Evolution of Radio Features in a Flare Productive Active Region NOAA7321

Masanori NISHIO[1], Tatuo TAKAKURA[2], Shinzo ENOME[1], Hiroshi NAKAJIMA[1],
Kiyoto SHIBASAKI[1], Toshiaki TAKANO[1], Yoichiro HANAOKA[1], Yong-Seok CHOI[1,2], and Hideki KOSHIISHI[1,2]

[1]*Nobeyama Radio Observatory, National Astronomical Observatory, Minamisaku, Nagano 384-13, Japan*
[2]*Department of Astronomy, School of Science, The University of Tokyo, Bunkyo-ku, Tokyo 113, Japan*

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. From observations by the radioheliograph and radio polarimeters, burst spectra with high turnover frequency and steep lower cutoff was obtained,it is suggested 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 instruments 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). Observation frequency is 17GHz, where energetic electrons with few hundred KeV have a important role in radio burst. In 1992, we had observed three flare productive active regions NOAA7260, 7270 and 7321 by the radioheliograph. These flare productive active regions had complex features and occupied large area wider than few arc-min. Therefore, wide field of view of the radioheliograph is quite essential to study these flare productive active regions.

In this paper, we will describe radio images of NOAA7321 observed by the Nobeyama radioheliograph and discuss evolution of radio emitting sources in NOAA7321.

2. Observation

The active region NOAA7321 emerged at S24E11 on Oct. 24, 1992 and quickly evolved on succeeding few days. This region reached to west limb on Nov.1 and was behind the west limb on Nov. 2. In the radio images taken by the Nobeyama Radioheliograph, no radio feature was detected associated with NOAA7321 on Oct. 24, where observation timė was from 2300UT on Oct. 23 to 0640UT on Oct. 24. On the other hand, in Yohkoh soft X-ray images taken at 0423UT on Oct. 24, a small source with weak brightness enhancement was seen associated with NOAA7321. On Oct. 25, a bipolar radio feature was observed at the location of NOAA7321, which two sources were placed in northwest to southeast direction. Northwest source of this bipolar feature polarized to left circular polarization ($\approx 40\%$) and southeast source showed right circular polarization ($\approx 20\%$). This feature was similar with those observed by white light, where two sunsopts were seen on northwest and southeast sides.The radio feature associated with NOAA7321 became more complex in following few days. On Oct. 28, five bright radio sources were observed in NOAA7321. Evolutions of radio features of NOAA7321 is shown in figure 1. The partial images in this figure are cut out in equal latitude. Therefore, displacement of brightest portions on north-south direction is real. On Oct. 31, a post flare radio loop were observed in NOAA7321.

By the Solar Geophysical Data (SGD), flares were detected after Oct. 25 in NOAA7321 and many flares were reported until Nov. 2. By the radioheliograph, radio counterparts of 30 GOES soft X-ray flares were observed in NOAA7321, 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. Summary of these radio events is shown in table 1. In many bursts observed in NOAA7321, polarization enhancements of about 10% were detected before or during impulsive phase. Onset of the X9.0 flare was 0231UT on Nov. 2. As mentioned above, NOAA7321 was behind the west limb on Nov. 2. By the radioheliograph, extremely bright sources were detected at west limb just in front of the location of NOAA7321.

The flares listed in table 1 were also observed by radio polarimeters at Nobeyama and Toyokawa. Observation frequencies of these polarimeters are 1, 2, 3.75, 9.4, 17, 35 and 80 GHz. With these radio polarimeters, we can obtain spectral profiles of radio bursts. The estimated spectra of the bursts in NOAA7321 had turnover frequencies of higher than or equal to 17 GHz in many case. In addition, steep lower cutoff profiles were obtained in some case. Figure 2 shows time profiles of the M1.1 flare on Oct. 27 obtained by 2, 3.75 and 9.4-GHz radio polarimeters at Toyokawa. We can see impulsive burst activities at 9.4 GHz. On the other hand, no clear variation was detected at 3.75 and 2 GHz associated with impulsive activities at 9.4 GHz. On Oct. 25 0653UT,

