EVOLUTION AND RADIO ACTIVITY OF A FLARE PRODUCTIVE ACTIVE REGION NOAA7321

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Abstract

By the Nobeyama Radioheliograph, evolution of radio features in flare productive active region NOAA7321 was observed. Delay of emergence of radio feature was detected comparing with soft X-ray feature observed by Yohkoh, which implied that coronal region above NOAA7321 had weak magnetic field strength and high temperature at initial phase of evolution. During evolution of this region, many radio bursts are observed by the radioheliograph and the radio polarimeters at Nobeyama and Toyokawa. These bursts showed radio spectra with high turnover frequency and steep lower frequency cutoff. Negative bursts were observed during entire observation period of NOAA7321. These results suggest that the radio bursts in NOAA7321 were caused by continuous appearance of strong magnetic field regions to lower corona.

1. Introduction

The Nobeyama Radioheliograph started routine observation at late June 1992. This instrument is an interferometer dedicated to solar observations, with which two dimensional images of the whole sun are observed with spatial resolution of about 10″ and temporal resolution of 50 ms (Nakajima et al. 1994; Nishio et al, 1994). Observation frequency is 17GHz, where energetic electrons with few hundred keV have an important role in radio bursts. Routine observations usually cover the time from 2300 UT to 0700 UT. In 1992, we had observed

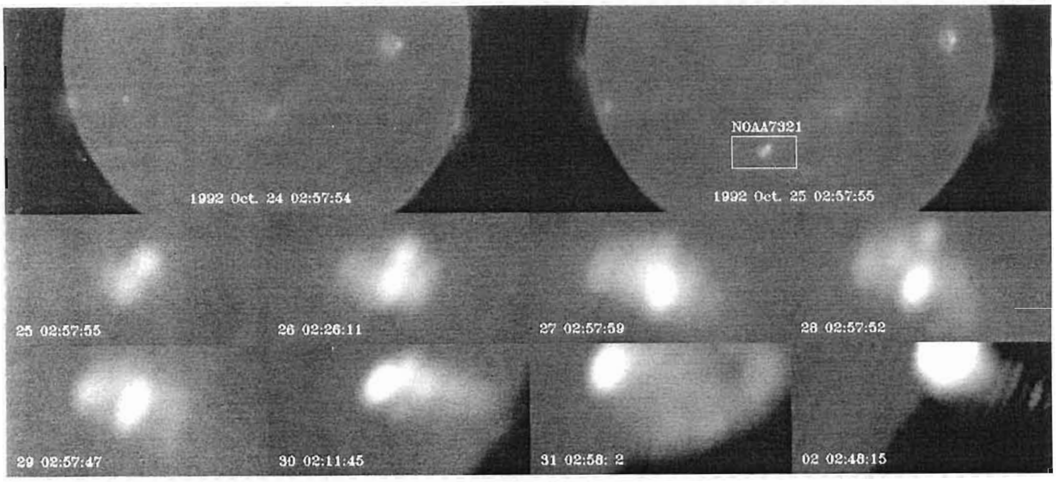

Fig. 1. Evolution of radio features in NOAA7321 observed by the Nobeyama Radioheliograph. Partial images shown in lower column are cut out in equal latitude. Therefore, displacement of brightest portions in these images is real.

three flare-productive active regions NOAA7260, 7270 and 7321 by the radioheliograph. On Nov. 2, a GOES X9.0 flare occurred at NOAA7321. This region showed rapid evolution in eight days before the X9.0 flare. In this paper, we describe 17-GHz radio images and radio burst spectra of this region, and analyzed the evolution of this region.

2. Observation

The active region NOAA7321 emerged at S24E11 on Oct. 24, 1992 (SGD, December 1992, No. 588) and was at west limb on Nov. 1. In Yohkoh soft X- ray images taken at about 0430 UT on Oct. 24, a compact source with weak brightness enhancement was seen associated with NOAA7321. By the radioheliograph, no radio feature was observed in NOAA7321 at this time. On Oct. 25, a bipolar radio feature appeared in this region, which is located in northwest to southeast direction. Northwest portion of this bipolar feature was polarized to left circular polarization ($\approx$ 40%) and southeast portion showed right circular polarization ($\approx$ 20%). In white light images of this region, two sunspots were seen on northwest and southeast sides. The northwest and southeast sunspots had S and N polarities, respectively. This region quickly evolved, and radio feature became complex in following few days. On Oct. 28, the radio feature consisted of five bright radio sources. On Oct. 31, a post-flare radio loop appeared concerning with a long duration event started at 1702 UT on Oct. 31. Figure 1 shows the evolution of radio features in NOAA7321. In this figure, each image is extracted from full frame solar radio images in equal latitude. Therefore, displacement of brightest portions in north-south direction is real.

