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Abstract

Type-I noise storm is one of the solar radio phenomena observed in a meter wavelength range. Type-I noise storms have two components. One is a short time duration (0.1 - 1 s) and narrowband ($\Delta f = f \times$ several%)emission that is called type-I bursts, and the other one is long time duration (hours - days) and wideband ($\Delta f \sim f$) continuum emission. The continuum and burst emissions are usually emitted simultaneously. Both burst and continuum components are highly circularly polarized up to 100 %. The observed polarization is always left handed to the magnetic field direction of the radio source region. Hence, the emission mode of type-I is o-mode. Therefore, they are thought to be a plasma emission stimulated at the local plasma frequency of the source region.

Type-I noise storms are the most frequently observed solar radio phenomena. It means that type-I noise storm is generated by the particle acceleration (energy dissipation) process that occurs frequently in the corona. The occurrence probability of them is highly associated with active regions. In addition, type-I noise storms often occur without flares, and typical durations of them are significantly longer than those of flares. Therefore, the generation mechanism of type-I is considered to be very common in the active region. However, the generation processes of type-I have not been understood well. It means that we have never understood yet the large part of energy dissipation processes of the solar corona. From these reasons, studies of this thesis are focused on the generation mechanisms of the solar radio type-I noise storm. This study have performed a comprehensive study of the type-I noise storm including the system development, data analysis, and modeling.

At the first step of this study, a new spectro-polarimeter named AMATERAS was developed to observe solar radio bursts with a high sensitivity and high resolution. AMATERAS is a large aperture telescope combined with superheterodyne receiver system and real-time digital analysis system. The observation band of AMATERAS is between 150 and 500 MHz. The minimum detectable flux in the observation band is less than 0.7 SFU with 10 ms accumulation time and 61 kHz frequency bandwidth. Both left and right handed circularly polarized components are observed simultaneously. This system is one of the best facilities for the metric solar radio observation in the world. The observational data are automatically archived soon after the daily observation and then made available on-line with their quick look figures.

Observed data are used to investigate both continuum and burst components of type-I noise storms with their association with flares, CMEs, magnetic structures, weak X-ray emissions, and type-III bursts.

The coordinated observations of an active region using AMATERAS and the STEREO satellites

from different heliocentric longitudes were performed for the first time to study the relationship between type-I noise storms and coronal magnetic structures. A type-I noise storm was observed between 100 - 300 MHz during a period from 6 to 7 February 2010. Several CMEs were observed during the observation period. The STEREO satellites were located suitable region to observe the earthward propagating CMEs and found that the radio flux of the type-I noise storm increased after the preceding CME and began to decrease before the subsequent CME. Potential-field source-surface extrapolation from the SOHO/MDI magnetograms suggested that there was a multipolar magnetic system around the active region from which the CMEs occurred around the magnetic neutral line of the system. Radio images at 432 MHz observed by Nancay Radioheliograph suggested that type-I noise storms were emitted around the center of the active region while type-III bursts were emitted from open field region near the source region of type-I. The observational results suggest that the type-I noise storm was activated at a side-lobe reconnection region that was formed after an eruption of the preceding CME. This magnetic structure was deformed by a loop expansion that led to the subsequent CME, which then suppressed the radio burst emission. Some part of non-thermal electrons leaked from the open field lines located near the active region, and these leaked electrons emitted type-III bursts.

Relationships between type-I noise storms and soft X-ray activities have been investigated by using IPRT and Hinode/XRT in order to find the source region of type-I. There were some small scale soft X-ray activities around the onset of the type-I burst when more than 10 % excess of the soft X-ray flux variation around the onset time of type-I noise storms is defined as a burst-related activity. However, the causal relationship between the observed soft X-ray activities and the onset of the type-I noise storms is unclear. It might be suggested that energy of individual burst elements had so small amount of high energy particles that they could not excite the chromospheric evaporation.

Spectral fine structures of type-I are investigated in order to clarify the micro scale plasma processes of type-I. Fundamental spectral structures of type-I are resolved for the first time by the high resolution observation of AMATERAS. In addition, we have found the existence of huge number of weak burst elements inside the continuum component. The fundamental spectral structures of bursts had a duration of between 100 and 1000 ms. Full-width half-maximums of the burst bandwidth were between 1 and 5 MHz. Frequency drift rates of burst elements were between 0 s/MHz (no drift) to ±0.5 s/MHz. There was no distinctive frequency drift rate and direction even if in a series of type-I group. Frequency distribution of type-I bursts followed power-law with the spectral index of 2 ~ 3. This soft spectrum implies faster saturation time or smaller growth rate of the slowest instability concerned with the type-I burst with assuming the logistic avalanche model.

A new self-consistent model of generation processes of type-I noise storm is proposed to explain the observed type-I and associated phenomena. This model requires two scales of generation processes of the type-I noise storm. The first large scale process is a slow reconnection by flares or CMEs. The role of the slow reconnection region is just a landlord who provides the generation areas for the secondary process. The second small scale process is a fast saturated or slow growth instability that is excited inside the landlord reconnection region. The individual element of this mechanism is so small that the generated burst element does not have enough energy to emit detectable X-rays. If there are open field lines near the source region of type-I noise storms, weak type-III bursts or micro type-III storms can be observed. Although the second process is still unknown, we propose the tearing instability as one of the possibilities to explain the small scale process inside the reconnection region since tearing instabilities are easy to be generated in a long current sheet such as a side-lobe reconnection region proposed in this study.

In this model, both continuum and burst components of the type-I noise storm and associated flares, CMEs, magnetic structures, weak X-ray emissions, and type-III bursts are all explained consistently without any contradiction. This study argues that type-I noise storm is a metric solar radio burst that is generated by a small scale particle acceleration process inside a large scale reconnection region in the corona.