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Characteristics of spatial gradient of ionospheric TEC assoicated with plasma bubbles and its impact on GNSS

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The plasma bubble is a sharp depletion in the ionospheric plasma density. Spatial gradient of the ionospheric TEC (total electron content) associated with the sharp depletion of the plasma density makes it difficult for GNSS augmentation systems to work properly. To mitigate the ionospheric threats associated with the spatial TEC gradient, it is important to know the characteristics of the TEC gradient.

Data used are obtained in Ishigaki (24.3N, 124.2E) with five GNSS receivers with mutual distances from 86 to 1557 m. TEC differences and thus the gradients between a pair of GNSS receivers are precisely derived with the single-frequency carrier-based and code-aided (SF-CBCA) technique. Directions of the TEC gradients are estimated with the TEC gradients between three of the five stations. The derived TEC gradients are compared with those derived with the dual-frequency TEC estimation with the assumption that the TEC gradient in quiet time would be zero. The velocity and propagation directions of the gradients are estimated with the correlation analysis of TEC variation of three of the five stations.

Associated with the plasma bubble events on 3 April 2008, the TEC gradients derived with the SF-CBCA method was amounted to be 3.2 TECU/km, which is equivalent to the gradients in the ionospheric delay at L1 frequency of 518 mm/km. It exceeds the upper bound of the ionospheric threat space (maximum assumed values in the safety design) of ground-based augmentation system (GBAS). The result is proved to be realistic with the dual frequency measurements, though there seems to be cycle-slip effects in TEC estimation. The velocity was estimated to be 118 m/s, and the propagation direction was estimated to be 75 degrees. The propagation direction is consistent with the direction of the TEC gradient of 74 degrees (clockwise from the North). The spatial scale of the TEC gradient is estimated to be 7 km.

These parameters derived in this study are all relevant to the ionospheric threat space of GBAS, and the threat space is shown to be modified so that this extreme TEC gradient is bounded. Thus, studying the characteristics of the TEC gradient with the parameters shown above are very important to the safety design of GNSS augmentation systems, and have to be investigated extensively. Further analysis of the data obtained in the periods of higher solar activity than that of the event analyzed here is necessary and is now going on.

Keywords: plasma bubble, ionospheric irregularity, TEC gradient, irregularity velocity, irregularity scale size, GNSS augmentation system