OBSERVATIONS OF THE SOLAR RADIO EMISSION AT IZMIRAN DURING THE PROTON FLARE OF AUGUST 4, 1972

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Abstract: The radio data obtained at IZMIRAN concerning the multicomponent type IV burst, connected with the proton flare of August 4, 1972, are presented. On 204 MHz the burst had the character of an intense continuum with strong counterclockwise polarization. During the first phase of the burst a double change of the sign of polarization was established on 3000 MHz. The predominant peculiarity of the dynamic spectra in the 45—90 and 181—224 MHz ranges was the simultaneous presence of various pulsations within a time scale ranging from 10—12 to 0.1 sec superimposed on the intense continuum. The positive frequency drift (~ 10 MHz (sec)) has been observed in many pulsations of $f < 70$ MHz. The total duration of the pulsation phase exceeded 6 hours.

As is known, during the first two weaks of August 1972, in which a complex active region (McMath 11976) transited across the disk, numerous small flares and some large flares were observed. The proton flare of August 4, 1972 was one of the largest flares. In H-alpha the flare began at 0621, achieved its maximum at 0638 UT continued until 0852[1] [1].

The flare was accompanied by a strong increase of the radio emission flux density in a broad frequency range.

In this report the radio data, obtained by means of the radiotelescopes at IZMIRAN (radiometer and polarimeter on 204 MHz, polarimeter on 3000 MHz and two radio-spectrographs on 45—90 and 181—224 MHz) are described. The main characteristics of these instruments have been described in [2—4].

Observations at Fixed Frequencies

The record of the flux density on 204 MHz is shown in Figure 1a. The event began at 0622 with a small group of bursts of moderate intensity $\sim 5 \times 10^{-20}$ Wm^{-2} Hz^{-1}. Then, during a short interval of time (~ 10 min), the intensity increased rapidly, and at 0640 reached the value $\geq 5 \times 10^{-18}$ Wm^{-2} Hz^{-1} when the recorder went off the scale. From this time for approximately 70 min, the intensity remained at a high level, although it was not constant. The intensity then rapidly (~ 5 min) decreased down to 10^{-19} Wm^{-2} Hz^{-1} and then began to decrease slowly down to 5×10^{-20} Wm^{-2} Hz^{-1} at the end of observations (1300). This intensity still visibly exceeded the emission level before the beginning of the event (10^{-21} Wm^{-2} Hz^{-1}).

The polarization measurements on 204 MHz commenced at 0730. But both the channels of the polarimeter which recorded the combination of Stokes' parameters I + V and I − V went off scale by 0830. Therefore, the polarization in this interval of time remained indefinite. After 0830 the I + V intensity was measured and the lower limit of the degree of polarization was evaluated at this stage of the event. The emission was polarized counterclockwise. The degree of polarization was more than 60 %.

On 3000 MHz the event began at 0610 (i. e. 11 min before the commencement of the optical flare) by a slow increase of intensity (Fig. 1b). The beginning of the complex burst with high intensity practically coincided with the beginning of the optical flare. Unfortunately, the recorder went off scale at once, but the attenuation (of the order of 100 times) was only introduced at 0630. However, a comparison with the data at close frequencies (see [1]) showed that the maximum of the emission took place in this interval of time. The decrease phase

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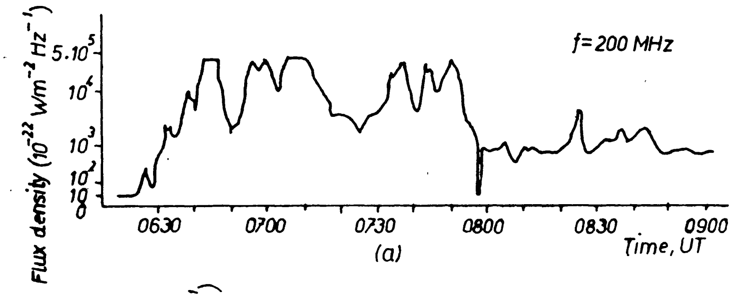
[1] Universal time is used throughout.

was not monotoneous; it represented a succession of emission peaks with a decreasing amplitude.

