The Frequency Drift in Spike Radiation Observed on May 10, 1991

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Abstract

In this paper, we have briefly analysed the the fast frequency drift (~ 25GHz/s) characteristic in the spike radiation observed by Beijing Astronomical Observatory at the frequency band of 2545 – 2645 MHz on May 10,1991. It has been considered that the frequency drift originates from the process of down-moving of energetic electron beams along a coronal magnetic loop which form the loss-cone distributions driving the electron cyclotron maser (ECM) instability.

1. Introduction

In solar radio radiation, there are many kinds of event to have the frequency drift characteristic. For example, classical type III bursts begin at the frequency of a few hundred megahertz and then shift rapidly to lower frequencies. As it is known, in the solar atmospheric plasma, if a disturbance moves outward from the sun and at each height produces emission at the local plasma frequency $\nu_p(or\ 2\nu_p)$, then the emission shifts from high to low frequencies at a rate depending on the speed of the disturbance and whether the emission is generated at the fundamental or second harmonic (Dulk,1985).

Especially, this drift characteristic in the solar radio fast events, has also been observed recently. For example, the drift rates of the fast-drift III_{dm}-like events are very high ($\geq 2000 MHz/s$) and their value remains high up to the end frequency. This fast drift characteristic may be explained by the energetic electrons moving through the solar atmosphere having large gradients in density (Wiehl et al.,1985).

Recently, moreover, the events of microwave broadband structures with relatively low drift rates have been observed to occur more frequently. They are different from type III bursts at lower frequencies, but originate from the gyrosynchrotron emission mechanism. This frequency drift may be explained by the variations of the plasma parameters in the source, e.g. the source moving in an inhomogeneous magnetic field or the electron population varying with the time, etc.. Furthermore, similar to type II bursts, this frequency drift may be interpreted by the plasma radiation from shocks (Bruggmann et al.,1990).

The frequency drift characteristic in the spike radiation has been observed by Beijing Astronomical Observatory at the frequency band of 2545 – 2645 MHz. For instance, high drift rates up to ~ 25 GHz/s have been obtained in the spike event on May 10,1991 (Jin et al.,1991). In this paper, we make a brief analysis for the spike event.

2. Example of frequency drift

A typical spike event has been observed by Beijing Astronomical Observatory on May 10, 1991. There are some spikes in this event to exhibit an obvious time difference at the frequencies of 2545 and 2645 MHz, as it is shown in Figure 1

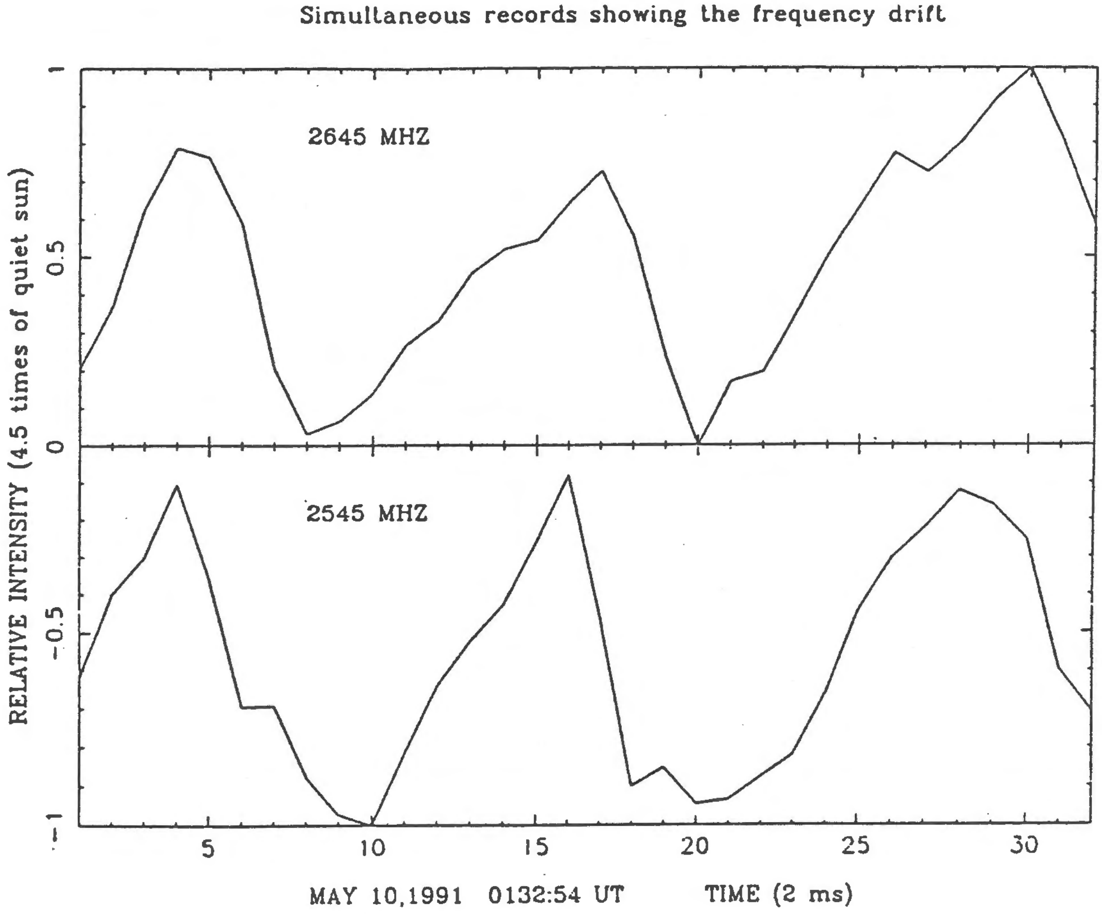

Fig.1 The frequency drift in the spike event observed on May 10,1991.

