MHD-oscillations in solar flare sources of microwave emission

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Magnetohydrodynamic waves are believed to be closely connected to the energy modulation processes of solar microwave emission. Such processes are responsible for the periodic and quasiperiodic components appearing in the microwave emission variations during solar flares. Aiming to detect these oscillations, the Wigner-Ville (W-V) method has been employed under time-frequency analysis of the radio emission of solar flare. The W-V transform (Wigner, 1932; Ville, 1948) presents a time-lag Fourier-conjugate of a local autocorrelation function of an analytic signal formed using the sample of the signal to be investigated. The output of W-V transform is a dynamic spectrum presenting the signal energy distribution on time-frequency plane.

A few solar microwave bursts at the frequencies of 22 and 37 GHz were investigated using the data taken with 14-m radio telescope (Metsähovi Radio Observatory , Finland). The time and intensity resolution during observations were 0.05–0.1 s and $\sim$100 K, respectively. All microwave bursts observed were certainly attributed to solar flares.

The dynamic spectra obtained make it possible to identify the corresponding microwave pulses with the natural oscillations of coronal magnetic loops (CML) considered as MHD-resonators (Zaitsev et al, 2000). As it follows from dynamic spectra , a few types of low frequency pulsations are excited in CML during solar flares.

- Fast and slow magnetosonic oscillations (MSO) with the time scale of $1\div1.5$ s and $200\div280$ s, relatively (see Fig. 1). The fast MSO appear as a train of duplicate chirps, each of 100–200 s duration, exhibiting the positive frequency drift with the drift velocity of $d\nu/dt \approx 0.125$ Hz/min and a frequency splitting of $\Delta\nu \approx 0.05$ Hz.
- CML eigen oscillations as an equivalent electric resonant circuit (Fig. 2). These oscillations have a period of $T_{\rm CML} \simeq 1$ s at the solar burst start, and then, to the end of burst, $T_{\rm CML} \simeq 4$ s.
- Modulation of microwave emission intensity by periodic pulse train with the pulse rate decreasing from $\sim$1 Hz at the burst start down to $\sim$0.5 Hz at its end (Fig. 3).

We have observed also strong 2.5 and 5 Hz lines appearing during some bursts. These lines reveal a complicated time-frequency structures (Fig. 4). However, their origin is still to be elucidated.

The MHD-pulsation parameters have been used to obtain some new information on the CML structures. That is the $r/L \approx 0.1$ ratio, where r is the loop radius and L is CML length. The plasma beta (the gas pressure to the magnetic field pressure ratio) of the loop turns to be equal to $\beta \approx 3 \cdot 10^{-3}$. The plasma densities inside ($\varrho_{\rm i}$) and out ($\varrho_{\rm e}$) of the loop obey the inequality $\varrho_{\rm e}/\varrho_{\rm i} \leq 2 \cdot 10^{-2}$. Besides, the CML electric current value was determined as high as $I \approx 1.5 \cdot 10^{12}$ A.

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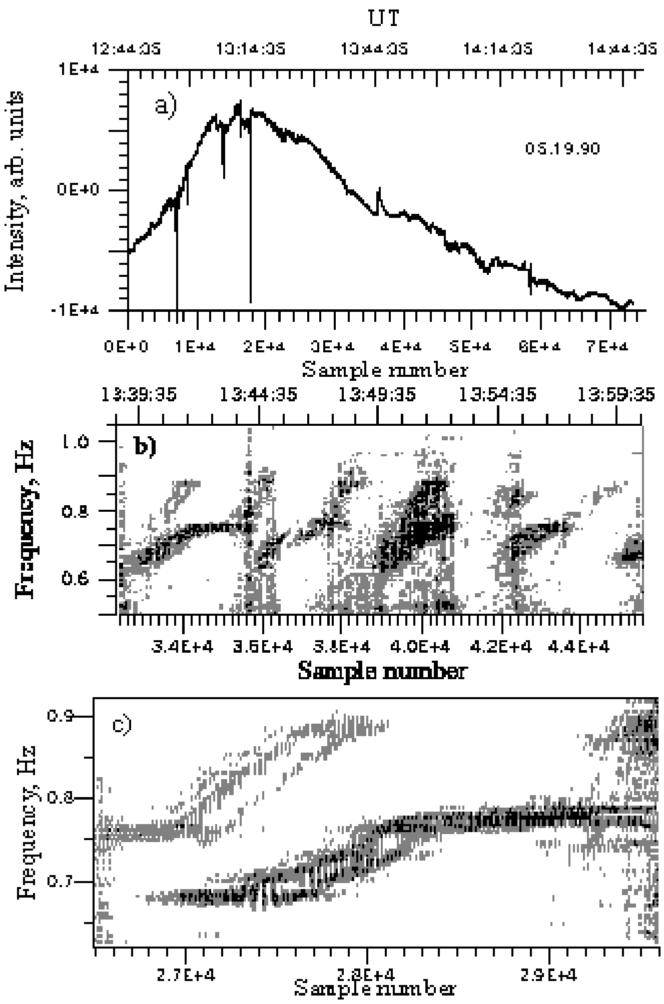