Oct. 28 0118UT, 0122UT and 0445UT, and Oct. 31 0658UT, negative bursts were observed by 2, 3.75 and 9.4-GHz polarimeters. These were not detected by the radioheliograph, and no information was obtained about positions. However, the negative burst on Oct. 25 was observed during a Hα flare activities in NOAA7321. Other negative bursts were observed before or after the radio burst activities in NOAA7321.

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 closely related with magnetic field structure in emission region. Assuming that slowly varying radio emission in NOAA7321 was caused by thermal gyro-resonance mechanism and third harmonics of gyro frequency was dominant, magnetic field strength of radio emitting region comes out to be about 2000 Gauss. The delay of emergence of radio feature suggests that coronal region above NOAA7321 had weak magnetic field strength and high temperature at initial phase of evolution.

The radio bursts in NOAA7321 had high turnover frequency comparing with usual radio bursts. 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 the source, B is the magnetic field strength and A is constant (cf. Tandberg-Hanssen and Emsli, 1988). From high turnover frequencies and steep lower cutoff spectral profiles of the bursts, and polarization enhancements before or during the bursts, it is implied that the radio bursts occurred in lower lying loops with strong magnetic filed strength and lower frequency radio emission from burst region was cut off by overlying gyro-resonance layer or plasma cutoff layer.

We have no clear observational result to identify the position of observed negative bursts with NOAA7321. However, the times of these events coincided with those of flares or radio bursts in NOAA7321, and it is possible to consider that the observed negative bursts occurred in NOAA7321. 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). The surges and the changes of magnetic field configuration are sometimes associated with flux emergence. Therefore, the observed negative bursts suggests that flux emergence in NOAA7321 continued for long time.

From these discussion, it is suggested that the radio bursts in NOAA7321 were caused by continuous appearance of strong magnetic field regions to lower coronal region.

References

Nakajima, H., Enome, S., Shibasaki, K., Nishio, M., Takano, T., Hanaoka, Y., Torii, C., Sekiguchi, H., Bushimata, T., Kawashima, S., Shinohara, N., Irimajiri, Y., Koshiishi, H., Kosugi, T., Shiomi, Y., Sawa, M., and Kai, K. 1994, *Proc. IEEE*, in press.

Tandberg-Hanssen, E., and Emsli, A. G. 1988, *The Physics of Solar Flares*, Cambridge University Press, Cambridge, p.193.

Shibasaki, K., Ishiguro, M., Enome, S., Takayanagi, T., and Torii, C., 1979, *Proc. Res. Inst. Atmospherics, Nagoya Univ.*, **26**, 53.

Table 1. Reported GOES flares on NOAA7321 and associated radio bursts observed by the Nobeyama radioheliograph

