ISSN 1845–8319

HIGH-FREQUENCY FIBER BURSTS OBSERVED DURING THE JULY 11, 2005 FLARE

M. KARLICKÝ[1], K. JIŘIČKA[1], H.S. SAWANT[2], J.R. CECATTO[2], F.C.F. FERNANDES[2] and M.C. ANDRADE[2]

[1] *Astronomical Institute of the Academy of Sciences of the Czech Republic, CZ-25165 Ondřejov, Czech Republic*
[2] *National Institute of Space Research, Sao Jose dos Campos, SP, Brazil*

Abstract. A unique quasi-periodic activity of the 1-2 GHz fiber bursts observed during the July 11, 2005, B4.0 flare is presented. Groups of fibers and individual fibers occur with the period of about of 65 s and 1 s, respectively. The frequency drift of the fibers was found in the interval -40 – -160 MHz s^{-1}. Unique cases of a sudden start and sudden end of a group of fibers are shown. Considering the whistler or Alfven wave velocities for the interpretation of the frequency drift of fibers and the Aschwanden's density model (2002) the magnetic field in the fiber radio source was estimated as 8-9 G or 25-60 G, respectively.

Key words: Plasmas–Sun: flares–Sun: radio radiation

1. Introduction

Fiber bursts are known for a long time as a fine structure of type IV-dm continua (Slottje 1981). In principle, there are two types of models of the fibers: a) the model considering whistler wave packets (Kuijpers 1975, Man et al. 1987, 1989), and b) the model with Alfven solitons (Bernold & Treumann 1983, Treumann et al. 1990). Benz & Mann (1998) compared both these models and they found that the model with whistlers is more realistic than that with the Alfven waves, see also the paper by Aurass et al. (2005) where the model with the whistlers was successfully used for the magnetic field estimation in the postflare coronal loops.

In this paper we present an interesting example of strong fiber bursts activity observed in the 1-2 GHz frequency range during the July 11, 2005 flare classified as B4.0. The fiber bursts are analyzed and interpreted in both types of models, and the results are compared.

2. Observations

During the weak flare in the NOAA AR 0786 at 16:34 – 16:41 UT, on July 11, 2005, classified as B4.0, a strong fiber burst activity in the 1-2 GHz range was observed by both the Ondřejov and the Brazilian (BSS) radio spectrographs (see example Fig. 1). The fibers appeared in 5 groups (Table 1) occurring with the characteristic period of about 65 s. They were superposed on different background continuum levels which has maximum before the GOES soft X-ray maximum. In Fig. 1 it can be seen that the mean frequency of the groups of fibers is varying in time. On the other hand, within the groups the fibers had the characteristic rate of about 1 fiber per second. The characteristic bandwidth of individual fibers was about 20 MHz.

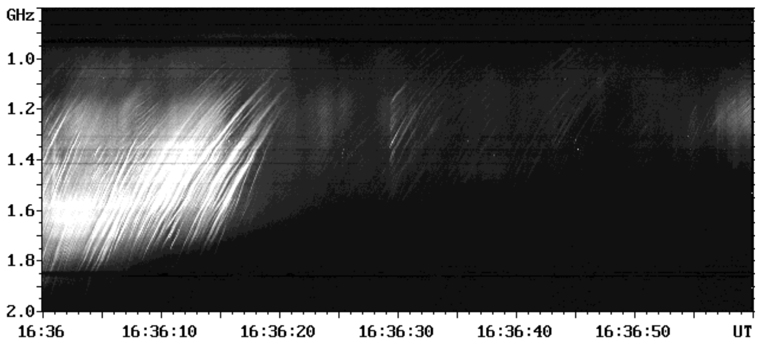

Figure 1: One part of the 0.8-2.0 GHz radio spectrum of the July 11, 2005 flare observed at 16:34 – 16:41 UT by the Ondřejov radio spectrograph.

It is interesting that at 16:36:29 UT the fibers abruptly started at one instant and at 16:40:18 UT the fibers abruptly ended at nearly one moment. These effects were observed by both the Ondřejov and the BSS radio spectrographs (Fig. 2). No other radio bursts were recorded during this event in the 0.1-4.0 GHz range (Zurich radio spectrum record).

In all 5 groups some characteristic fibers were selected and their drift rates vs. frequency were measured. The drift rate of fibers was found in the -40 – - 160 MHz s^{-1} interval. Using these measurements for the following computations (see Fig. 3) we selected two extreme cases of the drift rate of fibers. In analytical form they are

$$(df/dt)_{min} = 9.87 - 0.0516f \qquad (df/dt)_{max} = 13.65 - 0.0919f, \qquad (1)$$

where df/dt is in MHz s^{-1} and the frequency f in MHz.