Fig.1. (a) The time profile of microwave burst 05.19.90, 1244 – 1444 UT, at 37 GHz. One can see a moderate intensity fluctuations. b) A low frequency part of a dynamic spectrum,with duration is about 25 min. One can see the chirp trains occupying two frequency domains: $0.60 \div 0.75$ Hz and $0.75 \div 0.90$ Hz. c) The dynamic spectra of two separate chirps, each exhibiting the positive frequency drift rate of 0.125 Hz/min and a frequency splitting with the maximum value of 0.05 Hz.

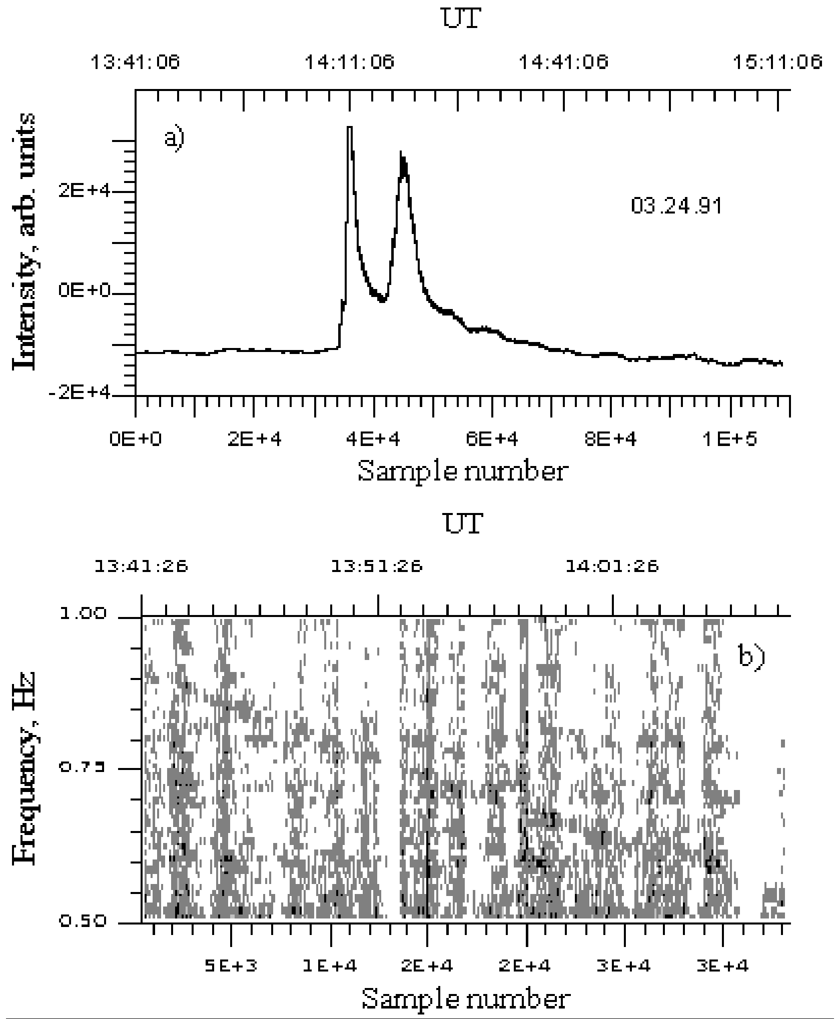

Fig.2. The solar microwave burst measured on 03.24.91, 1341 – 1511 UT. a) The time profile of 37 GHz the burst . b) Dynamic spectrum fragment showing the low frequency modulation of the microwave emission. It evidently shows the linear frequency-modulated (LFM) signal beginning at $\nu \approx 1$ Hz with the drift rate of $d\nu/dt \simeq -1.54 \cdot 10^{-2}$ Hz/min. During all the burst time, the LFM-signal frequency decreases from 0.95 down to 0.25 Hz.

