POST-FLARE PULSATIONS IN THE 54–78 MHz FREQUENCY BAND

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(Received 28 June 2002; accepted 29 August 2003)

Abstract. Quasi-periodic pulsations with periods mostly around 13 s in the frequency range of 54–78 MHz have been observed following the first X2 flare occurring on 24 November 2000. Assuming an impulsively generated propagating MHD wave in a coronal loop for the pulsations, the coronal magnetic field at 1.6 $R_\odot$ is derived as ≈ 6 G and the radius of cross section of the loop as $\approx 13\,000$ km.

1. Introduction

Investigation of the temporal oscillations in the solar corona has been done at almost all wavelengths starting from X-rays to decameter wavelengths (Aschwanden, 1999). The study of these oscillations is important from the point of view of periodic particle acceleration, coronal heating and oscillatory structures. At metric wavelengths several observations of the regular and quasi-periodic pulsations of radio bursts have been reported (Table I, Aschwanden, 1999). In recent years there has been considerable interest in the study of flare-generated coronal oscillations. Spatial oscillations of coronal loops from TRACE observations have been used by Aschwanden *et al.* (1999) to determine the density and temperature of coronal loops. Nakariakov and Ofman (2001) derived the coronal magnetic field from coronal loop oscillations. Karlický *et al.* (2001) showed that at the start of large solar flares quasi-periodic emission can occur at radio wavelengths. Meszarosová, Jiřička and Karlický (1999) analysed 19 radio bursts at 3 GHz and studied their characteristic periodicities. Quasi-periodic pulsations were seen at 17 GHz in the impulsive phase of a flare by Asai *et al.* (2001). We present here a time series analysis of the quasi-periodic pulsations in the frequency range of 54–78 MHz, which occurred following the first X2 flare of 24 November 2000. Assuming an impulsively generated propagating MHD wave in a coronal loop for the pulsations, we derive the strength of the magnetic field at 1.6 $R_\odot$ and the radius of the cross section of the coronal loop.

2. Observations

The observations reported here were made with the Digital Radio Spectrograph of the Gauribidanur Radio Observatory (Ebenezer *et al.*, 2001). This swept-frequency

Solar Physics **218:** 221–226, 2003.

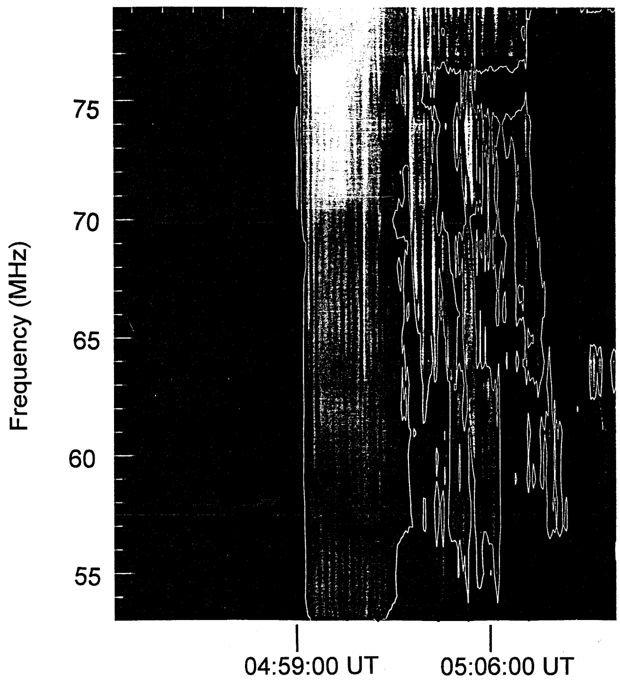

Figure 1. Dynamic spectrum of solar activity in the frequency range of 54–78 MHz on 24 November 2000 showing quasi-periodic oscillations which started at 04:59:34 UT.

spectrograph operates in the frequency range of 30–80 MHz. The time and frequency resolution are, respectively, 3.32 s and 1 MHz. The spectrograph is used in a conjunction with a 8-element log periodic array. The Sun is observed every day from 4 hr to 7 hr UT. A large radio event with pulsations following an Hα flare was observed on 24 November 2000 around 04:58 UT and lasted for about 4 min in our records. The pulsations were seen mostly during the maximum phase. Figure 1 shows the dynamic spectra of this pulsating burst in the frequency range of 54 to 78 MHz. Figure 2 shows the time profiles of this burst in the above frequency range.

3. Analysis of the Pulsations

From the observed time profiles, the pulse period $\Delta\tau$, the pulse duration ΔT and the pulse amplitude ΔI were measured. $\Delta\tau$ is the peak time separation between two adjacent pulses and ΔT is the time from the start to the end of a pulse at one frequency.