In NOAA7321, many flares were observed from Oct. 25 to Nov. 2. By the radioheliograph, radio counterparts of 30 GOES soft X-ray flares were observed, in which one X-class flare (X9.0 flare on Nov. 2) and three M- class flares (M1.0 and M1.1 flares on Oct. 27, and M1.3 on Oct. 31) were included. On Nov. 2 the NOAA7321 was located behind the west limb. The GOES X9.0 flare was observed by the radioheliograph as extremely bright sources at west limb just in front of the location of NOAA7321.

The radio polarimeters at Toyokawa and Nobeyama also observed many radio bursts occurred at NOAA7321. Observation frequencies of these radio polarimeters are 1, 2, 3.75, 9.4, 17, 35 and 80 GHz. Figure 2 shows time profiles of the GOES M1.1 flare on Oct. 27 obtained by 2, 3.75 and 9.4-GHz radio polarimeters at Toyokawa. At 9.4 GHz, this burst showed impulsive intensity variations. On the other hand, no clear intensity enhancement was detected at 3.75 and 2 GHz during the impulsive phase at 9.4 GHz. Radio spectra of the bursts at NOAA7321 observed by the radio polarimeters are shown in figure 3. It is noted that the larger part of bursts at NOAA7321 has turnover frequencies higher than or equal to 17 GHz. In addition, they show steep cutoff profiles at lower frequency parts, where the spectral index is greater than 3.

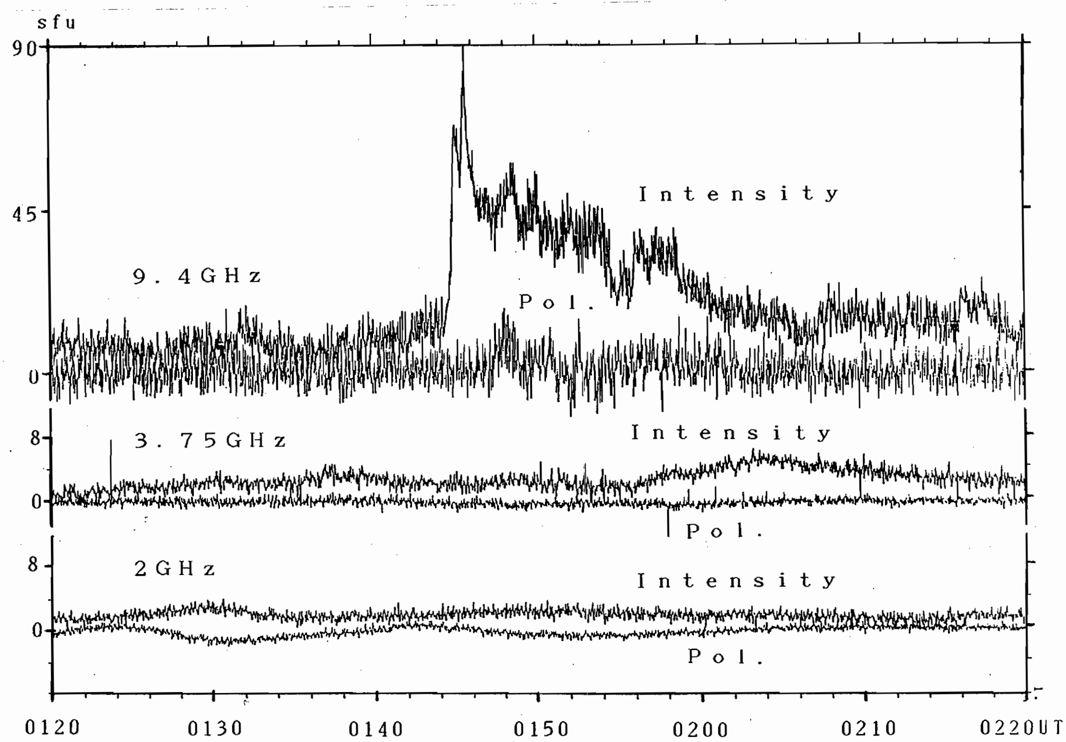

Fig. 2. Total radio flux density variations associated with M1.1 GOES flares on Oct. 27 observed by the Toyokawa 2, 3.75, and 9.4-GHz radio polarimeters.

On Oct. 25 0653 UT, Oct. 28 0118 UT, 0122 UT and 0445 UT, and Oct. 31 0658 UT, negative bursts were observed by 2, 3.75 and 9.4-GHz polarimeters. The negative burst on Oct. 25 was observed during an Hα flare in NOAA7321 and other negative bursts were observed before or after the radio bursts in NOAA7321. No variation of brightness or source structure associated with the negative bursts was detected in images obtained by the radioheliograph at 17 GHz..

