The Features of Spikes Received at 2545 and 2645 MHz Frequencies

Sheng-Zhen JIN, Xiao-Cong LI

Beijing Astronomical Observatory, Academia Sinica, Beijing 100080, China

Abstract

In this paper, some features of spike radiations and other fast fine structures of microwave bursts at 2545 and 2645MHz Frequencies, shch as the narrow bandwidth, the rapid frequency drift, the quasi- oscillation and the quick reversion of the polarization senses are introdused and discussed. We think that these features may be closely related to the electroncycrotron instability, the wave beam resonance condition,the movement of the MHD wave and the nonthermal beam in the solar corona source region.

1. Introduction

The spikes and fast fine structures(FFT) occured in solar microwave bursts are usually with very short time scales. Since 1980, they draw atentions of many solar radiophysicists. Generally, they are with very narraw radiation bandwidth ($\triangle\omega \geq 10\%$), very rapid frequency drift($df/dt \geq 10GHz$). Thy are usually modulated by some quasi-oscillation with periods in second and subsecond time scales. And the senses of polarization of the spikes are quickly reversed in short time interval.

Since June 1990, a new microwave polarimeter was put into observation at Beijing Astronomical Observatory. It received right and left hand circular polarizations (RHCP, LHCP) at 2545 and 2645 MHz frequencies. Signal from the four channels can be sampled in every 0.2 ms or 2 ms, and over one handred spikes and FFS events had been recorded(Jin et,al.,1991). Some features are demonstrated in this paper.

2. Narrow Bandwidth Radiation

Solar microwave spike and FFS radiations are known that they have very narrow bandwidth. According to Stahli and Benz(1987), at 3100 MHz frequency. the relative bandwidth of the spike radiation($\triangle\omega/\omega$) is less than 10%, and Benz(1986) at 0.1~ 2 GHz frequencies, the $\triangle\omega/\omega$ are less than 1.5%. According to the samples, we have recorded so far, it is evident that many spike and FFS emissions at 2545 and 2645 MHz are with 5% relative bandwith, and the profiles of them at different frequencies are different. Some spikes only occurred in one frequency.

Fig.1. shows the spike groups occurred at 0647 UT at 2545 and 2645 MHz , on May 16,1991. The peak flux of the spike groups at 2645 MHz is about 2.5 times $S_{\odot}$, the quiet sun flux on the same day , the duration time is about 500 ms, and it is composted of two subgroups. At 2545 MHz frequency, there are no obvious spikes recorded.

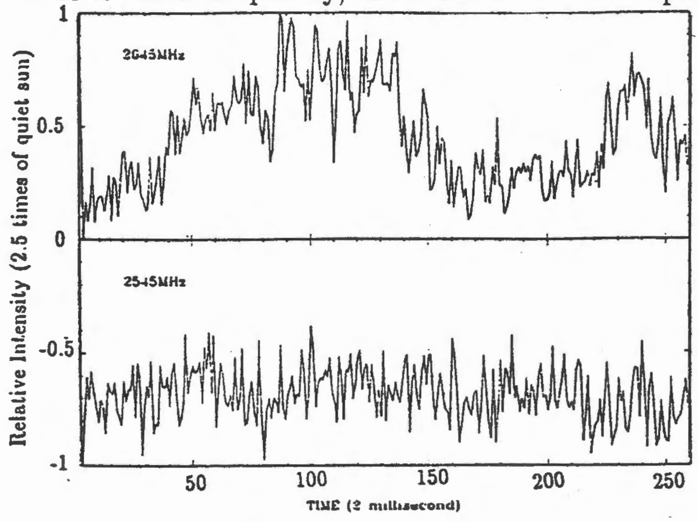

Fig. 1 The spike emission occurred at 0647 UT on May 16,1991.

Fig.2. demonstrats the spike radiations recorded at 0409 UT on January 25, 1991 , at 2545 and 2645 MHz. In the 300 ms time interval started at 0409:56 UT. The profiles of the spike, occurred at the two frequencies, are very different and there is no corresponding spike occurred at 2840 MHz frequency.

