Enhancements of electromagnetic broadband noise in 50MHz band which possibly associate with earthquakes

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Abstract

Electromagnetic noises in 50 MHz band have been observed at Tateyama observatory in Chiba prefecture in order to find any precursory electromagnetic phenomena associated with seismic activity. Electromagnetic waves were received by a Yagi antenna in the horizontal west direction with the horizontal polarization. Wideband characteristics of received signal were obtained with a spectrum analyzer. The data obtained during a half year from Feb. 10, 2000 to Sep. 17, 2000 were evaluated in terms of natural noise level. Enhancements of the broadband noise with duration of a few days were observed six times during the period. Relation between these enhancements and occurrences of earthquakes greater than or equal to M4.5 has been investigated. Most of the enhancements of the natural noise started a few days before the occurrences of earthquakes that are located in the west direction from the observatory. This fact may suggest that electromagnetic noises were generated and/or anomalous propagations of electromagnetic waves occurred just before and during the earthquakes.

Keywords: Electromagnetic wave, Precursor of earthquakes, VHF wave, Spectra of natural noise, Broadband noise

1. Introduction

There are many papers which report precursory electromagnetic phenomena of large earthquakes (Gohkberg *et al.*, 1982; Varotsos, and Alexopoulos, 1984; papers reported in the monograph edited by Hayakawa, and Fujinawa, 1994). Investigation of such electromagnetic phenomena associated with earthquakes has been much accelerated in various frequency ranges from DC to VHF (Very High Frequency: 30-300MHz) after Kobe earthquake on 1995/1/17 (papers reported in the monograph edited by Hayakawa, 1999). The characteristics of these phenomena have, however, still not been fully revealed yet because of insufficient number of well observed earthquakes.

In HF (High Frequency: 3-30MHz) and VHF range, several papers presented reporting detection of precursory electromagnetic emission and/or anomalous propagation. Maeda, and Tokimasa (1996) observed a series of pulse emission just before and after Kobe earthquake. Kushida, and Kushida (1998) have proposed an idea in which abnormal propagation of FM radio broadcasting waves occurs before earthquakes. Fukushima, and Ono (1998) observed enhancements of electromagnetic wave at 49.5MHz which might associate with earthquakes. Recently, Fukumoto, Hayakawa, and Yasuda (2001) presented an idea of any anomalous propagation in the troposphere because of low elevation angle of the received FM broadcasting wave over the horizon.

In this paper we will report our observational results in 50MHz range. We have found weak broadband noise spread full of the observing frequency band. Coincidences between enhancement of the broadband noise and earthquakes in the main part of Japan will be discussed.

2. Observatories

We have observed electromagnetic waves at VHF band at Tateyama observatory in Chiba prefecture, which locates the south end of Boso peninsula. A schematic picture of the observation system is shown in Fig.1. The observatory locates on a

small hill several kilometers far from the city area of Tateyama. A horizontally polarized 5-element Yagi antenna was used for the observations toward the west at horizontal elevation. The altitude of the position of the antenna is about 64m above the sea level. Received signal with the antenna was amplified with a pre-amplifier attached right under the antenna and transferred to an observation house with 50m-long coaxial cable. The gain of the pre-amplifier is about 25dB. Spectral characteristics of observed signal were obtained with a spectrum analyzer. Analyzed data of every 5 seconds are stored on a hard disk of a personal computer.

3. Result of observations

3.1. Asian TV waves

Fig. 2 shows examples of wideband spectral data, $50 \pm 2.5\text{MHz}$, with the west direction antenna at Tateyama observatory on successive days. Quiet periods show quite stable noise floor of around -99dBm , e.g. 3:00-9:00 on April 19, in the whole frequency range. Several artificial interferences at certain frequencies are recognized in the data. Two strong artificial signals at 48.25MHz and 49.75MHz are occasionally seen, e.g. 12:00-22:00 on April 21. The band including these frequencies is allocated to Japanese army in Japan and no domestic broadcasting stations exist. Two artificial signals seem to have sideband emission in a few MHz wide. This suggests that these signals are broadcasting waves of television from outside of Japan and propagate occasionally with some atmospheric conditions such as reflection by sporadic E-layer in ionosphere. The frequency 48.25MHz is used for Thai TV (20kW), Malaysia TV (100kW), and other several Asian countries, and 49.75MHz is used for TV in China.

3.2. Broadband noise

In Fig.2, weak broadband noise is recognized over the full range of the observed frequency band, which started at 7:15 on April 20 and lasted until noon on April 22.

The broadband noise seems to have no conspicuous frequency structures. No direct relation can be seen between the broadband noise and propagation of the two artificial frequencies. These facts suggest that the broadband emission is to be natural noise in this frequency range.