Of interest are the variations of the polarization on this frequency (Fig. 1). A slow increase of intensity before the flare was not polarized. With the beginning of the burst the emission became weakly clockwise polarized (~ 2 %). At 0628, i. e. near the emission maximum, the sense of the polarization changed to clockwise, and the degree of polarization achieved its maximum (~ 8 %) at 0634. During one of the intensity peaks at 0637, the second change in the sense of the polarization took place. The sense of polarization then remained unchanged until the end of the event (apparently, the rapid changing of the sense of polarization at 0645 was due to an interference). The degree of polarization suffered some small changes during at times corresponding to the intensity peaks in the decreasing phase of the burst.



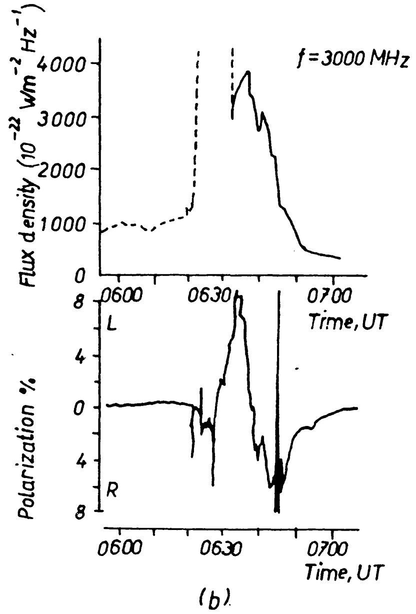


Fig. 1. a — Records of the intensity of the burst on 204 MHz; b — the intensity and degree of polarization on 300 MHz.

In order to obtain an idea of the event as a whole, the frequency spectrum of the burst was constructed (Fig. 2). The spectrum was constructed for the maximum flux density, recorded at different fixed frequencies (see [1]). One can see that the spectrum has three maxima at cm, dm and dkm wavelengths, which is typical of the multicomponent type IV bursts, usually associated with proton flares. The maximum flux density (~ 5×10^{-17} Wm^{-2} Hz^{-1}) occurred at frequencies of about 200 MHz.

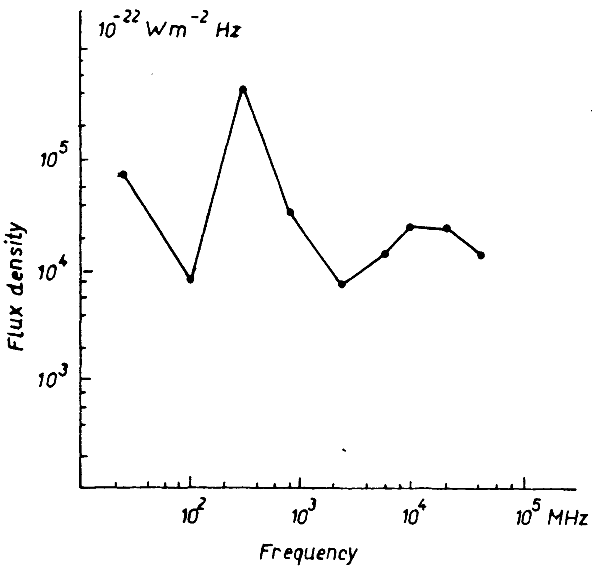


Fig. 2. Power spectrum of the type IV event of August 4, 1972.

It should be noted that radio bursts, associated with the proton flares of August 2 and 7, are characterized by analogous frequency spectra and may also be classified as multicomponent type IV bursts.

Spectral Observations

The spectrograph observations on 45—90 MHz began at 0628, i. e. 7 min after the flare began. That is why we have no information about the dynamic spectrum of the radio bursts which accompanied the initial phase of the flare in this frequency range. Throughout the observations (1300) numerous variations of the radio emission flux density were the predominant peculiarity of the dynamic spectra. During the first 9 minutes of the observations (until 0637) those variations were fairly irregular although one could see some individual bands of brightness with a lifetime of 2 sec and almost parallel to the frequency axis. Over a period of at least 20 minutes, a sequence of some tens of clear pulsations was seen in the background of the intense continuum (Fig. 3a). The pulsations appeared fairly regular, although strict periodicity was not observed. The time interval between the neighbouring pulsations varied between 10 and 20 sec. The lifetime of the pulsations on the single frequency was ~ 12 sec and it did not depend on the frequency within the range of the spectrograph. During a short time interval the brightness of the continuum covers a broad frequency range. Practically no pulsations have a visible frequency drift at frequencies $f > 70$ MHz. But at lower frequencies the majority of the pulsations display a drift of the order of 10 MHz/sec. It is interesting that in the given event the brightness appear at first at low frequencies, and then propagated towards higher frequencies. Approximately 10 % of the pulsations only occupy a part of the spectrograph range and are observed at frequencies $f > 60$ MHz.

