Plasma bubble monitoring by HF transequatorial propagation and its use for GNSS

Susumu Saito, Electronic Navigation Research Institute, Japan
Takashi Maruyama, Mamoru Ishii, and Minoru Kubota, National Institute of Information and Communications Technology, Japan
Guanyi Ma and Jinghua Li
National Astronomical Observatories, Chinese Academy of Sciences, Beijing, China
Yanhong Chen
Center for Space Science and Applied Research, Chinese Academy of Sciences, Beijing, China

INTRODUCTION
In the low-latitude and equatorial ionosphere at night, less dense plasma in the bottomside ionosphere often explosively rises to topside, which is called a “plasma bubble”. The plasma bubble is characterized by sharp plasma density depletion and irregularities of a wide range of scale sizes in it. They are threats to GNSS, because the irregularities cause scintillations of GNSS radio waves and the sharp gradients make a differential correction difficult. Therefore, it is important for GNSS to monitor plasma bubble occurrences and their propagation. Scintillations of satellite radio waves have been used to detect ionospheric irregularities. By a spaced-receiver technique, one can measure the drift velocity of irregularities with a horizontal scale comparable to the Fresnel size, which is about 300 to 400 m for the GPS L1 wave (1.57542 GHz) at the ionospheric F region height. The transequatorial propagation of HF radio waves (HF-TEP), which are sometimes received in the off-great-circle directions, has been used to detect large-scale bottomside ionospheric irregularities. Maruyama and Kawamura (2006) used a sophisticated direction finding system in Japan to receive the TEP of broadcasted HF waves from Australia and found that there is an off-great-circle propagation (OGCP) traveling eastward during the night. They conclude that the nighttime eastward-traveling OGCP was probably related to a plasma bubble. However, they were unable to confirm the one-to-one correspondence between the OGCP in the HF-TEP and plasma bubbles. In the present study, we examine the correspondence between those two.

EXPERIMENT
The occurrence of GPS scintillation and the drift velocities of plasma irregularities associated with plasma bubbles were measured at Hainan (19.5°N, 109.1°E, +13.9° Mag. Lat.), China with a spaced-receiver technique. Two Ashtech G12 receivers and one Ashtech BR2G receiver were used. The drift velocity of irregularities is derived from the motion of scintillation patterns on the ground (Ledvina et al., 2004). HF broadcasting signals from Radio Australia transmitted from Shepparton (36.2°S, 145.3°E), Australia, are received by the Oarai direction finder (ODF) at Oarai (36.3°N, 140.6°E), Japan to determine the direction of arrival with the MUSIC algorithm. Radio Australia signals with azimuth angles of arrival around 226° can be regarded as reflected at the meridian of Hainan, if we assume mirror reflection. The drift velocity of the large-scale irregularities associated with the plasma bubble is estimated by the change of the direction-of-arrival Maruyama and Kawamura (2006).

RESULTS AND SUMMARY
The data from March to October 2007 were used for the analysis. The ODF observed an OGCP in the HF-TEP around an azimuth of 226° on the same days the Hainan GPS receiver system detected scintillations. The one-to-one correspondences were very good. The drift velocities measured by the ODF are in good agreement with those simultaneously measured by the Hainan GPS receiver system. Even though there was only a small amount of simultaneous data, it is confirmed that the nighttime eastward-traveling OGCP in the HF-TEP is associated with plasma bubbles. Our results prove that the HF-TEP measurement is useful for monitoring plasma bubbles over a wide area and for forecasting the arrivals of plasma bubbles. Information on a “plasma bubble” or “no plasma bubble” condition in a certain region would be helpful to estimate more realistic errors of wide-area differential corrections of GNSS. It would also be possible to give a plasma bubble warning at a certain area before a plasma bubble arrives there. In order to make more precise measurements of the locations and velocities of plasma bubbles, the uncertainties in the directions of arrival must be reduced and the true propagation path need identified.

REFERENCES
Maruyama, T., and M. Kawamura, Equatorial ionospheric disturbance observed through a transequatorial HF propagation experiment, Ann. Geophys., 24, 1401-1409, 2006,