Observations of equatorial plasma bubble using aeronautical navigation radio waves at VHF frequencies

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We investigated the feasibility of monitoring of equatorial plasma bubbles (EPBs) using VHF radio waves used for aeronautical navigation systems such as VHF Omni-directional radio Range (VOR). There are 370 VOR stations in the Eastern and Southeastern Asian region that can be potentially used as Tx stations for the observations of anomalous propagation. We have examined the forward scattering conditions of VHF waves using the magnetic field model and confirmed that it is possible to observe the EPB-related anomalous propagation if we set up Rx stations in Okinawa (Japan), Taiwan, and Thailand. We will introduce preliminary results of pilot observations in Okinawa, Taiwan and Thailand.

Key Words: Equatorial Plasma Bubbles, VOR, ILS, GBAS VDB

1. Introduction

It has long been known that field-aligned plasma irregularities within equatorial plasma bubbles (EPBs) can cause long-range propagation of radio waves in the VHF frequencies such as those used for TV broadcasting through the so-called forward scattering process (e.g., Nakata et al., 2005). However, no attempt has been made to use such anomalous propagations of VHF radio waves for wide-area monitoring of EPBs. In this paper, we conducted a feasibility study of EPB monitoring using VHF radios for the aeronautical navigation system. In particular, we evaluated the feasibility of wide-area observations of EPBs by carrying out ray-tracing calculation of the forward scattering process as well as by conducting pilot observations in Okinawa, Japan. In the pilot observation, we compare the radio observation with all-sky airglow observations and GNSS scintillation measurements of EPBs in Ishigaki Island, Japan.

2. Results

There are 370 VOR stations in the equatorial/low-latitude region of the Asian sector. Those stations can potentially be used as the source Tx stations for the long-range propagation when a receiving point is set up in East and Southeast Asia. Of these stations, 11 stations at most use the same frequency channel. In order to derive the spatial distribution of EPBs using this observation method, it is necessary to establish a method to identify the source Tx station by combining the current measurement with the ray-tracing calculation, especially when radio waves using the same frequency channel are observed simultaneously.

The calculation of radio wave scattering conditions using the magnetic field model confirmed the possibility of EPB-related scattering when receiving points are located in Okinawa, Taiwan, and Thailand. On the other hand, when receivers are located in the mainland of Japan, the scattering points were not distributed in the low-latitude and equatorial regions where EPBs are expected to reach during the solar minimum.

Pilot observations were conducted in Okinawa, Japan in the autumn months in 2021, but signals, that are clearly be attributed to EPB-related scattering, were not received. This is simply because EPBs have not developed to higher latitudes during the previous solar minimum period, i.e., up to the possible sensing area of the test observation. In March 2023, however, possible signatures of EPB-related scattering were identified in the broadcasting band from 98 to 108 MHz, which implies the feasibility of monitoring the appearance of EPB using the VHF radio observations. In the presentation, we will introduce results of other pilot observations in Taiwan and Thailand to further evaluate the feasibility of the current method.

References

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