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Detection of UHR Frequencies by a Convolutional Neural Network from Arase/PWE Data

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The ambient electron density is one of the important properties of space plasma. Typical regions in the geospace are characterized by the different electron density profile (e.g., plasmasphere, plasma trough and plasma plume.) The most popular way to determine the quantitative electron density is observing the upper hybrid resonance (UHR) emission. The High Frequency Analyzer (HFA) is a subsystem of Plasma Wave Experiment (PWE) aboard Arase. The HFA measures wide frequency range (0.1-10 MHz) electric power spectra with a time resolution of 8 or 60 s. This covers a typical frequency range of Upper Hybrid Resonance (UHR) frequency in the inner magnetosphere. Hasegawa et al. [1] proposed a technique for the automatic UHR frequency determination using convolutional neural network (CNN). They reported that the mean absolute error (MAE) of the predicted UHR frequencies by the ResNet model was 3.664 bins when excluding additional inputs except for the observed electric field spectra observed by the Arase/PWE and labeled UHR frequency data. They also pointed out that additional features (orbital parameters and geomagnetic index) had almost no impact for the accuracy for the UHR frequency determination by CNN. They adopted MAE of the whole period of the data as an evaluation criterion for their proposed technique. However, they did not perform detailed evaluation (e.g., wave frequency dependence, wave intensity dependence, region dependence, and geomagnetic condition dependence.) For example, intensity of UHR emission has a temporal variation, and there are several mechanisms of sudden intense of UHR emission (i.e., equatorial enhancement of the plasma wave turbulence (EPWAT) [2].) In order to put this automatic technique into practical use, we need to perform further evaluation from the point of view of science. In this study, we evaluate CNN-based UHR frequency determination technique proposed by Hasegawa et al. [1] for scientific use-cases.

As for the input for the training of a CNN model, we used electric field spectra during a period from April to December 2017 observed by the PWE aboard Arase. As described in the previous section, HFA covers a typical frequency range of UHR emission along the orbit of Arase (2-10000 kHz.) However, the frequency bandwidth (d_f) of the HFA is limited (d_f =1.22 kHz at the lowest frequency step (2.4-159.9 kHz)) because of its wide frequency coverage. On the other hand, onboard frequency analyzer (OFA) [3] aboard Arase measures electric field from DC to 20 kHz with a finely d_f (d_f =0.064 kHz below 2.05 kHz and d_f =0.832 kHz at 19.5 kHz in a nominal operation mode.)

We found that the error rate of predicted UHR frequencies above 30 kHz is less than 0.07 (7% of the wave frequency) by using HFA spectra. Especially, the best performance (2% of the wave frequency) is achieved at 266 kHz. The frequency resolution of HFA spectra around this frequency range is 2.44 kHz, namely, the theoretical limit of accuracy of the UHR frequency detection (which comes from specification of the HFA) is approximately 1%. This is good enough ability of UHR frequency determination for scientific use-case. The error rate derived by the HFA spectra becomes worse when the wave frequency is below 10 kHz. We considered that this worsening shows a detection limit of UHR frequency due to the increasing of noise level of the HFA receiver.