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Spatial and temporal variations of TEC fluctuations and losses of lock associated with equatorial plasma bubbles

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Equatorial plasma bubbles (EPBs) are depletion of the plasma density in the ionosphere and, inside of EPBs, there are field-aligned irregularities (FAIs) which affects wide-band radio waves. Therefore, EPB causes scintillations on GPS signals because of rapid variations of signal amplitude and phase, and limit the availability of carrier phase measurements. The spatial scale of FAIs that causes the scintillation is determined by Fresnel scale, which is about 2-300 m for GPS signals. This means that loss of phase lock (LOL) on GPS signals is a good proxy for hundred-meter-scale FAIs. It is also widely known that rate of TEC change index (ROTI) enhances around EPBs. Assuming that the altitude of the ionosphere is about 400 km, the velocity of the pierce point of GPS satellites at the ionospheric altitude is approximately 70 m/s around the zenith. ROTI averaged during 5 minutes is a reference of ten-kilometer-scale fluctuations.

In this study, we analyzed LOL and 5-min ROTI to examine the spacial and temporal variations of electron density disturbances associated with EPBs. Examining LOL and ROTI, the developments of two different-scale irregularities are identified. LOL and ROTI data are obtained from GPS data from GPS Earth Observation Network (GEONET) of Japan. From 630-nm airglow images obtained by all-sky imager at Sata, Japan, in 2001, we selected 11 EPBs where the EPBs reach to the geographic latitude of 30 degrees. This is because we compare the distributions of LOL and ROTI determined by GEONET with the airglow imager at Sata whose field of view is 26-34N in geographic latitude.

Both LOL and the enhancement of ROTI were observed in 7 events out of 11 events. The distributions of occurrence of LOLs are approximately in accordance with the depleted region of the airglow intensity, namely the ionospheric electron density. The distribution of the enhancement of ROTI spreads in the vicinities of EPBs, which is wider than that of LOL. The hundred-meter-scale irregularities are distributed within EPBs while the ten-kilometer-scale disturbances are located around EPBs.

In the events associated with LOLs, the kilometer-scale disturbances can be more developed as showing the value of ROTI since there are lacks of observation due to LOL and ROTI would be smaller than the case where there is no lack of observation. In the events without LOL, on the other hand, the fresnel-scale disturbances are not developed enough to cause the scintillation in GPS receivers. The mean values of ROTI in the events associated with LOLs are larger than those not associated with LOLs. Therefore, the kilometer-scale and hundreds-meter-scale disturbances tend to grow and decay simultaneously.

Keywords: Ionosphere, plasma bubble, GPS, loss of lock, TEC, scintillation