Furthermore, in the most distinct group of fibers (group 2) we measured the time evolution of the fiber drift rate on 1700 MHz and found a systematic grow of this rate.

Table I: Fiber burst groups time intervals and frequency ranges.

Group	Start (UT)	End (UT)	Frequency range (GHz)
1	16:34:10	16:35:00	1.0-1.6
2	16:35:20	16:36:40	1.0-2.0
3	16:36:55	16:37:35	1.0-1.6
4	16:38:00	16:38:25	1.0-1.6
5	16:39:50	16:40:45	1.0-1.8

3. Data interpretation and magnetic field estimations

In the following we consider both types of models of fiber bursts: a) the model considering whistler wave packets (Model 1) (Kuijpers 1975, Man et al. 1987, 1989), and b) the model with Alfven solitons (Model 2) (Bernold & Treumann 1983, Treumann et al. 1990). In both models the whistler packets and Alfven solitons move along the flare loop in which superthermal electrons are trapped. It is assumed that the frequency of fibers corresponds to the plasma frequency in the radio source.

For the fiber drift rate D_f we can write

$$D_f = \frac{\omega_{pe}}{4\pi}\frac{1}{n_e}\frac{dn_e}{dr}v_r, \qquad (2)$$

where r is the radial distance in the solar atmosphere, ω_{pe} is the plasma frequency, n_e is the plasma density, and v_r is the radial speed of the radio source which equals to $v_r = v_g \cos\theta$. The angle θ is the inclination between fiber burst guiding field line and the electron density gradient and v_g is the

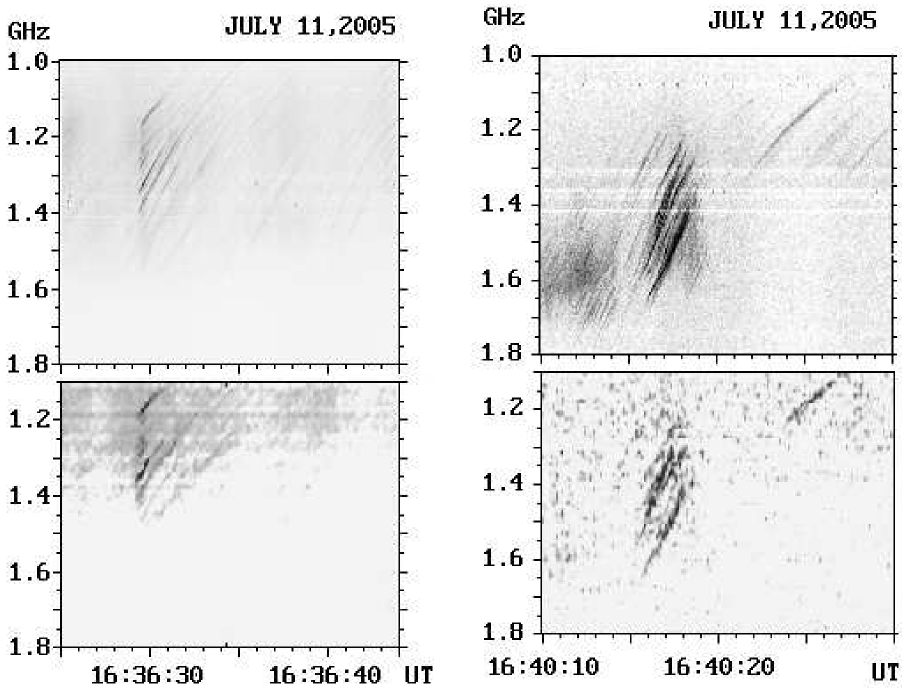

Figure 2: Sudden start (left) and sudden end (right) of fibers observed simultaneously by the Ondřejov radio spectrograph (top) and the Brazilian Solar Spectroscope (bottom).

whistler wave group velocity in Model 1

$$v_g = 2c\frac{\omega_{ce}}{\omega_{pe}}\sqrt{x(x-1)^3}, \quad (3)$$

where c is the speed of light and x is the ratio between the whistler and electron gyro frequencies ($x = \omega_w/\omega_{ce}$), or the Alfven velocity in Model 2

$$v_g = B/\sqrt{4\pi n_e m_p}, \quad (4)$$

where B is the magnetic field strength and m_p is the proton mass.