3. Discussion and Summary

From soft X-ray and radio observations of NOAA7321, it was found that emergence of radio feature was delayed by one day comparing with those of soft X-ray feature. As well known, both soft X-ray and radio emission originate in coronal region. Intensity of soft X-ray emission closely depends on plasma temperature and density of emitting region. On the other hand, radio emission with strong circular polarization is quite sensitive to the magnetic field of radio emitting region. For example, assuming that the radio emission originated by thermal

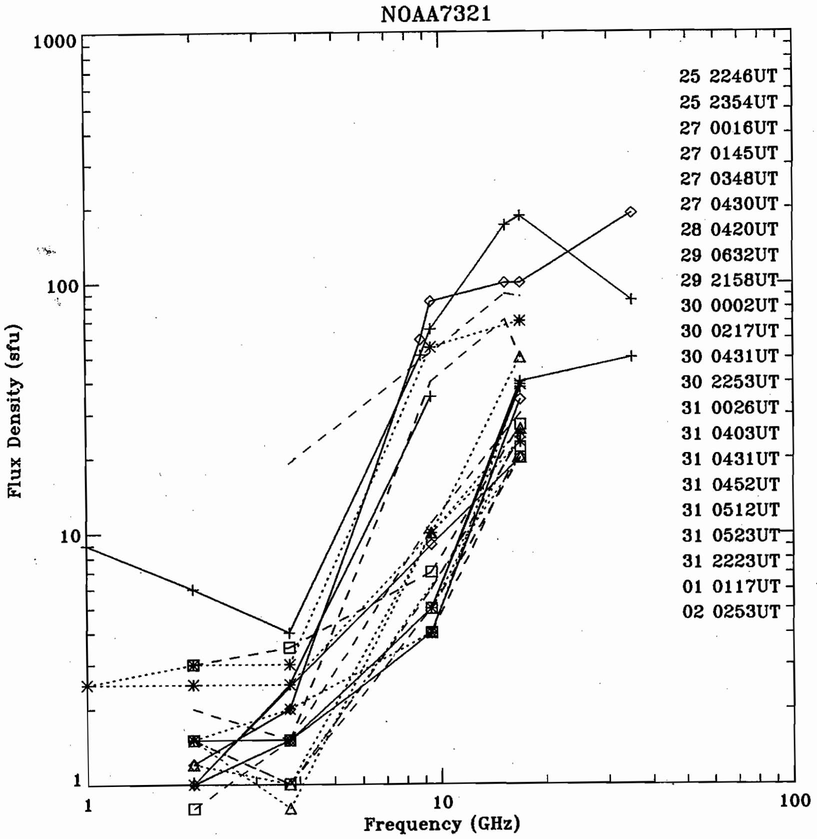

Fig. 3. Spectral profiles of radio bursts occurred at NOAA7321.

gyro-resonance at third harmonics of gyro frequency, which is usual condition to highly circular polarized slowly varying components, the magnetic field strength of 2000 Gauss is required at radio emitting region. The delay of emergence of the radio feature suggests that coronal region above NOAA7321 had weak magnetic field strength and high temperature at initial phase of the evolution.

The impulsive intensity variations and the polarization degree of moderate values (few 10 %) imply that the emission mechanism of the bursts is nonthermal gyro-synchrotron. The turnover frequency ν_{max} of nonthermal radio emission is given by

$$\nu_{max} = AN^{1/3}B^{2/3},$$

where N is the column density of high energy electrons, B is the magnetic field strength and A is constant (cf. Tandberg-Hanssen and Emslie, 1988). From this equation, it is noted that the turnover frequency is quite sensitive to the magnetic field strength. Higher turnover frequency of the radio bursts in NOAA7321 comparing with usual radio bursts (turnover frequency $\approx$ 9 GHz) suggests that the radio burst occurred at regions with strong magnetic field and/or high electron density.

The steep cutoff profiles at lower frequency imply that the bursting regions were overlaid by absorption or reflection layers. The gyro- resonance absorption was suggested as a mechanism to cause the steep cutoff profile (Dulk et al. 1983). This steep cutoff profile can be also explained by suppression of the radio emission below the plasma cutoff frequency. Takakura et al. (1994) explained the steep cutoff profile of a radio burst associated with a GOES M1.1 flare on Oct. 27 by 3.75 GHz and 9.4 GHz gyro-resonance layers overlying a loop-like emitting region at 17 GHz and 35 GHz. The steep cutoff profiles were observed for entire observation period of NOAA7321, which implies that these bursts continuously occurred under the layer with B $\approx$ 1000 Gauss and/or $n_e \approx 10^{11}$ cm^{-3}. We suggest that the radio bursts in NOAA7321 occurred in lower lying loops with strong magnetic filed strength.

The temporal coincidence of the negative bursts with Hα flares or radio bursts in NOAA7321 infers that the negative bursts also originated in same region. The negative bursts are usually related with surge activities or quick changes of electron density, electron temperature and magnetic field configuration (Shibasaki et al. 1979), and flux emergence is an origin of these phenomena. As the negative bursts were observed for entire phase of evolution of NOAA7321, it is suggested that flux emergence continued for long period in NOAA7321.

From these discussions, we suggest that the radio bursts in NOAA7321 occurred in lower lying loops with strong magnetic field strength comparing with that of usual bursts and continuous appearance of emerging flux region was origin of these bursts.

References

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