Development of a Denoising Model for One-Dimensional Interplanetary Scintillation Signals

*竹原 大智[1,2]、大鹿 雅史[3]、岩井 一正[1]、長島 陸冬[1,2]
*Daichi TAKEHARA[1,2], Masashi OSHIKA[3], Kazumasa IWAI[1], Rikuto NAGASHIMA[1,2]

1. 名古屋大学 宇宙地球環境研究所、2. 名古屋大学 大学院理学研究科、3. 名古屋大学 大学院情報学研究科
1. Institute for Space–Earth Environmental Research, Nagoya University, 2. Graduate School of Science, Nagoya University, 3. Graduate School of Informatics, Nagoya University

The solar wind is the plasma flow that is constantly streaming out from the Sun into interplanetary space. When distant radio sources are observed from the radio telescopes at the 327-MHz band, a phenomenon occurs in which the radio intensity fluctuates over time. This is a scattering phenomenon of radio waves caused by density disturbance in the solar wind crossing the line of sight and is known as interplanetary scintillation (IPS). At the Institute for Space-Earth Environmental Research (ISEE), Nagoya University, Japan, IPS observations are conducted using large radio telescopes installed at 3 sites in Japan. Using correlation analysis on the data obtained at each station, the solar wind speeds are derived.

In recent years, however, the rapid development of wireless communication technologies has led to a rapid increase in radio-frequency interference (RFI), a phenomenon in which artificial signals contaminate astronomical signals. Due to this, dramatic deterioration in the quality of radio observation data has become a serious problem. For this reason, developing a method that has the capability for accurate detection and removal of RFI is an important challenge.

In many studies on RFI detection, methods based on statistics and/or thresholds have been used for a long time. Although these methods are easy to implement, they face difficulties in dealing with the complexity and diversity of RFI in recent years. In contrast, machine-learning-based approaches have been actively proposed recently. Machine-learning-based methods are expected to be capable of detecting a wider variety of RFI than conventional approaches. Most existing studies are designed for wide-band observations and therefore target two-dimensional data. On the other hand, the IPS signals observed at ISEE are one-dimensional time series of signal intensity, and the effectiveness of machine-learning-based methods for this type of data has not yet been sufficiently investigated.

In this study, we apply machine learning to one-dimensional time series data obtained from IPS observations in order to automatically detect RFI and restore IPS intensity fluctuations lost due to RFI. As a first step, we constructed a dataset for training the model based on data observed at the Toyokawa station (SWIFT) of ISEE from June 2008 to 2025. Since IPS data contain not only various types of RFI but also cases in which the IPS response is weak, careful analysis is required when preparing the training data. Therefore, after removing trends from the observed data using cubic polynomial fitting, we defined the IPS signal using the physical model of Mejia-Ambriz et al. (2015) and physical quantities obtained from observations. In this study, the datasets are considered RFI-free signals, and labeled data are generated by injecting pseudo-RFI. As the second step of this study, we constructed multiple machine learning models using the labeled dataset and evaluated their performance in automatic RFI detection. The results showed that all models were capable of achieving high-accuracy classification. Moreover, the models successfully detected subtle RFI signals that had been difficult to identify using conventional threshold-based methods. These findings demonstrate that machine-learning-based approaches are effective for RFI detection even in one-dimensional data. However, since the evaluations in this study are

based on pseudo-data, it is necessary to verify the results using actual observed data and to assess how RFI removal affects solar wind speed estimation. In addition to these tasks, we will work on developing methods for restoring astronomical signals as the third stage of this study.

キーワード：RFI検出、機械学習、太陽風
Keywords: RFI Detection, Machine Learning, Solar Wind

