OBSERVATION OF VHF RADIO EMISSIONS FROM THE SUN

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1. Introduction

The Sun consists of the solar interior, the visible surface, the chromosphere, and the corona. The Sun is a source of radio noise that is produced by plasma oscillations, synchrotron emission, and random collisions of electrons with heavy particles. A solar flare is a burst of 'light' occurring in the chromosphere near a sunspot. Flares are frequent around the peaks of sunspot cycles. They are observed a wide band of wavelengths from radio to X-rays. Radio bursts are associated with flares and originate from all levels of the solar atmosphere between the lower chromosphere (UHF and SHF bands) and the outer corona to heights of several solar radii (VHF and HF bands) [1].

So, radio emissions from the Sun have been observed in various frequency bands. We have been observing radio emissions in VHF band associated with not only the solar activities but also natural electromagnetic (EM) phenomena from 1997 [2]. We are now operating 16 observatories in Japan. The observation in VHF band will be expected to reveal EM characteristics of the corona region.

We have realized an observation system for natural EM phenomena in VHF band, from 76MHz to 90MHz. Taking into account of frequency characteristics, this frequency band is hardly influenced by urban and manmade noises compared with other lower frequency bands [3]. Moreover, we can obtain a synthesized FM receiver with the noise figure of 2dB, and this receiver is expected to detect EM waves up to -120dBm [4]. This frequency band is assigned for FM broadcasting exclusive use in Japan, so it is well administrated against other radio interferences.

In this paper, the observation method will be described. Then, the observed radio emissions associated with the solar activities will be shown in VHF band in some observatories. Finally, observation results will be summarized.

2. Observation Method

2.1 Dual Frequency Method with Synthesized FM tuners

We are surrounded with many EM waves such as broadcasting, communication usage and manmade noises. The intensity of manmade noises is generally higher than that of natural EM phenomena. Especially, on the EM observation in the FM broadcasting frequency band, it is necessary to realize an observation method for identifying natural EM phenomena from FM broadcasting. So, we have developed a dual frequency observation method. In our method, we select two different frequencies (fn and fr) for the observation as shown in Figure 1.

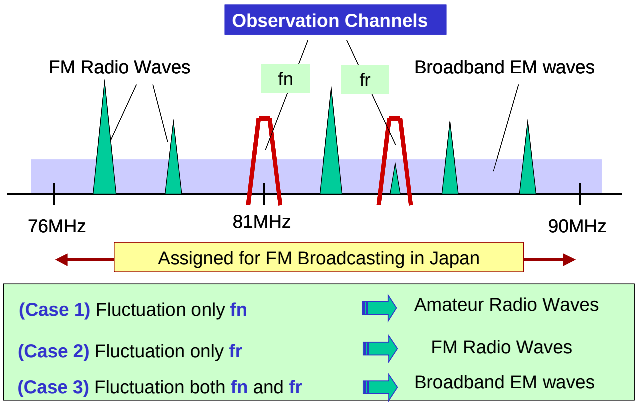

Figure 1: Dual frequency observation method

Observation frequencies of fn and fr are as follows;

A frequency of 'fn' is selected from 80.8MHz to 81.2MHz, which frequencies are not assigned for any FM broadcasting use in Japan. These frequencies are interfered by the 3rd order distortion of 27 MHz transmitters in rare cases.

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A frequency of 'fr' is selected from 76MHz to 90MHz except for 80.8MHz to 81.2MHz. The selected FM radio channel of fr is not usually received at the observation site, because this frequency channel is used at a remote FM radio station far from the observatory.

Case 1: Fluctuation in only fn frequency; in this case, a received signal is considered as a communication signal from a transmitter of a 27MHz citizen band in Japan.

Case 2: Fluctuation in only fr frequency; in this case, a received signal is considered as an FM broadcasting signal reached from a remote station to the observatory.

Case 3: Fluctuation in both fn and fr frequencies; in this case, a received signal is considered as a broadband EM wave.

Then, we can identify by this observation method if a received signal is a broadband EM wave or an FM broadcasting signal [4]. In our observation system, a synthesized FM tuner is adopted, and this tuner has a receiving bandwidth of 100kHz/3dB and a noise figure of 2dB. The receiving limitation level of the tuner is about -120dBm.