	X-ray				Hα	Radioheliograph			17GHz
DATE	BEGIN	MAX	END	CLASS	CLASS	BEGIN	MAX	END	FLUX[3]
OCT.25	0051	0057	0103	C1.5	-	Not detect[4]			-
	0519	0524	0533	C1.2	-	(0519)	–	–	-
OCT.26	0230	0235	0244	C2.0	-	(0227)	–	–	-
	0315	0319	0327	C1.3	-	0330	0330	0330	-
	0505	0509	0515	C1.3	-	0507	0508	0512	-
	0557	0600	0604	C1.3	-	0546	0546	0548	-
						0613	0613	0617	-
	2255	2302	2305	C1.9	SF	$\leq$ 2258	2302	2308	-
OCT.27	0011	0020	0025	M1.0	1N	0013	0016	0035	50
	0143	0150	0159	M1.1	-	0145	0146	0206	100
	0207	0210	0212	C4.5	-	(0207)	–	–	-
	0355	0358	0401	C2.3	-	0336	0356	0404	20
	0430	0433	0436	C1.4	-	0430	0430	0437	22
	0616	0620	0632	C5.2	-	0533	0615	$\geq$ 0640	-
OCT.28	0418	0422	0426	C2.3	SF	0420	0420	0421	185
OCT.29	0631	0634	0638	C2.1	1N	0632	0632	0633	70
	2359	0004	0010	C4.9	SF	0001	0001	0018	20
OCT.30	0053	0057	0101	C1.3	-	(0054)	–	–	-
	0217	0222	0248	C1.5	SF	0217	0217	0218	26
	0252	0300	0307	C2.5	-	0305	0305	0306	-
	0340	0346	0359	C1.1	-	(0345)	–	–	-
	0400	0418	0426	C1.5	1F	0431?	0431?	0431?	27
	0551	0554	0556	C1.9	SF	0530	0552	0604	-
OCT.31	0011	0027	0043	M1.3	SF	0018	0026	0046	23
	0347	0352	0403	C5.9	-	0348	0349	0407	24
	0429	0433	0435	C4.1	SN	0431	0431	0431	34
	0448	0455	0503	C5.2	-	0449	0449	0450	50
	0536	0543	0550	C6.3	-	0523	0523	0526	38
						0538	0538	0542	-
NOV.01	0050	0110	0125	C1.6	-	0108	0109	0110	-
	0131	0134	0137	C1.3	-	0141	0141	0141	-
NOV.02	0040	0057	0109	C1.4	-	(0045)	–	–	-
	0231	0308	0328	X9.0	-	0232	0249	$\geq$ 0640	30000

1. Times in ( ) is estimated by manual operation from radio images because no burst was detected by a burst detection procedure installed in the Nobeyama radioheliograph.
2. BEGIN, MAX, END are times in UT.
3. 17GHz FLUX is radio flux measured by 17-GHz radio polarimeter at Nobeyama and its unit is sfu.
4. GRF was observed in NOAA7323 at this time.

