Dual Frequency GNSS Receiver Error Correction

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Introduction

Global Navigation Satellite Systems (GNSSs) have had a profound impact on both military personnel and civilians by providing users with accurate timing and positioning information. Each satellite that is part of the GNSS constellation continuously sends out data on multiple frequencies (known as L1, L2, etc.). Traditionally, GNSS receivers recognize only one of these frequencies. More recently, however, it has become clear that receivers that recognize more than one frequency - or dual frequency receivers - allow for error corrections that single frequency receivers cannot [5].

The Wild Strawberry Team's capstone project implements a software-defined GNSS receiver that can correct for atmospheric errors when in dual frequency mode.

GNSS Receiver Errors

Possible errors in a GNSS receiver fall into two categories: systematic errors and errors that are affected by time and/or space. While single frequency receivers are generally able to handle systematic errors on their own, their solutions tend to break down in the presence of other errors, such as ionospheric scintillation [5].

What is ionospheric scintillation?

The signals sent from the GNSS satellites must travel through various levels of the atmosphere - such as the ionosphere - to reach receivers on earth. The ionosphere lies above the troposphere approximately 50 to 200 km above the earth's surface. It is composed of mostly molecules ionized by the sun's ultraviolet light [4]. As can be seen in figure 1, when traveling through these charged

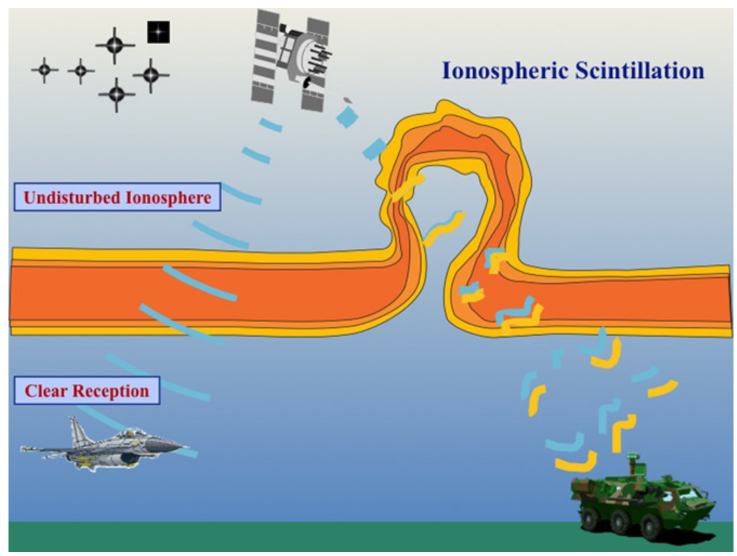

Figure 1: Ionospheric irregularities – or Ionospheric scintillation – causes disturbances in GPS signals [4].

particles, satellite signals' speed and other properties are greatly affected. However, the effects cannot be easily predicted due to there being frequent disturbances in the ionosphere [10]. These disturbances cause the calculated phase and amplitude of the signals to oscillate very quickly, leading to other errors such as cycle slips (phase measurement discontinuities), loss of lock (when the receiver stops tracking a satellite because of lost data), and the position solution being off by as much as meters [4]. If a lot of ionospheric scintillation is present - such as near the equator - then loss of lock can occur on many satellites, rendering the receiver not just error prone, but effectively useless [6].

Correcting for Ionospheric Scintillation

As is pointed to by some research, single frequency receivers can function as long as there is not much ionospheric scintillation present and there are at least four unaffected satellite signals in the receiver's view [2]. However, when many or all satellites are affected by the disturbances, single frequency receivers are inaccurate while dual frequency receivers still allow for this error to be mitigated by providing the user multiple data sets per satellite [7].

How can dual frequency receivers correct for these irregularities?

When the errors between the different frequencies for a given satellite are compared, the user can ascertain a better idea of how the ionospheric irregularities are affecting the data, and can therefore correct for it. Known as the Ionosphere-free method or iono-free equations, dual frequency receivers can use a linear combination of code or carrier-phase in order to eliminate the ionosphereic irrecularities [8]. One of the most valuable aspects of this method is that it does not require any information from other ground stations or receivers [7].

How effective are dual frequency receivers at correcting for these errors?

