Mitigation of Ionospheric Scintillation Effects for Precise GNSS positioning

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Global Navigation Satellite Systems (GNSS, such as Global Positioning System (GPS), GLONASS, Galileo, Beidou) underpin a number of modern life activities, such as air/marine transport, autonomous vehicles/machinery control and in areas such as construction, agriculture and offshore operations. Techniques such as RTK (Real Time Kinematic) and PPP (Precise Point Positioning), exploiting the precision of the GNSS signal carrier phase measurements, are at the core of these applications and are especially sensitive to ionospheric perturbations. In particular, a phenomenon known as ionospheric scintillation, characterised by fluctuations in signal amplitude and phase, may seriously disrupt satellite tracking and degrade system accuracy, reliability and integrity. The occurrence of scintillation shows large variability with local time of the day, season, latitude, longitude, as well as solar and geomagnetic activity. Strong scintillation frequently occurs over the equatorial/low latitudes, it is moderate to strong over the high latitudes and almost absent over the mid latitudes. Polar and high latitude scintillation is associated with auroral precipitation and instability of structures formed on polar cap patches, and effects are enhanced during geomagnetic disturbances. Equatorial/low latitude scintillation, on the other hand, is not fully driven by solar transients and often occurs during the post sunset hours, even on geomagnetically quiet days. Over these regions, scintillation occurrence is associated with the instability of structures on the edges of the Equatorial Ionization Anomaly (EIA). Mid latitude scintillation occur much less often, usually only in association with strong geomagnetic storms near solar maximum.

Although GNSS is routinely used in smartphones and in-car navigation with an accuracy of a few meters, it can deliver centimetres in real time if advanced techniques and error modelling are employed. Enhancing the real time accuracy of GNSS is key to supporting a range of applications and, more importantly, to inspiring new ones that can arise when this is fully developed. Currently, there are two specific candidate GNSS techniques that can meet this real time demand, namely PPP and RTK. However, RTK, PPP and related techniques, especially at low latitudes, can be significantly handicapped by scintillation that is frequently observed in this region. Strong scintillation is capable of leading to loss of GNSS satellite signal tracking and especially phase tracking, which is crucial to high precision professional applications relying on a real time capability. On the other hand, low to moderate scintillation introduces additional biases appearing as double difference residual errors. The situation is particular adverse in Brazil, a country located entirely across the magnetic equator, where the ionospheric behaviour is particularly dynamic and unpredictable. Following a brief introduction, this lecture will present some significant results on the impact and mitigation of scintillation effects on high accuracy GNSS positioning techniques over the equatorial and low latitude region of Brazil.