In order to investigate occurrence of the broadband noise, we see average power in the upper end of the observing spectra, i.e. from 52.1 to 52.5MHz, to avoid direct contamination of Asian TV broadcasting waves. In the processed data from Feb.10 to Sep.17, 2000, we have found six cases of enhancement of the broadband noise above -97dBm and lasting for more than 48hours. Fig. 3 shows the six cases of the enhancements.

3.3. Enhancements of the broadband noise and earthquakes

Earthquakes larger than or equal to M4.5 are listed in Table 1, which occurred during the period from Feb.10 to Sep.17, 2000 in Japan except for those in Hokkaido and Okinawa. An original list is one in the home page of Association for the Development of Earthquake Prediction (<http://www.adeq.or.jp>). We omitted earthquakes related to volcanic activities in and around Miyake/Nijima islands that started Jun. 27, because the number of the earthquakes is large and there seems to be no apparent coincidence with the enhancements of the broadband noise.

The epicenters of earthquakes are marked on the map in Fig.4 with circles and crosses with the serial numbers of the earthquakes in Table 1. Earthquakes occurred in the six enhancement periods are shown by arrows in Fig.3. We can find earthquakes occurred in the west direction from Tateyama in every cases of enhancements, which are shown with thick arrows in Fig.3 and whose epicenter are shown with filled circles in Fig.4. The enhancements of the observed broadband electromagnetic noise shown in Fig.3 would be associated with the earthquakes, because those location is in the west of observation point, Tateyama.

4. Discussion and conclusion

Six cases of enhancements of broadband electromagnetic noises around 50MHz accompanied by the earthquakes were observed at Tateyama observatory during the period from Feb.10 to Sep.17, 2000. The enhancements have following characteristics:

- 1) Each enhancement started at least 24 hours before the related earthquake and lasted for more than 48 hours as shown in Fig. 3.
- 2) The enhancements seem to be no direct association with abnormal propagation of Asian TV broadcasting waves around 50MHz.
- 3) The spectra of the enhancements of the noise have no special structures in this band 50 ± 2.5 MHz and show rather flat spectra.

There are no clear coincidences of the noise enhancements with solar activities and strength of magnetic field, Kp index, observed on the ground. These facts suggest that the abnormal broadband enhancements of electromagnetic noise would possibly be seismic phenomena rather than any artificial and/or extraterrestrial origin.

The mechanism of the enhancements of noise cannot be solved with the present observations. We, however, have found some information on the noise listed above. Electromagnetic waves of wide frequency range can be radiated as well as generation of charges from fractured rocks as reported in several theoretical and experimental investigations, e.g. Ishido, and Mizutani (1981), Enomoto, and Hashimoto (1990), Yoshida, Uyeshima, and Nakatani (1997) etc. However, electromagnetic waves in this frequency band cannot propagate in the ground because of heavy attenuation. Therefore, direct propagation of electromagnetic waves from the focuses of earthquakes should be excluded as the mechanism. Direct propagation from epicenters of earthquakes is also excluded because of following reasons: 1) each epicenter locates beyond the line of sight from the observatory and electromagnetic waves cannot reach directly to the observatory, 2) no abnormal enhancements of broadband noise was observed during nearby earthquakes as shown in Fig.3. These facts strongly suggest that any anomaly in atmosphere (including ionosphere) would occur associating earthquakes. Electromagnetic waves can propagate in the long

distances reflecting, deflecting and/or scattering in it.

Sakai, Takano, and Shimakura (2001) observed hints of broadband emission in 77MHz band during their monitoring observations of FM broadcasting wave propagating long distance. It is possible that these broadband emissions observed at 77MHz and 50MHz would be the same phenomenon. Further observations of electromagnetic noise over these frequencies are strongly required to reveal characteristics of the broadband noise.

