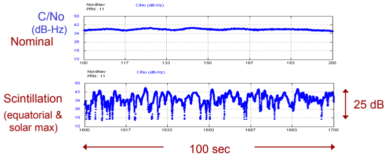
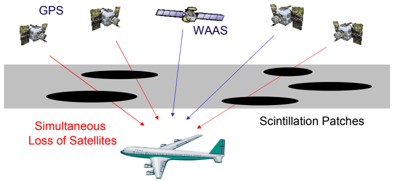
2 Scintillation and Deep Signal Fading

Signal to Noise Ratio (C/No) of PRN 11 (Ascension Island, 18 Mar 2001)



Scintillation causes deep GPS signal fading (more than 25 dB fading sometimes) which leads to carrier lock loss of a GPS receiver.

3 Scintillation and Navigation



Carrier lock loss due to scintillation reduces number of tracked satellites.

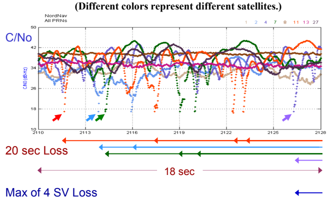
- The operational aircraft navigation system using GPS and WAAS requires minimum of four tracked satellites with good geometry.
- Both code and carrier information are required to calculate position estimate.
- Number of simultaneous loss of satellites is an important parameter for navigation.

4 Simultaneous Loss & Reacquisition Time

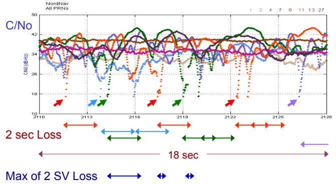
Number of simultaneous loss of satellites is strongly dependent on a receiver's reacquisition time after losing carrier lock.

- The current WAAS MOPS allows up to 20 second reacquisition time.
- Maximum of 4 simultaneous loss of satellites is observed in the following example, if 20 second reacquisition time after deep signal fading is assumed, which may not provide enough navigation availability during scintillation.

Example based on Real Scintillation Data
(Different colors represent different satellites.)



- However, this situation is dramatically changed if 2 second reacquisition time is assumed as the following case. Now we observe maximum of 2 satellite loss for the same period. With given satellite geometry, 2 satellite loss for a small fraction of time is not a critical problem for navigation.

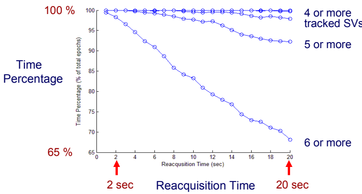


- This is a simple example to illustrate strong dependency between reacquisition time of a receiver and number of simultaneous loss. Longer reacquisition time increases number of simultaneous loss.
- **The data collection campaign** was performed for 8 days at Ascension Island in Mar. 2001 and the data was provided by Dr. Theodore Beach, AFRL.
- For the rest of this paper, 45 minutes of the worst case scintillation data is considered from the whole 8 days' data set.
- The raw IF sampled data from the campaign was processed in 50 Hz rate using a NordNav commercial software receiver.

5 Benefit of Shorter Reacquisition Time

Shorter reacquisition time increases number of tracked satellites.

- Analysis is based on the 45 minutes of worst case scintillation data.



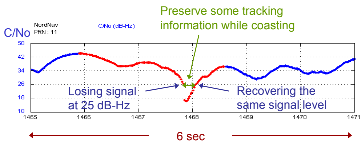
- Simulating 20 second reacquisition time (WAAS MOPS limit)
  - 4 or more tracked SVs: 97.9%, 5 or more: 92.3%, 6 or more: 68.1%
- Simulating 2 second reacquisition time
  - 4 or more tracked SVs: 100%, 5 or more: 100%, 6 or more: 98.3%

The current WAAS MOPS (Minimum Operational Performance Standards) limit (20 second) has to be reduced for this clear availability benefit.

- WAAS requires 99.999% availability.

6 Coasting for Short Fading Duration

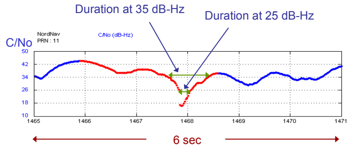
In order to reduce reacquisition time, a receiver may coast for short fading duration and reacquire a lost channel using preserved tracking information.



- Desired coasting time depends on a receiver's sensitivity. If a receiver loses carrier lock at higher C/No, it needs to coast longer for the same level of protection.
- The WAAS MOPS should provide guideline of coasting time for aviation receivers to guarantee enough navigation availability under strong scintillation.

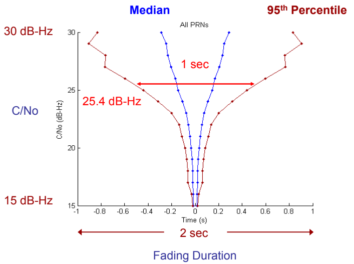
7 Fading Duration Model

Fading duration can be calculated at each 50 Hz C/No data point.



- Fading duration in this paper is defined as time to recover the previous C/No value. Hence, fading duration at 35 dB-Hz is longer than duration at 25 dB-Hz as the above example.

This fading duration model can give a guideline for desired coasting time.



- This model was obtained after analyzing statistics of fading duration at each C/No data point (18,502 samples) of the 45 minutes of worst case scintillation data..
- As an example of interpretation, if a receiver loses carrier lock at 25.4 dB-Hz and can coast for 1 second, it would be protected against 95% of deep signal fadings caused by strong scintillation.

A receiver with desired coasting capability can track enough number of satellites even during strong scintillation period.

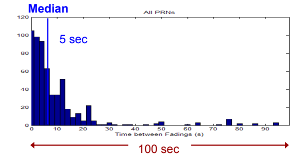
- Coasting strategy can reduce a receiver's reacquisition time.
- Reduced reacquisition time increases number of tracked satellites. cf) 5. Benefit of Shorter Reacquisition Time

8 Time between Deep Fades & Availability

Navigation availability depends on not only number of tracked satellites but also noise level of smoothed pseudoranges.

- Aviation receivers smooth code measurements by less noisy carrier measurements for 100 seconds to reduce noise level.
- If a receiver loses carrier lock frequently, effective smoothing time decreases, noise level of smoothed pseudorange increases, and therefore navigation availability decreases.
- Time between deep fades is a good measure of effective smoothing time.

The worst case scintillation data demonstrates very frequent deep fades.



- The median of time between deep fades is only 5 seconds which is very short compared to 100 second smoothing time constant.
- This result predicts high noise level of pseudorange measurements and poor navigation availability even if a receiver tracks enough number of satellites by coasting strategy.

9 Conclusion

The allowable maximum reacquisition time in WAAS MOPS should be reduced to increase number of tracked satellites during strong scintillation.

- With this modification, certified aviation receivers can track enough number of satellites even during strong scintillation period and as a result at least horizontal navigation would be possible.
- The fading duration model of this paper can give a guideline for coasting time.

Frequent deep fades predict high noise level of pseudorange measurements.

- Due to high noise level of smoothed pseudoranges, vertical navigation may not be possible during strong scintillation even if a receiver tracks enough number of satellites.

10 Acknowledgement

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