It can be seen from Figure 1 that the spikes at the 2545 MHz is about 4ms earlier than the ones at the 2645 MHz. This indicates that these spikes have a positive drift rate of about 25 GHz/sec from lower frequency to higher frequency (i.e. reverse drift).

3. Brief analysis

Nowadays, it is generally believed that spike radiation can be explained by the electron cyclotron maser (ECM) instability driven by the loss-cone distribution.The growth via ECM occurs only when the energetic electrons satisfy the wave-particle resonance condition (Dulk,1985):

$$\omega - \frac{s\Omega_e}{\gamma} - k_{\|}v_{\|} = 0 \qquad (1)$$

the waves satisfy the following conditions (Winglee,1985)

$$\omega^2 \gg k_{\|}^2 c^2, \qquad (2)$$

where ω is the frequency of the waves , $k_{\|}$ the wave vector component parallel to $\vec{B}$, s the harmonic number , $\Omega_e = eB/mc$ the electron cyclotron frequency , γ the Lorentz factor , $v_{\|}$ the electron velocity component parallel to $\vec{B}$, c the velocity of light . As the considered electrons are semi-relativistic ones , they can be shown that

$$0 < \frac{v^2}{c^2} \ll 1. \qquad (3)$$

From equations (2) and (3) , therefore , equation (1) may be approximately taken as

$$\omega \approx s\Omega_e. \qquad (4)$$

From equation (4) , one can obtain

$$\frac{d\omega}{dt} \approx \frac{se}{mc}\frac{dB}{dt}, \qquad (5)$$

i.e.

$$\frac{d\nu}{dt} \approx 2.8 \times 10^6 s \frac{dB}{dt}. \qquad (6)$$

we mainly take account of the emission at the second harmonic, so $s = 2$.

According to the observations (see figure 1), the frequency of the spikes drifts from 2545 MHz to 2645 MHz during the time of about 4ms, that is to say, the drift rate is about

$$\frac{d\nu}{dt} \approx 25MHz/ms.$$

Taking account of equation (6), therefore, it is clear that

$$\frac{dB}{dt} \approx 4.5Gauss/ms.$$

It will be shown from this that during the period of 4ms, the magnetic field strength in the source region of spike radiation has increased by ~ 18 Gauss because of the motion of the source.

According to equation (4), the field in the radiation source at $\nu_1 = 2545MHz$ can be calculated to be

$$B_1 \approx 454Gauss.$$

It is assumed that the magnetic field is a magnetic dipole field, so the field can be written as follows (Zhao.,1991):

$$B = \frac{1}{2} d_0^3 \frac{[r^2 + 4(h + d_0)^2]^{1/2}}{[r^2 + (h + d_0)^2]^2} B_0, \tag{7}$$

where h is the height above the photosphere, r the distance from the central axis of the active region, d_0 the depth of the dipole below the photosphere. B_0 the magnetic field at the photosphere. Taking $r = 0, d_0 = 10^9 cm, B_0 = 2000 Gauss$, the height of the radiation source can be obtained

$$h_1 \approx 6.39 \times 10^8 cm$$

In the same way, when the frequency drifts to $\nu_2 = 2645 MHz$ the magnetic field in the source is about

$$B_2 \approx 472 Gauss$$

and the height of the source is about

$$h_2 \approx 6.18 \times 10^8 cm$$

Therefore, one can estimate the mean velocity of the electrons during the period 4ms:

$$v \approx 0.175c.$$

It may be concluded from the above that the energetic electron beams travel downwards at the velocity of $\sim 0.175c$, and hence produce the positive frequency drift of $\sim 25 MHz/ms$.

It is well understood that the ECM mechanism gives the radiation near the electron cyclotron frequency and its second harmonic. This process requires a kind of unstable electron distribution offering free energy for the maser. The most possible configuration is the loss-cone distribution. The energetic electron beams form the loss-cone distributions at different positions when they move downwards along the loop. Then in these unstable regions, the spike radiation is generated by maser action. Therefore, the radiation presents the positive frequency drift (i.e. reverse drift) characteristic, that is to say, the radiation frequency increases with the time.

4. Conclusions

In this paper, the frequency drift characteristic in the spike radiation observed on May 10,1991 has been briefly analysed. It has been believed that the high frequency drift rate ($\sim 25 GHz/s$) originates from the down-moving along the loop of the energetic electrons which form the loss-cone distributions driving the ECM instabilities.

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