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Num.	Date	Time(JST)	Epicenter	Latitude	Longitude	M	Depth(km)
1	2/11	16:08	Iwate South	39N	140.9E	4.9	10
2	2/11	22:29	Fukushima	37.3N	141.7E	4.9	40
3	2/13	13:33	Iwate	39.9N	143.2E	4.9	0
4	2/14	22:23	Aomori	41.4N	142.4E	4.7	70
5	2/16	20:53	Fukushima	37.4N	144.6E	5.3	10
6	3/20	6:26	Sendai	38N	141.5E	5.4	80
7	3/26	1:10	Sendai	38N	141.5E	4.7	80
8	4/2	21:25	Miyazaki	32.5N	131.2E	5.1	150
9	4/6	10:14	Ibaraki	36.4N	141E	4.5	40
10	4/10	6:08	Boso	34.7N	140.6E	4.7	50
11	4/10	6:30	Ibaraki South	36.2N	140.1E	4.9	60
12	4/13	6:51	Iwate	40.1N	142.4E	5.1	30
13	4/15	2:41	Wakayama	33.6N	135.4E	4.9	50
14	4/21	20:07	Wakasa	35.7N	135.7E	5.8	350
15	4/26	0:28	Sanriku	40.2N	143.4E	5.1	10
16	4/26	4:48	Aizu	37.6N	140E	4.6	10
17	4/26	21:49	Iwate	40.1N	143.2E	5.1	0
18	4/26	21:55	Sanriku	40.2N	143.5E	5.1	0
19	4/28	11:42	Nara	33.9N	135.7E	4.5	60
20	4/30	21:40	Sanriku	40.4N	143.9E	5	20
21	5/2	5:45	Sanriku	40.2N	143.5E	4.9	0
22	5/2	6:08	Sanriku	40.2N	143.5E	4.9	10
23	5/2	14:25	Sanriku	40.3N	143.4E	5.2	0
24	5/8	18:45	Kashima-Nada	36.4N	140.8E	4.6	40
25	5/16	4:09	Kyoto	35N	135.5E	4.6	20
26	5/16	19:40	Kashima-Nada	36.5N	140.7E	4.8	50
27	5/19	4:56	Boso	33.8N	141.2E	4.6	60
28	5/24	9:37	Aomori	41.3N	142.8E	4.6	20
29	5/24	19:24	Aomori	41.3N	142.7E	4.8	50
30	5/30	23:28	Fukushima	37.1N	141.2E	4.5	50
31	6/3	13:38	Miyagi	38.6N	141.5E	4.7	110
32	6/3	17:54	Chiba	35.7N	140.8E	5.8	50
33	6/4	20:40	Miyagi	37.9N	141.8E	5.2	60
34	6/5	9:54	Fukui	35.7N	136.1E	4.7	0
35	6/7	6:16	Ishikawa	36.8N	135.5E	5.8	10
36	6/8	9:32	Kumamoto	32.7N	130.8E	4.9	10
37	6/10	8:32	Tokaido	30.6N	138.9E	6.7	520
38	6/16	16:36	Aomori	41.5N	141.1E	4.6	140
39	6/22	20:36	Ishikawa	36.8N	135.6E	4.5	10
40	6/25	15:34	Tanegashima	31N	131.7E	5.8	10
41	7/1	5:34	Sukushima	37.3N	141.7E	5.3	40
42	7/3	22:24	Tanegashima	31.1N	131.5E	4.7	30
43	7/6	13:09	Kanto	36.5N	142.3E	5.2	30
44	7/8	3:37	Sanriku	39.1N	144.5E	5.1	10
45	7/11	2:01	Ibaraki	36.2N	140.9E	4.7	40
46	7/12	1:29	Ibaraki	36.2N	140.9E	4.7	40
47	7/17	8:00	Tottori	35.4N	133.4E	4.6	20
48	7/20	2:19	Sanriku	38.8N	143.4E	5.4	0
49	7/21	3:39	Ibaraki	36.6N	141E	6.1	50
50	7/21	14:16	Chiba	35.2N	141.2E	5.5	40
51	7/26	16:24	Kochi	33.7N	133.5E	4.5	10
52	7/31	13:37	Sanriku	39.6N	143.8E	5.2	10
53	8/3	14:30	Tanegashima	31.1N	131.5E	4.8	40
54	8/18	22:47	Ibaraki	36.3N	141.5E	5	20
55	8/19	21:41	Ibaraki	36.3N	141.6E	5.4	30
56	8/27	8:42	Chiba	35.8N	140.1E	4.5	70
57	8/27	16:54	Akita	39.7N	139.4E	4.5	20
58	8/28	17:20	Fukushima	37.8N	142.1E	5.3	40
59	9/7	14:51	Ehime	33.5N	132.4E	4.6	50
60	9/14	2:23	Sanriku	40.2N	143.5E	5.2	0

Table 1: All earthquakes occurred in Japan except for Hokkaido and Okinawa areas during the period from Feb.10 to Sep.17, 2000 whose magnitudes are larger than or equal to M4.5.

Fig.1. Schematic picture of the observation system. A horizontally polarized 5-element Yagi antenna was used for the observations toward the west at horizontal elevation. Received signal with the antenna was amplified with a pre-amplifier attached right under the antenna and transferred to an observation house with 50m-long coaxial cable. Spectral characteristics of observed signal were obtained with a spectrum analyzer.

Fig.2 : Spectral data with the west direction antenna at Tateyama on successive days from April 19 to April 22. Weak broadband noise emission can be recognized, which starts at 7:15 in April 20 and lasts until noon in April 22.

Fig.3. Six cases of the power enhancements of the weak broadband noise. Earthquakes which are larger than or equal to M4.5 and occurred in Japan except for in Hokkaido and Okinawa during the corresponding periods are shown with arrows. We can find earthquakes occurred in the west direction from Tateyama in every cases of enhancements, which are shown with thick arrows

Fig.4 : Locations of the earthquakes during the period from Feb.10 to Sep.17, 2000. The enhancements of VHF electromagnetic broadband noise were observed in association with the earthquakes located in the west direction as shown with filled circles.