GNSS based air navigation, equatorial space weather, lessons learned in Peru

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ABSTRACT

The ionosphere is a region of the upper atmosphere that is partially ionized. GNSS signals are delayed by varying amounts of time depending on the density of ionized particles, which itself depends on the intensity of solar radiation and other solar energy bursts. An ionospheric phenomenon is rapid and large ionospheric delay changes resulting in range measurements errors that must be addressed by system design. Solar storms can cause severe ionospheric scintillation that can cause temporary loss of one or more satellite signals. The likelihood of disruption due to scintillation will depend on the geographic area and will require scientific assessment. Ionospheric phenomena have negligible impact on en-route through NPA operations. In this paper I am going to give some insights about the importance of having a space weather expert in the GNSS air navigation service planning and implementation team

Key words: Ionosphere, GNSS, Solar storms, Scintillation, NPA operations, Space Weather Expert.

1. **Introduction:** The type and severity of ionospheric effects vary with the level of solar activity, the region of the world and other factors such as time of year and time of day. Rare solar storms can cause large variations in ionospheric delays that can affect receivers over a wide area. Solar activity peaks every eleven years. Severe scintillation can disrupt satellite signals, but it occurs in patches and does not affect wide areas of the ionosphere simultaneously. It therefore generally affects only a few of the satellites in view of an aircraft [1].

   The aim of this paper is to provide up to now which is the actual implications of the ionosphere irregularities in the propagation of the signal travelling from a GNSS satellite transmitter to a static or moving receiver through the ionosphere, and at the same time which are mitigations at the technical level, at the regulations level and at the methodology level. In this case the PBN concept and its flexibility provide a good alternative to deal with signal propagation uncertainties. Anyway, Peru is in the geomagnetic equatorial region, which is vulnerable to amplitude and phase fluctuations of the signal due to sudden and fast ionospheric gradients. On the other hand, PBN concept strongly depends on the GNSS. Therefore, a weather expert must be included in a GNSS/PBN regulations team in any country, particularly in the case of Peru.

2. **Performance Based Navigation (PBN):** One key to increased airspace capacity is a transition to total area navigation environment in which aircraft maintain flight paths within defined corridors. GNSS-based PBN provides seamless, harmonized and cost-effective guidance from departure to vertically guided final approach that provide safety, efficiency and capacity benefits. The Performance Based Navigation (PBN) Manual (Doc 9613, hereafter referred to as PBN Manual) describes implementation processes and requirements for aircraft, aircrew knowledge and training [2]. The PBN concept represents a shift from technology based to performance based navigation, but for all except the least demanding applications, GNSS is required. GNSS enables States to develop a PBN implementation plan in accordance with ICAO resolution A37-11- Performance Based Navigation global goals.

3. **Automatic Dependence Surveillance (ADS):** Improved surveillance performance is the key to reduced separation standards, increased airspace capacity and the ability to support user preferred trajectories. ADS-B is based on aircraft broadcasting GNSS position, velocity and other on-board data. ADS-B ground stations, which are much less costly than radars, receive and process aircraft ADS-B data for use on controller situation displays. Several states have implemented ADS-B in areas where there is no radar coverage [3]. This has allowed for a reduction in separation from as much as eighty to five nautical miles, thus increasing airspace capacity and supporting reductions in fuel consumption and emissions.

4. **The Equatorial Ionosphere:** the equatorial ionosphere is organized around the geomagnetic equator, which differs substantially from the geographic equator [1] [4]. While in mid-latitudes, severe ionospheric storms may infrequently cause outages of SBAS APV service, but in equatorial regions service outages would be much more frequent due to the formation of wide bands of accumulated ionized particles located approximately 15 degrees north and south of the magnetic equator. Narrow, elongated volumes, called depletions (or bubbles), in which the density of ionized particles can drop well below that in the surrounding ionosphere, often develop in the midst of these bands just after local sunset and persist late into local night. The combination of these phenomena results in large spatial and temporal variations in ionospheric delay and therefore presents a major challenge to the integrity of SBAS ionospheric corrections. It is therefore not practical to provide single frequency SBAS APV service in equatorial regions [3].

5. **Ionosphere impact in GNSS signal in Equatorial regions:** As we mentioned previously, severe scintillation can disrupt satellite signals, but it occurs in patches and does not affect wide areas of the ionosphere simultaneously [3, Doc9849]. It therefore generally affects only a few of the satellites in view of an aircraft (see figure 1). Losses of signal tracking due to scintillation are of short duration, but they may occur repeatedly during periods of several hours. This can cause GNSS service to be degraded or temporarily lost for duration dependent on the receiver's ability to rapidly re-acquire a signal following the event [4]. Scintillation affects all GNSS frequencies, so multi-frequency receivers will not offer stronger protection. On the other hand, multi-constellation GNSS would allow the receiver to

track more satellites, reducing the likelihood of service disruption.

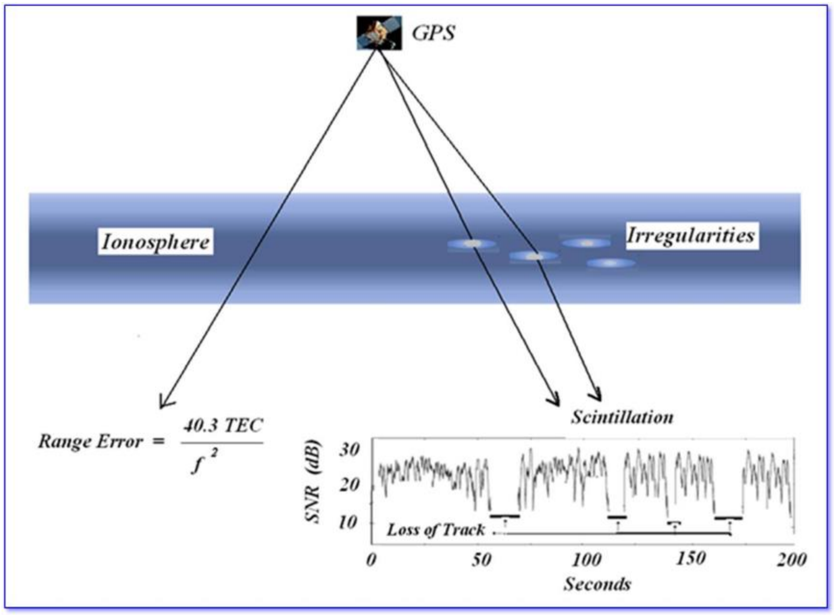

Figure 1. The effects of the ionosphere on GPS signals are illustrated. GPS signal refraction is caused by ionospheric irregularities that produce variations in signal group delay and phase advance. *Source: http://www.cpi.com/capabilities/sw.html*

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