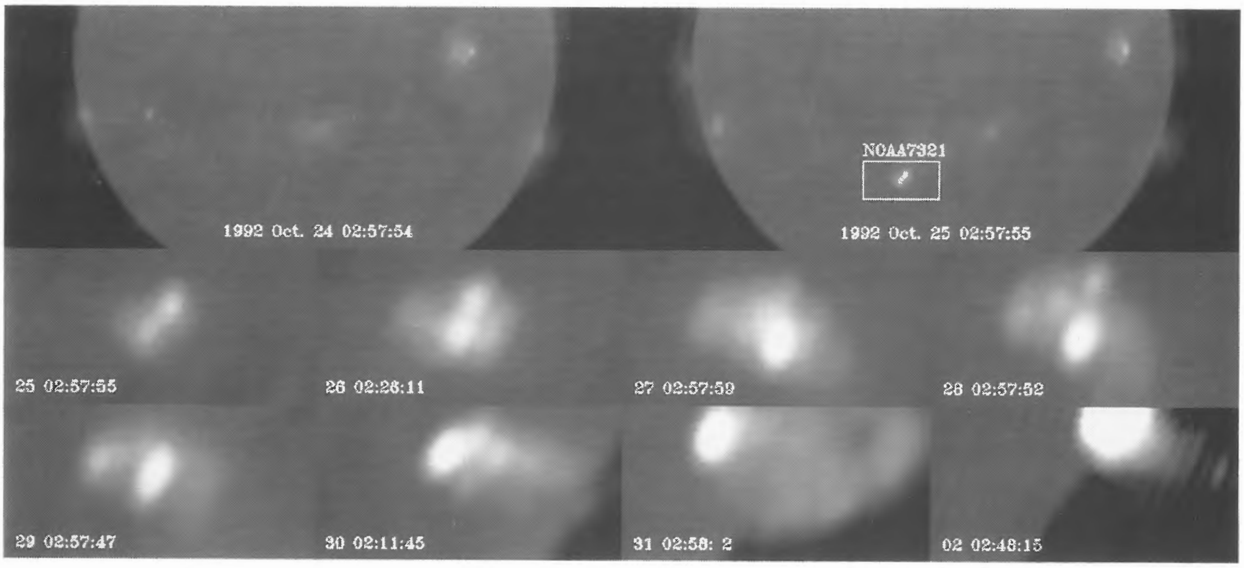

Fig. 1. Evolution of radio features in NOAA7321 observed by the Nobeyama Radioheliograph. Partial images shown in lower column are cut out in equal latitude. Therefore, displacement of brightest portions in these images is real.

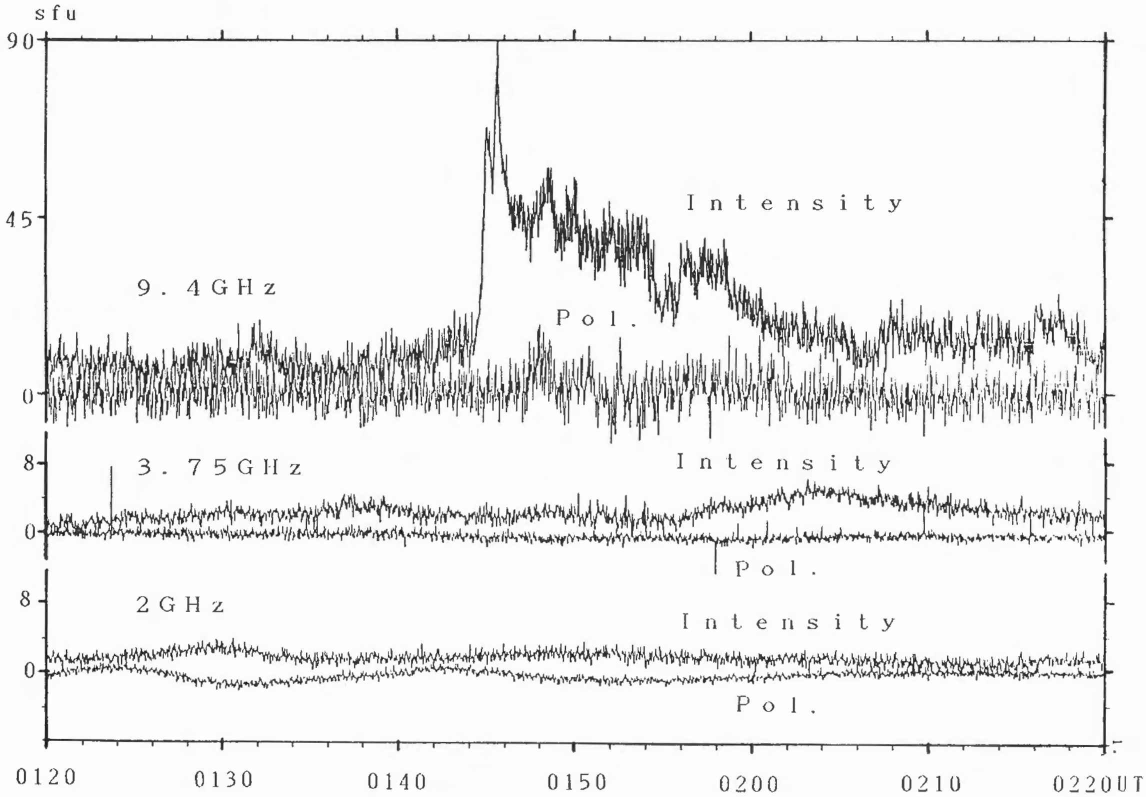

Fig. 2. Total radio flux density variations associated with M1.1 GOES flares on Oct. 27 observed by the Toyokawa 2, 3.75, and 9.4-GHz radio polarimeters.