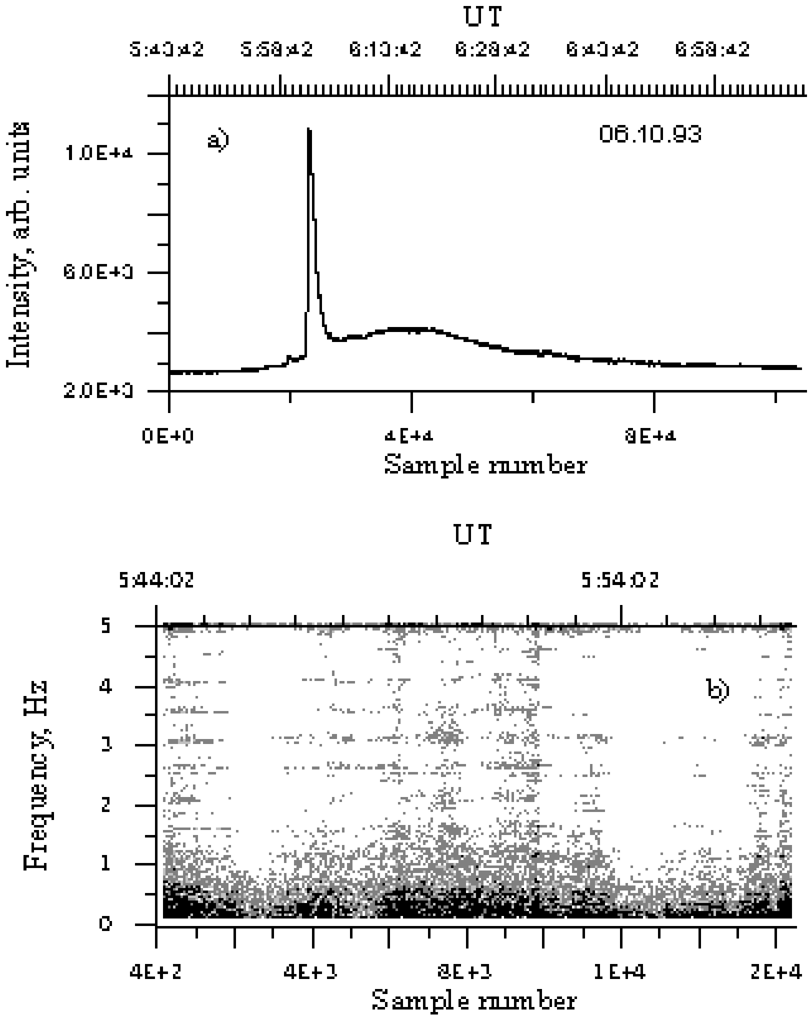

Fig.3. The microwave solar burst on 06.10.93, 1341 – 1511 UT. a) Time profile of the burst at 22 GHz. b) The dynamic spectrum of low frequency pulsations shows a pulse-train spectrum with the pulse rate of $\nu_{\mathrm{p}} \sim 1$ Hz at the burst start. At the end of the burst $\nu_{\mathrm{p}} \sim 0.5$ Hz.

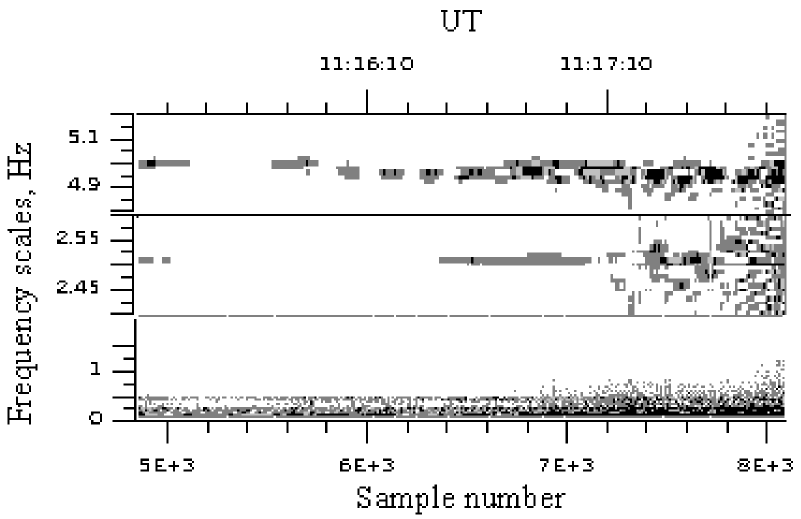

Fig.4. The spectral lines in vicinity of $\sim$2.5 Hz and $\sim$5 Hz as found during microwave solar burst on 06.27.93 at 37 GHz. The lines have rather complicated structure both on time and frequency. The line average frequency ratio <2, and, under line maximum intensities, turns to be equal to $\nu_5/\nu_{2.5} \simeq 1.96$.

References

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