We have constructed the observation system based on the dual frequency observation method with the synthesized FM tuner. In our observation system, four FM antennas are installed on the rooftop of the observatory toward east, west, south and north directions, respectively. Each antenna is connected with two synthesized FM tuners to measure the received levels of fn and fr channels respectively. The system specifications are summarized in the Table 1.

Table 1. Observation system specifications

* Receiver: PLL type synthesized FM Tuner
* Receiving antenna: Yagi-Uda antenna
* Receiving bandwidth of 3dB: 100kHz
* Limitation of received level: -120dBm
* Observation frequency-band: VHF band

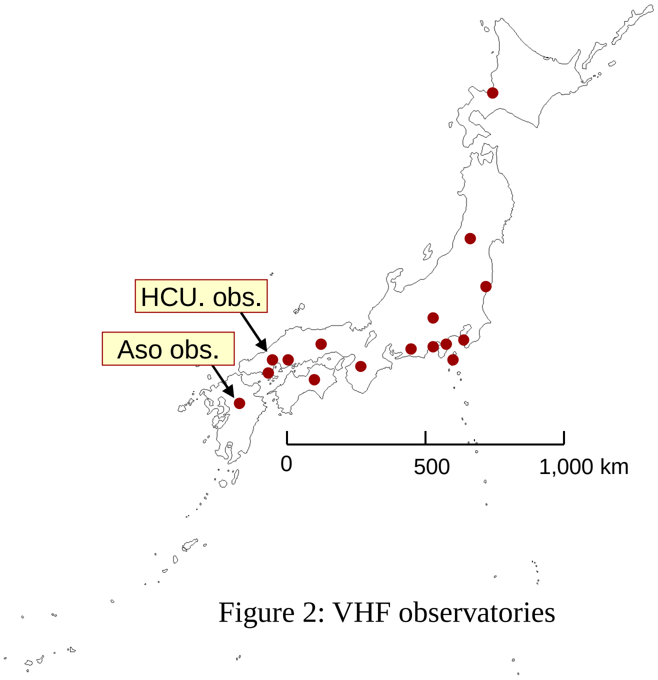

Figure 2: VHF observatories

2.2 EM Environment at Observatories

We are now operating the observation system at 16 sites as shown in Figure 2. All of observation data are collected to Hiroshima City University (HCU) through Internet or communication networks. So, we can immediately get the observation data from any observatories.

Before the observation, it is essential for the reliable observation to evaluate the EM environment of an observation site. It is well known that galactic noise predominates above about 10MHz in "quiet" rural areas [5]. We tried to detect galactic noise in VHF band by our observation system. Figure 3 shows the seasonal variation of EM waves of 80.9 MHz received at the HCU. These received levels were observed on September 7, December 8, 2001 and March 1, 2002, respectively. The occurrence times of the peak level are shifted by two hours a month. It corresponds to the culminate time of the Galaxy. So, it is suggested that HCU observatory is "quiet" EM environment without manmade noise.

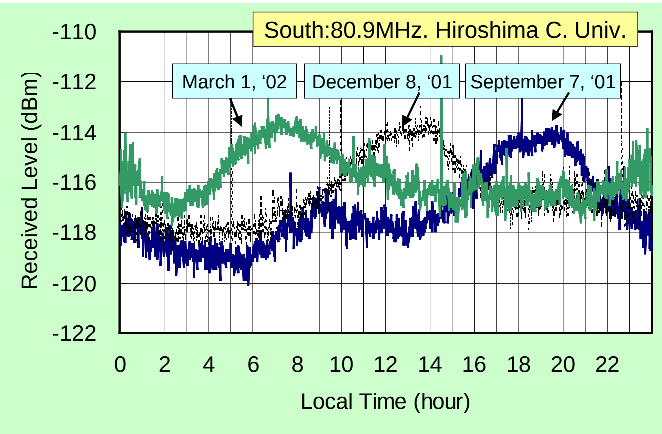

Figure 3: Seasonal time variation of 80.9MHz associated with galactic noise

3. Radio Emissions associated with Solar Activities

3.1 Shorter Time Duration Phenomena

Figure 4 shows the time variations of received levels both 81.0 MHz (fn) and 85.6 MHz (fr) in south direction at HCU on October 19, 2001. A sharp rise is followed by a slower decline. It shows a typical solar flare of Type II, radio burst of about ten minutes duration. The received levels both 81.0 MHz and 85.6 MHz are similarly fluctuated. So, it is suggested that the detected EM wave has a broadband spectra. The detected peak level is -91dBm in both observation frequencies. It was informed that a solar flare of X 1.6/2B was occurred at 0:47 on October 19, 2001 (UT) [6]. It has been confirmed that a solar flare of X-class has been detected in our observation systems with synthesized FM tuners.