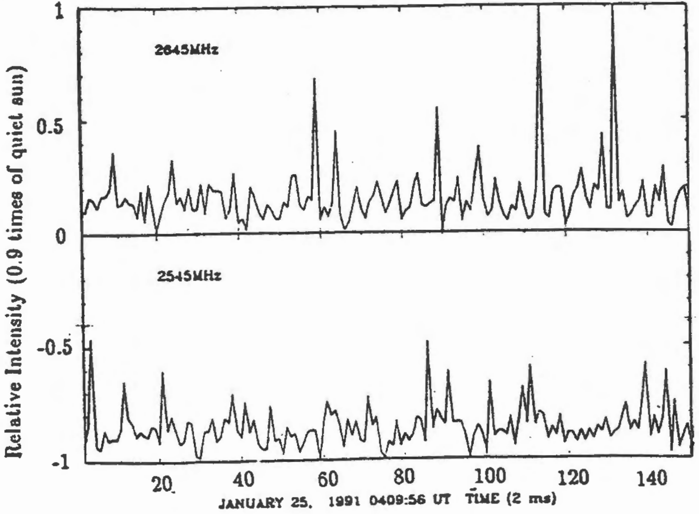

Fig. 2 The spike emission occurred on January 25, 1991.

We know that the spike emissions generally come from the electronmagnetic emission stimulated by the electron-cycrotron maser instibility under the particle wave resonance condition.

$$\omega = \gamma^{-1} s\Omega_B + k_{\|}u_{\|} \qquad (1)$$

where γ is the Lorrentz factor, s is the hamonicas of the radio wave, $k_{\|}$ is the projection on the magnetic field of the wave vector, $u_{\|}$ is projection on the magnetic field of the beam velocity, and Ω_B is the electron gyro-frequency. It is believed that the resonance condition limit the bandwidth of the spike radiations.

3. Frequency Drift

The rapid frequency drift rate of the spike and FFS events has interested many solar radiophysicists. Stahli and Benz[2] showed the frequency drift rate from-0.7GHz/s to -17GHz/s at 3100 MHz frequency. Aschwanden and Benz (1986) demonstrated the frequency drift rate from 1 GHz to 4 GHz/s, at 326 MHz and 770 MHz frequencies respectivelly.

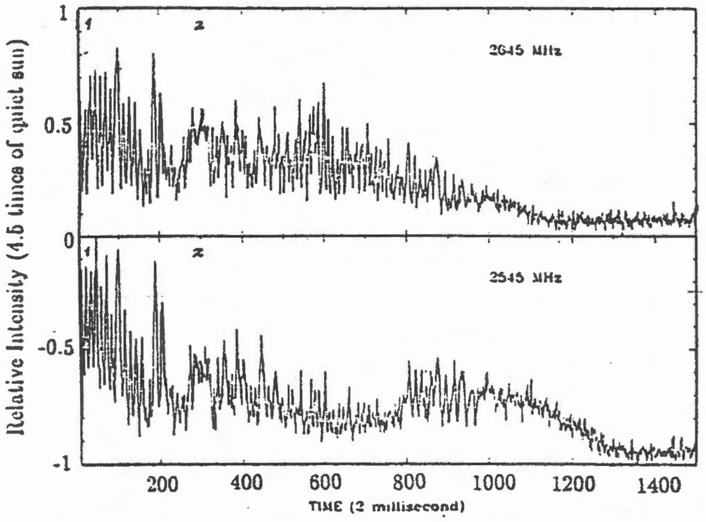

Fig. 3 The frequency drift of spike emissions occurred at 0132:54 UT on May 10,1991.

