

Effect of Ionospheric Scintillations on GNSS – Summary of a White Paper

**SBAS Ionospheric Working Group
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Introduction: The forthcoming arrival of signals on a second aeronautical civil frequency eliminates the major limitation on today's use of GNSS caused by ionospheric delays. These new signals will enable the use of GNSS in parts of the world where concern over significant ionospheric gradients prevents adoption of the current single frequency system. However, a phenomenon known as ionospheric scintillation can cause the occasional loss of a signal leading to interruptions in service. Mid-latitude regions are rarely affected by scintillation except during severe ionospheric storms which occur only a few times per eleven year solar cycle and last only a few hours. In contrast, regions near the equator can experience scintillations almost daily in the hours after sunset. Polar regions also are more likely to be affected by scintillation.

Scintillation in Mid latitudes: The current augmentation systems: WAAS, MSAS, EGNOS, and LAAS all primarily operate in mid latitudes where the ionosphere is typically the most benign. On rare occasion, these systems have been affected by ionospheric storms. The dominant effect of these storms can be eliminated by the use of the two aeronautical frequencies. Scintillation may occur during the more significant storms and it may cause some short-term interruptions in service. However, its impact is not expected to be very significant in mid latitude regions.

Scintillation in Low Latitudes: The use of augmentations to GNSS near the magnetic equator has been limited by stronger variability in the ionospheric delay. Dual frequency operation will remove this limitation allowing more widespread adoption. However, amplitude and phase scintillation is much stronger and much more common in this region. During solar maximum years, it can be nearly a daily event occurring primarily in the hours between local sunset and midnight. Scintillation may interfere with the receivers' ability to track the GNSS satellites continuously. The loss of the signal is easily identified by the receiver and thus is not an integrity threat, but rather a threat to the availability of the service.

Scintillation in High Latitudes: High latitude scintillation is often associated with the more familiar night time aurora. At very high-latitudes scintillation can occur at any local time. In the winter, moderately strong L-band scintillation is observed in association with so-called polar cap patches. The polar region scintillation is also strongly affected by geomagnetic activity. In general, high latitude amplitude scintillation cause weaker fades than will occur in equatorial regions, although the phase fluctuations may be as strong or stronger.

Scintillation Effects: Ionospheric scintillation affects users of GNSS in three important ways: it can degrade the quantity and quality of the user measurements; it can degrade the quantity and quality of reference station measurements; and, in the case of Satellite Based Augmentation Systems, it can disrupt the communication from the SBAS geostationary satellite to the user receiver. Scintillation can briefly prevent signals from being received, disrupt continuous tracking of these signals, or worsen the quality of the measurements by increasing noise and/or causing rapid phase and amplitude variations. Further, it can interfere with the reception of data from the satellites, potentially leading to loss of use of the signals for extended periods. The net effect is that the system and the user may have fewer measurements, and those that remain may have larger errors. The influence of scintillation on system performance at a given time and location depends upon many factors. The two most important are the undisturbed performance of the system (how much margin it has) and the severity of the scintillation (how badly the signals are affected).

Mitigations: There are several actions that GNSS service providers can take to lessen the impact of scintillation. Increasing the margin of performance is chief among them. The more satellites a user has before scintillation, the more they are likely to retain after being affected. Further, a larger number of satellites implies that a user can tolerate more noise on their measurements. Therefore, incorporating as many satellites as possible is an effective means of mitigation. Further, the more quickly a user can recover from a deep fade, the more satellites they are able to use at a given time. For deep fades that last less than a few tenths of a second, the signals should be reintroduced back into the position solution within a few seconds or less. Provided there are enough satellites at the outset, it has been shown that a receiver that can reincorporate the satellite within 1 to 2 seconds after each deep fade may be able to maintain availability even during severe scintillation events.

Summary:

- Mid-latitude performance is likely to be minimally impacted by scintillation.
- Low latitude regions may experience significant signal fading from local sunset to midnight during solar maximum years.
- High latitude may experience deep fading and phase fluctuations during solar maximum years. The influence of scintillation will be less severe than for near equatorial regions but greater than mid-latitude regions.
- Scintillation effects can be mitigated by utilizing a greater number of GNSS satellites. New GNSS constellations are being developed and their inclusion in the position solution will lower the overall impact of scintillation.
- Very deep fades are typically very short. Receivers that can reacquire and reintroduce signals into their position estimate quickly (within 1-2 seconds) will have fewer simultaneous outages.
- Vertically guided approaches should be feasible for all regions of the globe when dual frequency constellations become available. However, scintillation may cause loss of lock of either or both frequencies.
- Scintillation may cause some operational restrictions in the early stages when fewer dual frequency satellites are available

Recommendations:

- Scintillation data from the years of high solar activity should be collected in different regions of the world and studied to better characterize the severity, and the spatial, temporal, seasonal and solar cycle characteristics of scintillation effects on airborne and reference receivers.
- The correlation of fades and phase fluctuations across the two frequencies should be determined.
- Modeling of behavior and forecasting of scintillation effects should be improved to allow for better planning around potential impacts to performance on a statistical basis.
- The additional signals from new dual frequency GNSS constellations should be utilized to improve the overall system robustness.
- Receivers should minimize the time to reacquire and reintroduce the signal into the position solution after a very brief outage (within 1-2 seconds if feasible. However the current SARPS and MOPS requires only a 20 seconds reacquisition time)..
- Additional potential methods to mitigate scintillation effects should be proposed and evaluated.

A full “white paper” describing the potential scintillation effects on GNSS in detail for the various ionospheric regions of the world is available upon request.