Analyzing the tolerance of the legacy and modernized GNSS signals under ionospheric scintillation: a preliminary case study in the Brazilian region

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The main goal of the Global Navigation Satellite Systems (GNSS) modernization program was to launch new satellites with additional navigation signals for both civil and military users, enhancing accuracy and satellite signal availability. In the literature the terms "legacy" and "modern" are commonly used to distinguish between GNSS signals Originally, Global Positioning System (GPS) satellite transmitted signals on two frequencies, L1 (1575.42 MHz) and L2 (1227.60 MHz), with the C/A and P code on L1 and only the P code on L2. They are considered the “legacy” signals. The modernization of GPS introduced a third signal, L5 (1176.45 MHz), characterized by a more complex signal structure, following the modernization represented by IIR-M and IIF blocks [1]. The modernized GPS-III signals, offering higher navigation accuracy, transmission power, and signal integrity, utilize more complex modulation schemes than legacy GPS signals [2]. An extra signal was also introduced in the L1, the so called L1C, which may be more robust than the L1C/A. While the impact of the ionosphere on legacy signals is well documented in the literature, limited knowledge exists for modernized ones. Different signal frequencies and channels experience varying impacts of ionospheric scintillation, which can degrade signal quality and accuracy of navigation and positioning applications based on GNSS. The severity of ionospheric scintillation can lead to the loss of satellite signal tracking [3]. Hence, a thorough assessment of modernized signal quality and positioning performance is crucial for GNSS. This study analyzes the tolerance of GPS signals from modernized satellites under ionospheric scintillation in the challenging Brazilian ionospheric environment. In this case study we evaluated the tolerance of the modernized GPS signals taking into account the number of loss of observables from different signals and channels during different ionospheric scintillation levels. The analyses were carried out for PPTE station (20.1° S, 51.4° W), located in a region known for the occurrence of strong ionospheric scintillation. The period analyzed spans from DOY 071 to 077 of 2023, close to the maximum of current solar cycle 25. Only GPS-III satellites were chosen for the analysis, as this block presented satellites with both modernized and legacy signals. The analysis involves correlating the number of lost observations with different levels of scintillation (weak, moderate and strong). We considered the L1 C/A, L1C, L2C and L5C signals. The results showed that the modernized signals, with signal structure composed of Data + Pilot presented a similar behavior for L1 and L5. The losses of observable occur under strong scintillation conditions ($S4 > 0.7$), reaching around of 2-3% of the cases. Analyzing only the L1 frequency for the different channels, the losses of data for the C/A channel (L1C) were higher than for the Data + Pilot one (L1X). These preliminary results show that the L1 frequency with the Data + Pilot structure is a more tolerant signal for losses during the ionospheric scintillation. Furthermore, comparing the GNSS observables, pseudorange is more tolerant compared to carrier phase, once the number of pseudorange observables is larger than carrier phase. These were preliminary results; in the future with a larger dataset, we expected to propose recommendations on which signal and channel have the least interference during the events of ionospheric scintillation in the Brazilian scenario. Such additional results will be presented during the event.

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