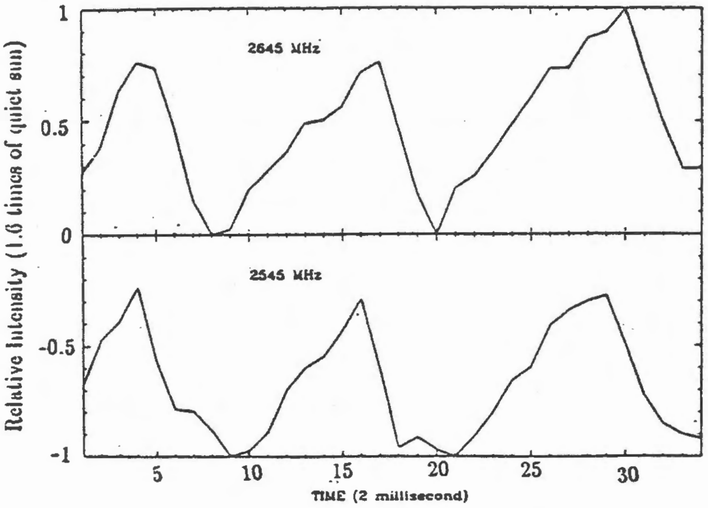

Fig. 4 The frequency drift of spike emissions occurred at 0132:02 UT on May 10,1991.

Several spikes and FFS events with rapid frequency drift have been recorded between 2545 and 2645 MHz frequencies. The frequency drift rate is about 15~ 30 GHz/s of the spike radiations. Fig.3.displys the profiles of the spikes occurred on May 10,1991. The background burst at 2545 MHz was delayed about 500 ms compared with that at 2645 MHz, the frequency drift rate is 0.4 GHz/s. The spike radiations superimposed on the backgrounds werw shown the same profile. The fine structures labeled by "1" and "2" in Fig.3. are shown in Fig.4., and Fig.5. respectivelly. It can be seen that the spikes at 2645 MHz was delayed about 6 ms compared with that at 2545 MHz in Fig.4., and the spikes at 2545 MHz was delayed about 4.0 ms compared with that at 2645 MHz in Fig.5.. The frequency drift rates are 15 GHz/s and -28 GHz/s respectivelly.

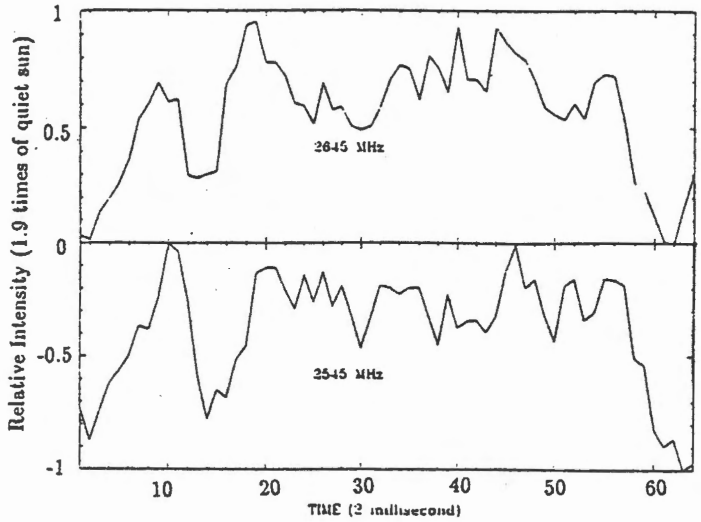

Fig. 5 The frequency drift of spike emissions occurred at 0132:55 UT on May 10,1991.

It is known that the spike and FFS radiations are depended on the interactions of particle-wave and beam-wave, stimulated by the nonthermal electron beams in the solar corona. Obviously both the direction and the time scale of the frequency drift are closely related to the direction and the velocity of the nonthermal electron beam in the source region. From Eq.1.

$$d\omega/dt = (sq/\gamma m)dB/dt - ku(sin\theta cos\alpha d\theta/dt + sin\alpha cos\theta d\alpha/dt) + kcos\alpha sin\theta du/dt \quad (2)$$

where q is the charge of a electron, m is the rest mass of a electron, S is the harmonics of the radio wave. γ is the Lorentz factor, B is the the magnetic induction in source region, k is the wave vector, u is the velocity of the nonthermal electron beam, θ is the radio angle between k and B, α is the pitch angle between u and B. Assuming that B, θ, α are unchanged, the reversion of the direction of u may lead to the reversion of the frequency drift rate. If the distribution of the electrons in the nonthermal beam is lose-cone distribution, the velocity directions of the electrons incideut and reflected may be reversed, so the directions of frequency drift rate caused by those two beams may be changed.