Generally speaking, such pulsations are fixed during the whole observation period. However, beginning with 0700 the pulsations became hardly visible, because the continuum intensity increased considerably and the device turned out near the saturation. During the last 20—30 minutes, only when the continuum intensity essentially decreased, the pulsations again became visible approximately in the same manner as in the initial period of the event. In the 181—224 MHz range, according to the data of the spectrograph with a high time resolution, these pulsations probably correspond to the band of emission and absorption in the total frequency with a lifetime of 3—10 sec (Fig. 3b). They were visible for more than 4 hours. The spectrograph operate from 0709 to 1157. In the first 40 minutes of observation the activity had the character of an intense continuum, because the

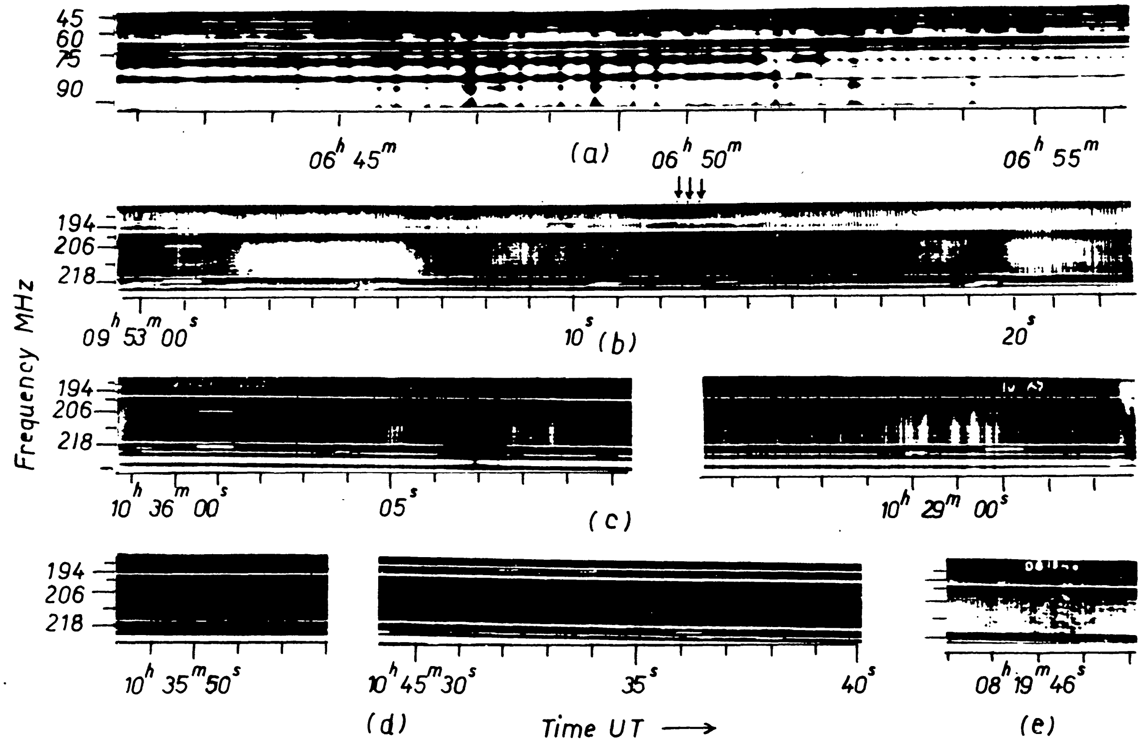


Fig. 3. Fragments of the dynamic spectra of the type IV radio burst of August 4, 1972 in a — 45—90 MHz and b—e — 181—224 MHz frequency ranges.

fine details in the spectrum are almost indistinguishable. These pulsations were visible most clearly during the 12 min after 0945. The boundaries of the pulsations are not homogeneous. They do not display a frequency drift. A number of pulsations occupy only a part of the spectrograph range. In these cases they have a clear low-frequency boundary.