Figure 5 shows the time variations of received levels of 81.0 MHz (fn) observed at Hiroshima, Yokosuka, and Shimizu observatories on October 19, 2001. The similar fluctuations are also observed at the same time at the different sites. The observations at some different sites are essential to identify whether it is a global or local phenomenon.

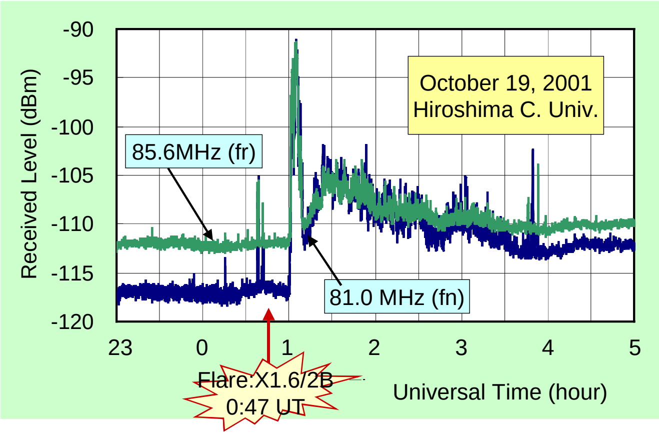

Figure 4: Time variation of received levels of fn and fr associated with a solar flare detected at HCU obs.

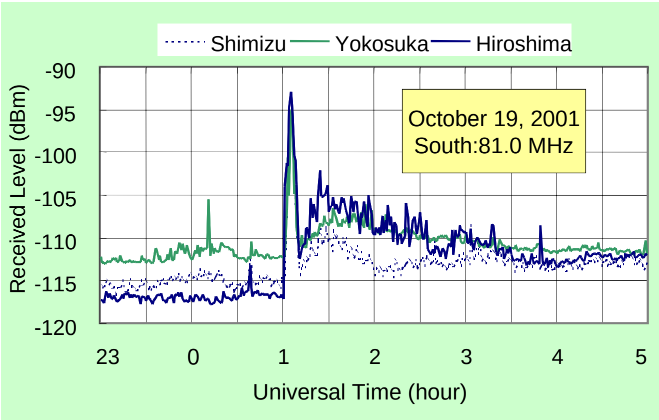

Figure 5: Time variation of received levels of 81MHz associated with a solar flare detected at three different sites

3.2 Longer Time Duration Phenomena

Figure 6 and 7 show the EM phenomena observed from east antenna at HCU and Aso observatories on March 25 to April 2 in 2001, respectively. Received levels are increased to about -100dBm correspond to the sunrise. The duration times are about six to ten hours longer than that of solar flares shown in Fig. 4. These EM phenomena have been observed for nine days at HCU and Aso observatories. Then a big magnetic storm lasted on March 31and April 1. A solar flare of X20 was occurred at 21:32 on April 3, 2001 (UT). These longer time duration phenomena were observed at some observatories in Japan. The received levels fluctuated correspond to the movement of the Sun. It is suggested that they are EM phenomena associated with a solar activity such as "noise storm" which are generally classified some types [7]. The phenomena shown in figure 6 and 7 will be considered as a Type I noise storm. Because, they have been continued for nine days in a metric band (VHF band).

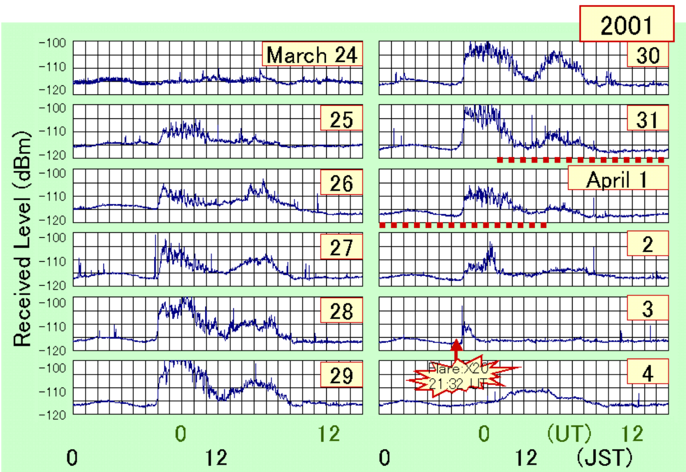

Figure 6: Time variation of received level of 81MHz associated with a Type I noise storm detected at HCU obs.