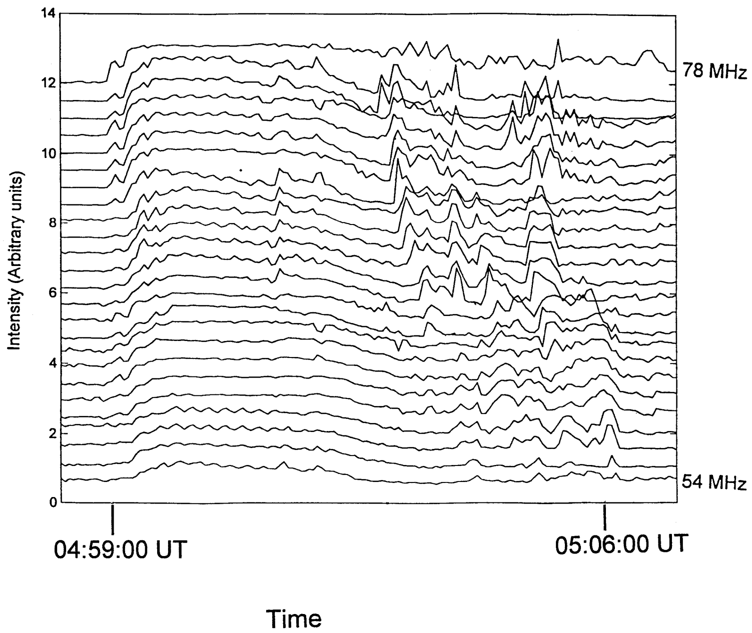

Figure 2. Time profiles of the quasi-periodic pulsations in the frequency range of 54–78 MHz. The intensity at each frequency is arbitrarily shifted in this figure.

3.1. Pulse period, duration, and intensity

A power spectra analysis of the time profiles of the pulsation at several frequencies in the band 54–78 MHz was performed after background subtraction at each frequency. Figure 3 shows a typical example of the power spectra of the pulsation at 54 MHz. The frequency component at 0.007 Hz corresponds to the total duration of the pulsating event. Another component at 0.078 Hz corresponds to the pulse period of ≈ 13 s.

Figure 4 shows the distribution of the pulse periods measured from the time profiles of the burst at several frequencies. The period ranges from 11 s to 19 s with the most common value around 13 s. It is to be noted here that Meszarosová, Jiřička, and Karlický (1999) have found periods above 10 s in their study of radio bursts at 3 GHz. The variation of the pulse amplitude with its duration is shown in Figure 5. The linear correlation coefficient is 0.29.

4. Discussion

The three basic models of pulsations are: (1) MHD oscillations, (2) cyclic, self-organizing systems, and (3) modulations of accelerations (Aschwanden, 1987). We compare the temporal characteristics of the three models. Figure 5 shows a weak correlation between the pulse amplitude and its duration, thereby ruling out the

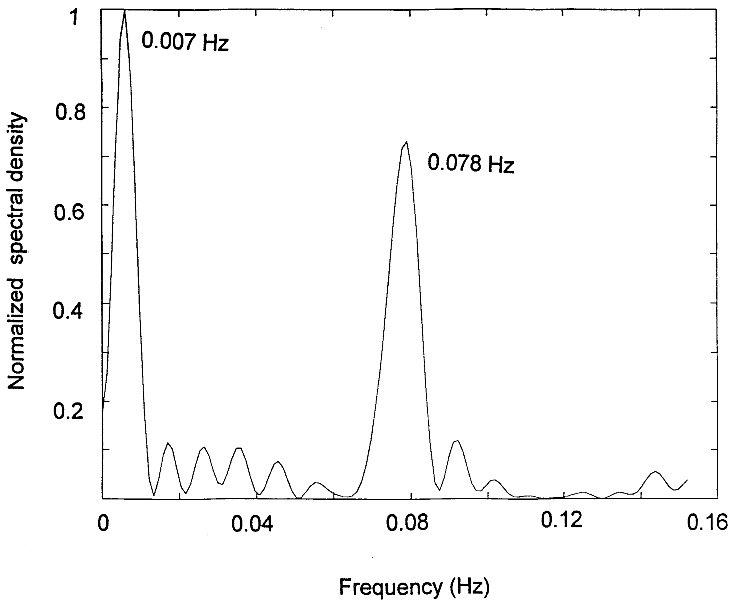

Figure 3. Estimated power spectrum of the intensity at 54 MHz.

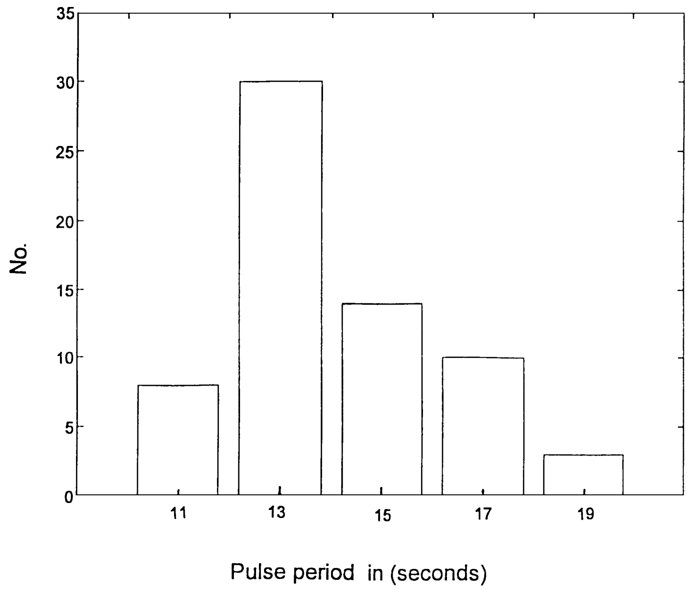

Figure 4. Histogram of the number of bursts versus pulse period.

