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Ionosphere Monitoring Using Dual Frequency Smartphones

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Since version 7 of the Android operating system (2016), GNSS raw measurements (code, phase, doppler) are made available to users on compatible smartphones. Up to Android version 6, only position fixes and limited satellite information were available. The first compatible smartphones were single frequency and most of them were affected by the duty cycle preventing users to collect continuous phase measurements. The first dual frequency (GPS L1/L5, Galileo E1/E5a) multi-constellation smartphone, Xiaomi Mi8 was launched in June 2018. It provides high quality code and phase observables. Nevertheless, due to the low quality of smartphone antennas, the observables are strongly affected by multipath.

The paper assesses the potential of smartphone dual frequency GNSS measurements for monitoring the ionosphere Total Electron Content (TEC). We consider absolute TEC reconstruction and TEC rate of change computation as the latter is a crucial parameter for the study of small-scale irregularities in TEC which can pose a threat to the integrity of precise positioning. In this paper, we focus on the detection of Travelling Ionospheric Disturbances but the same technique could be used to monitor ionospheric scintillations. For such applications, collaborative networks of smartphones could provide a densification of the existing reference networks which would contribute to a better modelling of ionospheric small-scale irregularities and to an improved mitigation of their effects on precise positioning.

On the roof of our building, we are operating 7 geodetic reference receivers (2 Trimble NetR9, 2 Septentrio PolaRx4, 1 Septentrio PolaRxS dedicated to ionosphere monitoring and 2 Septentrio PolaRx5) which are connected through 2 splitters to 2 Trimble choke ring antennas allowing a comparison between smartphones and geodetic receivers. In our study, we consider 4 dual frequency smartphones (Xiaomi Mi 8, Huawei Mate 20, Google Pixel 4, Google Pixel 6) and a BCM47765 Evaluation Kit kindly provided by Broadcom.

As Smartphones antennas are very susceptible to multipath even on L5/E5a, we perform 2 experiments. In the first experiment, we install our smartphones in a shield box in which we put a reradiating L1/L5 antenna connected to our reference geodetic antenna. The idea is to assess the “intrinsic” precision of the GNSS chip inside the smartphone without being “contaminated” by multipath coming from the low-quality smartphone antenna. Such an experiment makes sense as patch antennas for smartphones are being developed and should become commercially available in the future. In the second experiment the smartphones are installed on the roof of our building which has an open sky and collect measurements using their own antennas.

In a first step, as TEC is usually reconstructed from the geometry-free combination of code and phase measurements, we analyse the quality of this combination (precision, susceptibility to multipath, number of cycle slips, …) and compare the results obtained with geodetic receivers in the frame of the 2 above-mentioned experiments.

In a second step, the absolute TEC is reconstructed. In order to compute the geometry-free phase ambiguities, two different techniques are tested: code-phase levelling and phase levelling using IONEX maps. As far as code-levelling is concerned, the stability of Smartphone L1/L5 and E1/E5a DCBs is monitored and compared with geodetic receivers. Due to the strong multipath influence on code measurements, the ambiguity computation based on IONEX maps gives the best results when the smartphone antenna is used.

Finally, we assess if the TEC rate of change from smartphones allows the detection of ionospheric irregularities like Travelling Ionospheric Disturbances. Again, we show that the multipath effect is the main limitation to the detection of ionospheric irregularities when the smartphone antenna is used.