Using the aforementioned method, dual frequency receivers have proven highly effective when in the presence of ionospheric scintillation. Displayed below in figure 2 are the results of one study on the effectiveness of different types of receivers under ionospheric irregularities. On the left is a single frequency GPS receiver, in the middle is a dual frequency GPS receiver, and on the right is a dual system GPS/BeiDou (Beidou being China's GNSS constellation) receiver. The amount of error for each incorrectly fixed (red), correctly fixed (green), and float (gray) navigation solution is plotted for all of these receivers. (An incorrectly fixed solution refers to a solution that the receiver thinks is correct despite it being inaccurate. A correctly fixed solution refers to a solution that the receiver thinks is correct and is correct. A float solution refers to a solution that contains too much error for the receiver to be sure about.) The single frequency receiver has more float

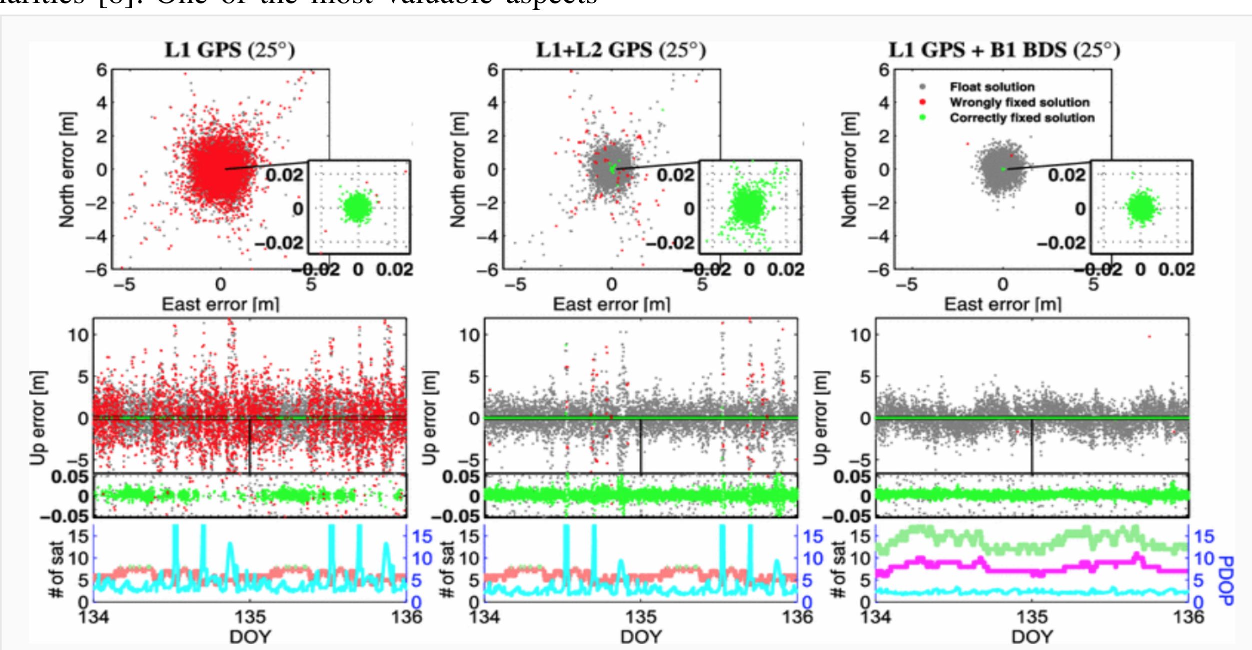

Figure 2: A comparison of a single frequency receiver against two dual frequency receivers [9].

and incorrect solutions than

either of the other two receivers that are recognizing more than one GNSS code [9]. These graphs support the aforementioned statement that dual frequency receivers are much more effective than single frequency receivers in the presence of ionospheric scintillation.

Conclusion

Ionospheric scintillation is one of the major sources of error in the calculation of navigation solutions. It can cause incorrect position and time solutions and can even cause the initial signal acquisition to take longer than normal [6] As of now, single frequency GNSS receivers cannot provide a way to cope with this error.

Dual frequency receivers are relatively new with some GPS codes (such as L2) only having been released fairly recently [2]. Research on them is not as robust as single frequency receivers but, thus far, they have proved fairly effective at mitigating the error due to ionospheric irregularities. Their ability to produce accurate time and position information makes them strong candidates for military use where being off by meters can mean life or death.

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