4. Quasi Period Oscillations.

The spike and FFS radiations usually are associated with quasi period oscillations.(Jin et al.,1989, Jin et al., 1990, Zhao et al.,1990 Fu et al 1990)The periods of this quasi-oscillations are in second or subsecond time scales. It is believed that, the quasi period oscillations of the spike and FFS events are caused by the MHD waves in the source region or the nonthermal beams modulated in the acceleration region.

Fig.6. indicats the spike groups occurred on July 30,1990. It started at 0728 UT , and it is lasted about 100 ms. The peak flux density of the spikes is about 20 times

that of the quiet sun, and it is composted of 30 individual spikes. The average period of the quasi- oscillations are about 3 ~ 5 ms. The spike groups occurred on May 10, 1991 is shown in Fig.7. The spikes started at 0132 UT, at 2645 MHz. The period of the quasi-oscillations is about 28± 2 ms.

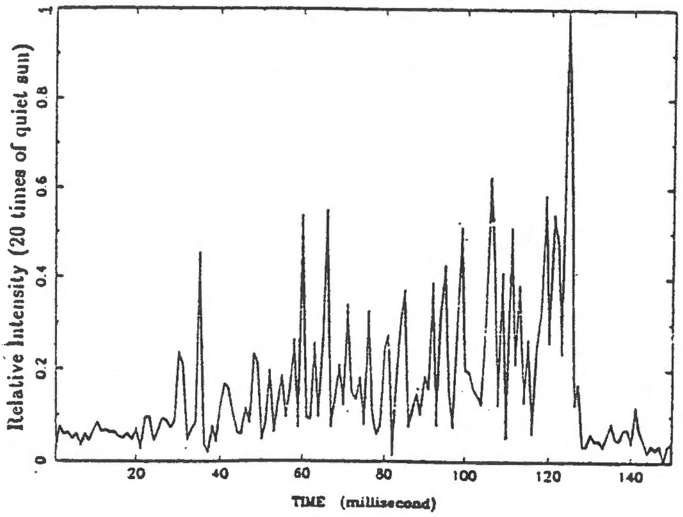

Fig. 6 The oscillation of spike emissions occurred at 0728 UT on Jyly 30,1990.

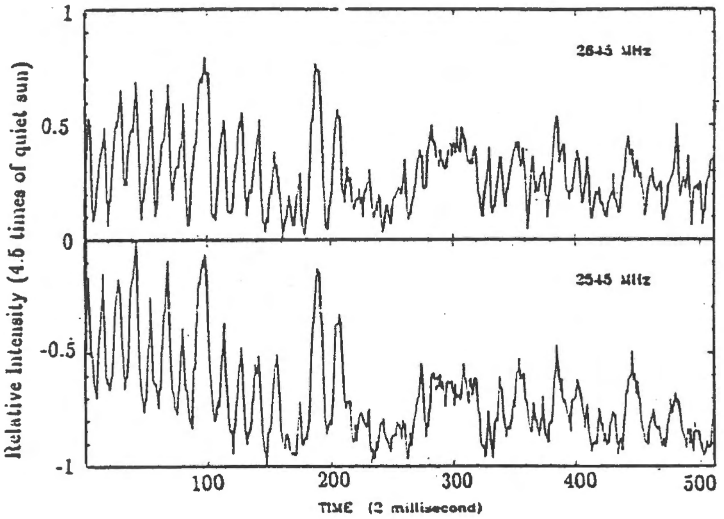

Fig. 7 The oscillation of spike emission occurred at 0132 UT on May 10, 1991

5. Reversion of the polarization senses

The quick fluctuations of the polarization sense is another characteristics of spike radiation. Gary observed the spike radiations, the polarization sense of the spikes is reversed from 86% RHCP to 23 % LHCP at 2840 MHz in 1990.(Gary,D.,et al.,1990)

An intensive solar flare associated with a microwave burst was recorded on May 16, 1991. In the peak phase of the microwave burst, a lot of spikes and FFS emissions were recorded. Fig.8. shows the polarization components of the spikes occurred at 0647 UT. The peak flux densities were about 8.5 $S_{\odot}$ of the LHLP wave and 1 $S_{\odot}$ of the RLCP wave. The polarization senses are reversed 6 times quickly and alternated. The LHCP is about 80% to 90%, and the RHCP is 30% to 40%. The average reversion time interval is 50~100 ms, and the shortest reversion time interval is about 60 ms.

