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Retrieval of in-situ Electron Density in the Topside Ionosphere from Cosmic Radio Noise Intensity by Artificial Neural Network

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In the topside ionosphere, the cosmic radio noise spectrum close to the plasma cutoff frequency contains information on the electron density at the point where the cosmic radio noise was measured. However, the received radio noise spectrum is a complicated function of frequency spectrum of radio source, variations in the effective antenna aperture and the radiation resistance, and others. As an alternative to a theoretical approach, in order to determine in-situ electron density, we applied an artificial neural network to the cosmic radio noise spectrum observed by the ISS-b satellite.

In the topside ionosphere, the short-wave cosmic radio noise (CRN) intensity at frequencies lower than the ionospheric critical frequency is free from interferences by man-made radio noises and transmissions on the ground. In order to measure the cosmic radio noise in the HF band, many rocket-borne and satellite-borne radio receivers were launched above the F-layer ionization peak in 1960's and 1970's. As the frequency lowers, however, the intensity is influenced by the surrounding ionospheric plasma. The extraterrestrial radio waves having a large incidence angle into the stratified ionospheric layer are reflected and never reach the antenna at the frequencies close to the local electron plasma frequency. Thus, there is a cone of directions within which a radio signal coming into the earth can reach the antenna in the topside ionosphere. The effective aperture of the antenna reduces gradually at first with decreasing frequency and to reach rapidly towards zero near the plasma cutoff frequency.

Usually, electrically short dipole antennas are used on rockets and satellites for receiving the HF cosmic radio noise in the topside ionosphere. Received signals vary directly as the antenna radiation resistance that changes with frequency by the influence of plasma; the resistance decreases gradually at first with decreasing frequency then plunges rather rapidly to a cusp after which it again decreases slowly. The cusp corresponds to the extraordinary wave cutoff frequency, at which the radiation resistance is about half the value in the free space.

From the viewpoint of ionospheric interests, the CRN spectrum near the cutoff frequency contains information on the electron density at the point where CRN was measured. In this paper we will retrieve in-situ electron densities from a large amount of satellite CRN data.

The received radio noise spectrum is a complicated function of frequency spectrum of radio source, variations in the effective antenna aperture and the radiation resistance, and others. Thus, there is a large difficulty of theoretical formalization of the relationship between the in-situ electron density and radio noise spectrum. As an alternative to a theoretical approach, we applied an artificial neural network to the observed CRN spectrum.

Topside sounding was made by the Ionosphere Sounding Satellite launched in 1978. An automatic gain control (AGC) voltage of the sweep-frequency sounder receiver supplies CRN spectra. In order to train the neural network, in-situ electron densities were directly scaled from the plasma resonance spikes and the traces in ionograms for several passes. Each pass contains about 100 ionograms, and it is not an easy task to scale the plasma parameters by eye. With the aid of the neural network, we determined in-situ electron density for about 150,000 ionograms or CRN spectra. The results were applied for global ionospheric mapping, and some dynamic processes affecting large-scale ionospheric structure are also discussed.