International Beacon Satellite Symposium BSS-2016
Trieste, Italy

A Systematic Amplitude Scintillation Analysis on GPS Aviation Receiver during Non-Precision Approach through a Spirent Simulator

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ABSTRACT

Ionospheric scintillation can cause amplitude and phase degradation of GNSS signals when they pass through regions of irregularities consisting of strong electron density gradients. Low latitudes have a high probability of experiencing amplitude scintillation which may cause receivers to lose lock on one or more satellite signals at the same time. This can result in positioning errors and reduced integrity in aviation receivers which operate without an augmentation system, making them unreliable for aircraft take-off and landing in these regions. Severe amplitude degradation can possibly lead to aircraft disasters such as crashes. The behaviour of typical commercial GNSS receivers under such conditions has previously been analysed through the implementation of physical or mathematical models to represent ionospheric events. In this research, a systematic analysis using a Spirent simulator was performed to analyse GPS L1 aviation receiver performance under scintillation conditions. The receiver's tracking capability for different fade depths and durations was observed for the repeated simulations, and the behaviour was analysed through a series of probability planes. Based on the results obtained, a relevant fade depth and duration was selected and introduced to the nominal GPS signal to observe how scintillation can impact aircraft performance, especially during the critical non-precision approach.

Key words: Ionospheric Scintillation, GNSS, Aviation, Simulation

Introduction

One type of disruption to the radio signals during the process of ionospheric scintillation is the rapid enhancement and fading of amplitude, usually known as amplitude scintillation [1]. The strength of amplitude scintillation is commonly identified by the S_4 index, which is the standard deviation of the received signal power normalized by the average signal power [4]:

$$S_4 = \sqrt{\frac{\langle I^2 \rangle - \langle I \rangle^2}{\langle I \rangle^2}} \quad (1)$$

where I is the signal intensity and $\langle\rangle$ represent time-averaged measurements.

Similar to typical receivers, aviation receivers calculate the position solution using both code and carrier measurements. If scintillation takes place, deep signal fading may cause the receiver to lose lock of the signal, which then needs to be reacquired by the receiver. The factors important for aviation applications impacted by scintillation are signal fading durations, time between deep fading, signal fading frequency, and time reacquisition [3], which need further investigation.

Systematic Analysis through Spirent Simulation

Spirent GSS6560 is a GPS simulator which consists of a signal generator producing 12 independent channels of GPS L1 C/A signals. It is capable of creating variations (perturbations) on the signal, thereby allowing receiver performance to be analysed. The first phase of this study was presented at ION GNSS+ 2014 [2] which analysed the response of a geodetic receiver to perturbed signal conditions. The response was characterized in terms of the probability to lose lock as a function of fade depth and duration.

In the research presented here, the same method was applied to analyse the threat posed by scintillation on a Garmin 480 GPS aviation receiver. A set of artificial signal perturbations consisting of simplified instances of different fade depths and durations was developed that emulate the effect of scintillation at the receiver. Using the Spirent simulator, the signal perturbations were superimposed on to a selected nominal GPS L1 C/A signal to analyse the performance of the aviation receiver. Every single fade depth-duration was repeated 10 times to calculate the probability of loss of lock.

Further investigation was carried out to understand scintillation effects on the aircraft receiver while it is in motion by adding the perturbations to an aircraft approaching scenario. Fades were introduced to various combinations of satellites within the satellite best-set and the effects on the integrity performance were observed (Figure 1 (a) and (b)).

Preliminary Results

Figure 1(c) shows the probability to lose lock of a GPS L1 signal as a function of fade depth and duration for the aviation receiver. The fade depths smaller than 20 dB revealed no effects on signal tracking for all fade durations except for the anomaly found at a fade duration of 55 seconds. The reason for the anomaly is as yet unclear. Small fade durations between 1 and 10 seconds shows a transition region for fade depths between 20 dB and 24 dB where the receiver appears to be struggling to maintain lock. Durations longer than 10 seconds have a high probability to lose lock for fade depths exceeding 20 dB. This result is used as the baseline to investigate the integrity performance of the Garmin 480 in an aircraft approaching scenario. Horizontal Protection Level (HPL), Geometric Dilution of Precision (GDOP) and position errors are used as the integrity parameters.

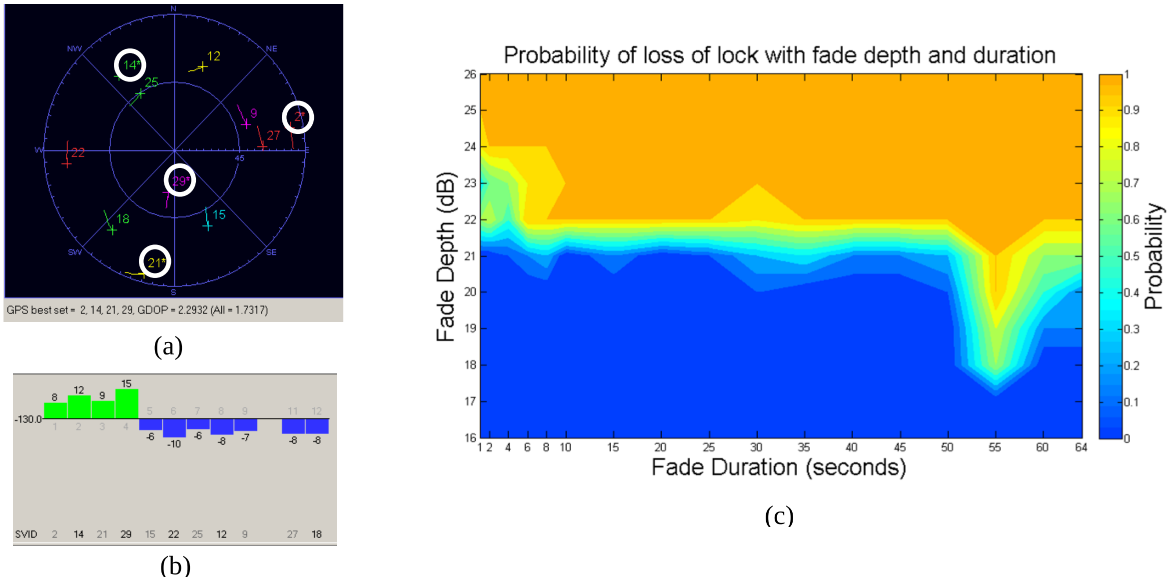

Figure 1. (a) Sky plot of all GPS satellites in view during the simulations, and the GPS best-set selected from the geometry that gives low GDOP (in white). (b) Power level graph when fades are introduced to various combinations within the best-set to understand their effect on the receiver. *Source: simGEN, Spirent Communications.* (c) Probability of losing lock of a single satellite in a Garmin 480 aviation receiver at different fade depths and durations.

Conclusion

GPS fades caused by ionospheric scintillation influence the ability for the receiver to maintain lock on signals. This affects the integrity in GPS systems, which is important for aviation applications. The study discussed here used a Garmin 480 GPS aviation receiver to analyse its performance under simulated scintillation conditions. It was observed that the receiver's ability to maintain lock is challenged when experiencing fade depths of 20-24dB for durations of 1-10 seconds. Longer durations are more likely to lose lock particularly when fade depths are greater than 20 dB. First results showed that the geometry of the best-set satellites can also affect the integrity in aviation receivers, particularly during aircraft approach. Future studies will investigate scintillation effects on GPS integrity for precision approach guidance with SBAS.

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Acknowledgements: Spirent Communications