

## Studies of spatial gradient in TEC and plasma bubble monitoring for GNSS

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Propagation delays in the ionosphere is one of the major error source in the global navigation satellite systems (GNSS). To support a use of GNSS in a critical phase, augmentation systems such as the satellite-based augmentation system (SBAS) or the ground-based augmentation system (GBAS) are being developed and some of them are already in operation. Various techniques of mitigating ionospheric anomalies have been implemented. However, large safety margins have been left to ensure that possible miss-detection of ionospheric anomalies shall not result in a dangerous condition. This degrades availability of the systems and prevent them from more advanced operations. So far, SBAS and GBAS have been developed so that they are self-contained, i.e. without relying on information from external sources. This would further limit their performances.

In the low latitude region, plasma bubbles are the most important ionospheric anomalies accompanying a sharp spatial total electron content (TEC) variation and hence the ionospheric propagation delay. VHF backscatter radars have been used to detect plasma bubbles for many years and known to be able to image the 3-D shapes of them with a beam-steering function. In this study, we propose a wide-area monitoring of plasma bubbles by a VHF backscatter radar in support of GNSS augmentation systems.

Two approaches are taken to evaluate the effects of VHF radar monitoring, simulation and experimental studies.

In a simulation approach, effects of VHF radar monitoring is evaluated for GBAS with a ionospheric density model with plasma bubbles and with a VHF radar observation model. Position estimation errors in GBAS are evaluated with and without VHF radar monitoring. In an experimental approach, effects of VHF radar monitoring is planned to be evaluated for GBAS with the Equatorial Atmosphere Radar (EAR) and GNSS receivers near the EAR site and in Bangkok which is in the same magnetic meridian. The experiment is planned in September and October, 2012. At the meeting, results of the simulation study and preliminary results of the experiment will be reported.