Figure 8 shows time variation of received levels of fn and fr at Aso observatory on March 30, 2001. In this figure, some notch points were detected both fn and fr levels. The time differences between fn and fr are gradually increased 3 to 25 minutes as shown in figure 8. These time differences will be frequency drift phenomena caused by a Type I noise storm.

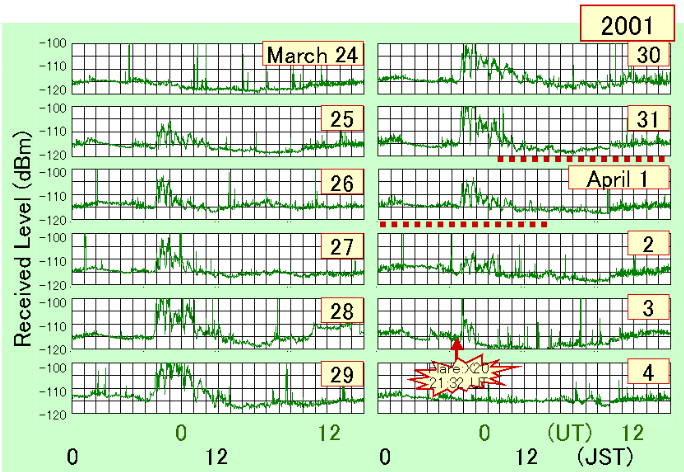

Figure 7: Time variation of received level of 81MHz associated with a Type I noise storm detected at Aso obs.

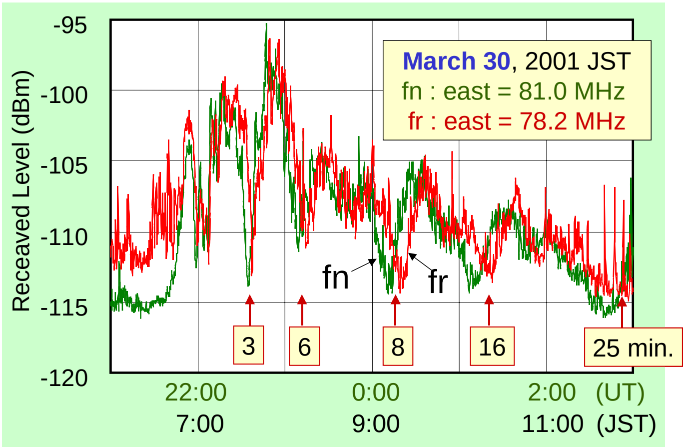

Figure 8: Time variation of received levels of fn and fr associated with a Type I noise storm detected at Aso obs.

4. Conclusions

The dual frequency method with synthesized FM tuners has been described. We are now operating 16 observatories in Japan. Observing of radio emission at some different sites is essential to identify whether it is a global or local phenomenon. The solar activities and the galactic noise have been observed as broadband EM waves at different observatories.

In this paper, radio emissions associated with solar activities, shorter and longer time duration phenomena have been reported. The shorter time duration phenomenon is broadband radio burst associated with a solar flare, X1.6/2B, Type II, on October 19, 2001. It has been confirmed that a solar flare of X-class has been detected in our observation systems with synthesized FM tuners.

The longer time duration phenomenon is broadband EM waves associated with a solar activity from March 25 to April 2, 2001. It has been confirmed that the noise storm lasted for nine days has been detected in our observation systems. And the phenomenon with frequency drift was detected.

The dual frequency method with synthesized FM tuners is very simple and useful to observe solar activities. We will continue to observe in VHF band to reveal EM characteristics of the corona region. We would like to appreciate administrators in Aso, Shimizu, and Yokosuka observatories installed our system. We wish to thank Prof. Maeda of Hyogo College of Medicine for his kind comment to "noise storm". This research is supported by the Grant-in-Aid for Scientific Research (C) No.14550367 and HCU Grant for Special Academic Research.

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