Using these equations we can write the equation for the magnetic field in the Model 1 as

$$(\lambda_r D_f)^2 = 7.04 \times 10^{33} B^2 \frac{C\omega_w}{B}(1 - \frac{C\omega_w}{B})^3, \quad (5)$$

where $C = 5.68\times 10^{-8}$, $\lambda_r = (1/n_e\ dn_e/dr)^{-1}$, or in Model 2 as

$$B = \lambda_r D_f / 9.796 \times 10^{14}, \tag{6}$$

where the height scale is in cm, and the drift rate D_f in Hz s^{-1}.

For the density we use the Aschwanden density model (2002)

$$n_e(h) = n_1 (h/h_1)^{-p}, \tag{7}$$

where $n_1 = 4.6\times10^8 \exp(-p)$, $h_1 = 1.6\times10^{10}$ cm, and p is the parameter (= 2.38). Due to a limited extend of observed frequencies and corresponding heights in the low corona (close to the loop footpoint) we neglect the effect of the loop curvature and its inclination to the vertical direction. In Model 1 we use the fiber bandwidth for an estimation of the whistler frequency. Then, using all these facts we estimated the magnetic field in both models (Fig. 3). The parameter x (the ratio of whistler and electron-gyro frequencies) was found to be in the 0.80-0.88 range, i.e. in the range of the strong whistler absorption. While in Model 1 the magnetic field is 8-9 G, in Model 2 is 25-60 G.

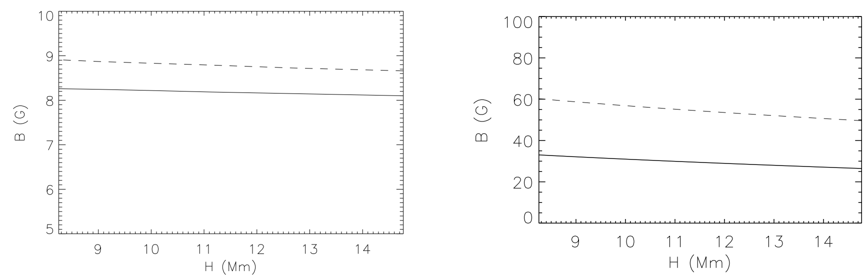

Figure 3: Magnetic field strength vs. height in the fiber model 1 (left) and model 2 (right) in the density model of Aschwanden (2002). The height interval corresponds to the 1-2 GHz range. The full and dashed line corresponds to the minimum and maximum of the absolute drift rate of fibers, respectively.

Fibers appeared quasi-periodically in groups and their mean frequency was varying in time. We propose that these variations express an oscillation (compression and decompression) of the flare loop. Namely, with the compression of the flare loop the mirror ratio in the loop magnetic trap decreases while the loss-cone angle in the distribution of the superthermal electrons increases which leads to stronger instabilities generating radio emission and vice versa.

4. Conclusions

Using the Model 1 and the Aschwanden density model (2002) low magnetic fields in the fiber radio source in the low corona was found (8-9 G). Moreover, the ratio of whistler and electron cyclotron frequencies is high (x=0.8-0.88), i.e. x is in the range of the strong electron-cyclotron absorption of whistlers. Partly, we can decrease the value of the x parameter by considering lower values of the whistler frequency. Another way how to increase the resulting magnetic field and decrease the x parameter is to consider the density model with greater height scales than that in the Aschwanden model (2002). On the other hand, Model 2 with the Alfven velocity gives higher values of estimated magnetic field (25-60 G). Though in our case the Model 2 looks to be closer to reality, to decide between them calls for further detailed analysis of the fibers.

Acknowledgements

MK thanks for financial support from Brazilian FAPESP project 2005/58691-2. This research was also supported by Grant IAA3003202 of the Academy of Sciences of the Czech Republic.

References

Aschwanden, M. 2002, *Space Sci. Rev.* **101**, 1

Aurass, H., Rausche, G., Mann, G., Hofmann, A. 2005, *A&A* **435**, 1137

Benz, A.O., Mann, G. 1998, *A&A* **333**, 1034

Bernold, T., Treumann, R. 1983, *ApJ* **264**, 677

Kuijpers, J. 1975, *Sol. Phys.* **44**, 173

Mann, G., Karlický, M., Motschmann, U. 1987, *Sol. Phys.* **110**, 381

Mann, G., Baumgartel, K., Chernov, G., Karlický, M. 1989, *Sol. Phys.* **120**, 383

Treumann, R., Gudel, M., Benz, A.O. 1990, *A&A* **236**, 242