Apart from these pulsations, some more short-lived bands with a lifetime of 0.3—1 sec were observed in the emission in the 181—224 MHz range during a large part of the observational period (Fig. 3c). As many as 3—5 events per minute appeared and, as a rule, covered the whole frequency range. Some of these bursts displayed a frequency drift of ± 100—150 MHz/sec, the majority of these bands occupied the whole frequency range practically instantaneously.

In this frequency range some short-lived spike-bursts were observed on the background of intense continuum. They are characterized by a preferential negative frequency drift (~ 100 MHz/sec) and by an instantaneous bandwidth of ~ 1 MHz. They appeared more rarely than the pulsations described above. However, in almost every minute interval either an individual spike or a group of spike-bursts (numbering up to ten individual bursts) may be found (Fig. 3d). So far the spike bursts had been observed on the single frequencies during type IV bursts [5—7]. In the given case, the observations were performed by means of a radiospectrograph. It permitted to estimate the bandwidth of these bursts. The analysis showed that in the described event the spike-bursts, accompanying the type IV burst, mostly have a broader bandwidth (> 20 MHz) than analogous bursts, accompanying the noise storms. The latter occupy the frequency range from 5 to 20 MHz and display a greater variety in the velocity and direction of the frequency drift [8, 9]. As to other parameters, the bursts are approximately identical. They are probably generated by the same mechanism. However, in the given event, groups of spike bursts without a frequency drift have been observed. They had the character of pulsations within a broad frequency range. One of these groups is marked with arrows in Figure 3b.

The question of the presence of short-lived pulsations in the 45—90 MHz range will be considered as open, because the comparatively small time resolution of the spectrograph does not permit one to observe the event with such a short lifetime reliably.[2]

In the 181—224 MHz range a zebra structure [10] was also observed for 1.5 sec beginning at $08^h19^m45.4^s$ (Fig. 3e). This event is formed by a system of intermitant bands of emission and absorption. At first they do not display a frequency drift, but then they drift towards high frequencies with at a rate of ~ 10 MHz/sec.

Speaking of the peculiarities of the fine structure of the radio burst of August 4, 1972, it should be mentioned that the radio emission pulsations are fixed fairly often during the difinite phases of type IV bursts [7, 11—14]. So far, however, information has only been forthcoming about events in which the short-lived (~ some sec) pulsations without a frequency drift are observed at sufficiently high frequencies ($f >$ MHz). As a rule, the whole pulsation phase lasted a few minutes and only in some cases reached 20 min. In the given event, the pulsations, in particular with a lifetime of 12 sec, were clearly visible at lower frequencies upto 45 MHz, where many pulsations displayed a positive frequency drift. The whole pulsation phase lasted for more than 6 hours. This long duration of the pulsations contradicts the hypothesis suggested in [7,12], where the presence of the pulsations is associated with the propagation of a shock wave through the top of the postulated discrete magnetic flux tube high in the corona. The pulsations are probably due to a much longer lived factor influencing the intensity of the radio emission rather than the simple propagation of a shock wave.

The important feature of the event of August 4, 1972 is the simultaneous presence of different pulsations. This conclusion may be drawn not only from the variety of the pulsations with the time scales smaller than 20 sec, but also from the presence of clear pulsations with time scales of about 5 min, observed on frequencies of 12—40 MHz [15]. It is difficult to understand this feature of the pulsations, as well as the frequency drift of the 12-sec pulsations at low frequencies with regard to the interpretations suggested in [7, 12].

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[2] In the preliminary information of a number of observatories, in particular Weissenau, the intensity variation observed is the background of the continuum of August 4, 1972, was regarded as groups of type III bursts (see [1]).

However, the comparison of the characteristics of the variations mentioned above, with the features of the type III bursts shows that this statement is based on a misunderstanding which probably is due to the insufficiently high resolution of the radiospectrographs.

It can be noted that the pulsations, particularly in the 45—90 MHz range, were typical of the continuum emission associated with the active McMath 11976 region. They were also observed during some intervals of August 3 and 5, 1972.

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