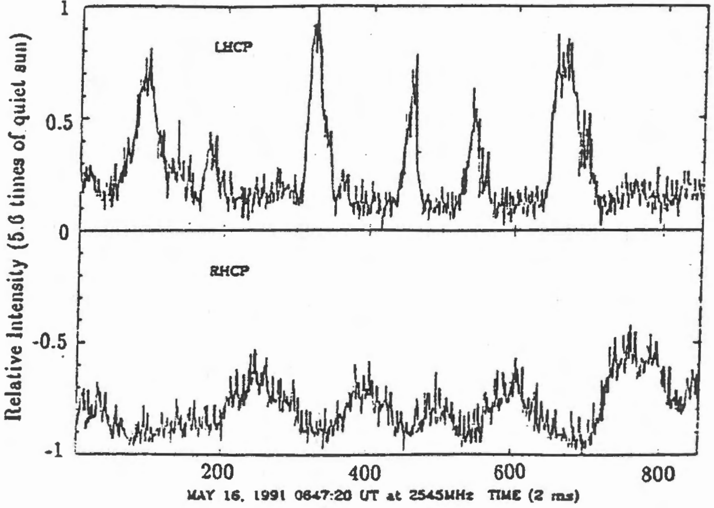

Fig. 8 The reversion of the polarization senses of the spikes occurred at 0647 UT on May 16, 1991.

The reversion of polarization sense depends on the alternation of the radiation of X mode wave and O mode wave. The mode and the frequency of the dominant radiation from the electron-cyclotron maser instability is dependant on the ratio ω_p/Ω_e(the plasm frequency to the electron-gyrofrequency). For the radiation from the corona, ω_p/Ω_e is probably from 0.1 to 2.0. When $0.3 < \omega_p/\Omega_e < 2^{1/2}$, the emission may be in the X mode at the second harmonics and when $2^{1/2} < \omega_p/\Omega_e < 3^{1/2}$, it may be in the O- mode at the second harmonics. If the ratio ω_p/Ω_e fluctuated near $2^{1/2}$, the emission mode may be alternated(Winglee,R.M.et al.,1986)

6. Discussion

The narrow bandwidth radiation, the rapid frequency drift, the quasi period oscillation and the quick reversion of the polarization senses of the spike and FFS emissions directively reflect the mechnisms and the physical conditions of the source region. These radiations are close related to the growth ratio of the electron-cyclotron maser instability stimulated by the interaction of wave-wave and wave-beam.

The futher observations and analyses are very important for the studies of the maser instibility, the interaction and resonance of the radiowave and the nonthermal beam, and the physics of source region and beam acceleration region.

References

Shenzhen Jin, Xiaocong Li et al., ,*Acta Astrophysics Sinica.*, **11**, 394.

Stahli.M.and Benz,A.O.,*Astron. Astrophys.*, **175**,271.

Benz,A.O., *Solar phys.*,**104**,99.

Aschwanden,M.J. and Benz,A.O.,*Astron. Astronphys.*, **158**,102.

Shengzhen Jin and Xiaocong Li, *ACTA Astrophysics.*, **9**,157.

Shenzhen JiN, Qijun Fu, Renyang Zhao and Chumin Hu, *Solar Phys.*,bf 130,175.

Renyang Zhao, Shengzhen Jin, Qijin Fu and Xiaocong Li *Solar Phys.*,**130**,157.

Qijun Fu,Yuanfang Gong,Shengzhen Jin and Renyang Zhao, *Solar Phys.*,**130**,161.

Gary,D., Hurford, G. and Flees,D. Bull.Am.,Astron. Soc., **22**(1990) No.2 823.

Winglee,R.M. and Dulk,G.A.,*Solar Puys.*104,93.