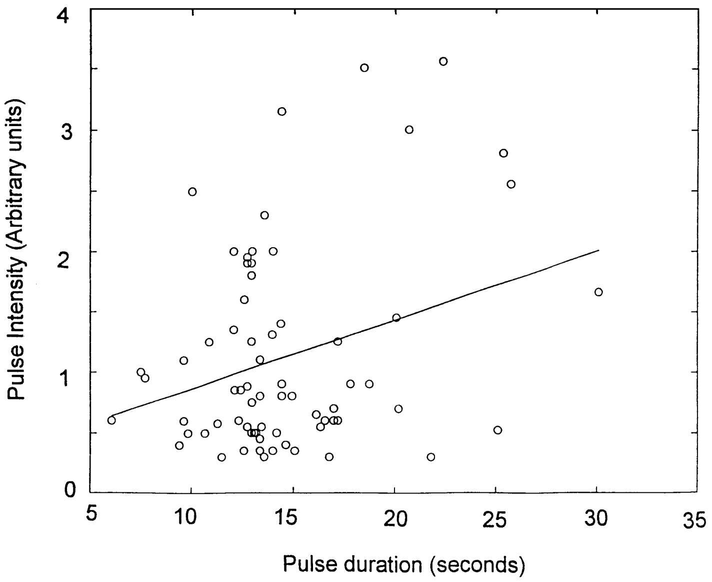

Figure 5. A plot between the pulse duration ΔT and its amplitude ΔI, showing a weak correlation between ΔT and ΔI.

self-organizing system. The pulsations do not exhibit the absorption phenomena that are characteristics of modulation of accelerations. Therefore we concentrate on MHD oscillations. In a magnetically structured corona with density inhomogeneities, the surface forms a natural boundary for standing and propagating waves. Flares may generate fast-wave pulsations in coronal loops according to Roberts, Edwin, and Benz (1983, 1984). If a disturbance is impulsively generated in a coronal loop as in the case of a flare, fast sausage mode MHD waves are produced. The time period P in this case is given by $P = 2.6 \times a/V_a$ (Roberts, Edwin, and Benz, 1984), where a is the radius of the cross section of the coronal loop and V_a is the Alfvén velocity. The Alfvén velocity is given by $V_a = 2.2 \times 10^{11} B/(N_e)^{0.5}$, where B and N_e are, respectively, the magnetic field strength and electron density inside the loop. The Hα flare corresponding to the observed pulsation event started at 04:57 UT (*Solar Geophysical Data*, 2000) in active region AR 9236. The existence of loop structures was seen in the *Yohkoh* images of this region. The onset of the pulsations started at 04:59:34 UT, i.e., 2 min and 34 s after the solar flare. If we equate this time to h/V_a where h is the height at which the 66 MHz (the center frequency of the observed band 54–78 MHz) radiation occurs, we can estimate the velocity of the exciting agent. Assuming 2 times Newkirk's electron density (Newkirk, 1967) for the active region and fundamental radiation for the pulsations, we get $h \approx 4 \times 10^5$ km above the photosphere. The derived velocity is ≈ 2600 km s^{-1}, the Alfvén velocity. From the relation between the Alfvén velocity V_a and the magnetic field strength B given above, the magnetic field strength is derived as ≈ 6 G. The estimated strength of the magnetic field lies in the range of magnetic fields for active regions reported by Dulk and McLean (1978). For the pulse period of 13 s, the derived radius of cross section of the loop is $\approx 13\,000$ km. The radio emission is possibly due to synchrotron radiation from electrons trapped inside the coronal loops.

5. Conclusion

We described a pulsation event in the 54–78 MHz frequency range associated with the onset of a solar flare of 24 November 2000. From the time delay between onset of the Hα flare and the radio pulsations, the Alfvén velocity is determined and the coronal magnetic field is derived as ≈ 6 G. From the most common value of the pulsation period (13 s), we estimated the radius of the cross section of the coronal loop as $\approx 13\,000$ km.

Acknowledgements

We would like to thank N. NanjeGowda, G. N. Rajasekara and Anwar Saheb for maintaining the antenna, receiver system and collection of data. We would also like to thank an anonymous referee for very fruitful comments and suggestions, which contributed to improving the present manuscript. *Yohkoh* is operated by ISAS by a team of Japanese, American, and British scientists whose dedication has made data available to the solar community.

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