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# Narrowband drifting fine structures in type IV bursts

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Solar Type IV bursts are a type of intense radio phenomenon that accompanies solar flares. Following the discovery by Elgaroy (1959), many observations have suggested that Type IV bursts are accompanied by several kinds of spectral fine structure. One type of prominent fine structure is fiber bursts, which are generally assumed to be emitted through the wave-wave coupling between Langmuir waves and whistler-mode waves propagating in the solar corona. Recent observations in a frequency range of several GHz with high frequency and time resolution have revealed that narrowband fine structures similar to fiber bursts occur in Type IV bursts. In the meter-wavelength range, however, few spectral observations with high resolution have been carried out, unlike at decimeter wavelengths. By performing observations that can detect spectral fine structure in metric Type IV bursts, we can obtain another powerful remote-sensing tool to survey as-yet unknown physical plasma processes, including the process responsible for the generation of energetic particles and the propagation of plasma waves during solar flares, in the region where X-ray and UV observations cannot be used.

We have developed a new solar radio spectrograph, the Zao Solar Radiospectrograph (ZSR). Development of the ZSR was carried out by modification of the array antenna system for the observation of Jovian synchrotron radiation located at the Zao observatory of Planetary Plasma and Atmospheric Research Center, Graduate School of Science, Tohoku University, Japan (Watanabe et al., 2005). It has the ability to observe solar radio bursts in the frequency range from 315 to 332 MHz with a resolution of 10 ms and 100 kHz, which is ten times higher resolution than typical for previous solar radio spectral observations at meter wavelengths. The minimum detectable flux of 4.10 and 4.33 SFU are achieved in the X and Y components, respectively, where 1 SFU = $10^{-22}$ W m$^{-2}$ Hz$^{-1}$.

During the observation of ZSR since June 2008, narrowband, fiber-like structures in the spectra of Type IV bursts were detected on 2 and 3 November 2008. Statistical analysis of the drift rates shows that most of the bursts have different spectral characteristics from those of metric fiber bursts as regards the sign and the magnitude of the drift rate. First, the observed drift rates show both positive and negative rates, whereas the metric fiber bursts usually exhibit negative drift rates. Secondly, the absolute values of the observed drift rates are tens of MHz s$^{-1}$, while the typical drift rate of fiber bursts at 325 MHz is approximately -9 MHz s$^{-1}$ (Benz and Mann, 1998). In addition, all fine structures analyzed have a narrow emission bandwidth of less than 17 MHz.

The observed narrowband features with drift rates of a few tens of MHz s$^{-1}$ have been interpreted by the generation process of metric fiber bursts; the emission features are thought to be caused by whistler-mode waves propagating in the corona.

These observed narrowband events are difficult to detect with conventional spectrographs, which are usually characterized by a frequency resolution of 1 MHz and a time resolution of 0.1 s. These results imply that higher frequency and time resolution (such as 100 kHz and 100 ms) are necessary to investigate fine structures accompanying Type IV bursts.

We also discuss particle and plasma-wave dynamics responsible for the observed fine structures. By referring the presence of a Type U burst in dynamic spectra and comparing with soft X-ray imaging data of the flare region taken by Hinode/XRT, we show that the observed fine structures can be explained as emission caused by upward- and downward-propagating whistler-mode waves inside the magnetic flux tubes of post-flare loops, while these whistle-mode waves are generated by electron beams that are accelerated by side-lobe reconnection in the lower corona.

Keywords: Sun, radio, type IV burst