

# SHORT-PERIOD PULSATIONS OF THE PULSAR CP 0808 AND THE MAIN CHARACTERISTICS OF ITS RADIO EMISSION IN THE METER-WAVE RANGE

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**Abstract**

**Full Text**

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**SHORT-PERIOD PULSATIONS OF THE PULSAR CP 0808 AND THE MAIN CHARACTERISTICS OF ITS RADIO EMISSION IN THE METER-WAVE RANGE**

*(Presented by Academician V. A. Kotelnikov on 11 IX 1969)*

Investigations of the radio emission of the pulsar CP 0808 in the range (60 ÷ 110) MHz were carried out on the East-West line of the FIAN DKR-1000 cross-type radio telescope in Pushchino; this has already been reported in part <sup>(1)</sup>. The main results obtained are given below.

1. The pulses of pulsar CP 0808 in the range 110-60 MHz consist of several subpulses (1, 2, or 3), separated from one another on average by 53.6 msec.

Analysis of the positions of the subpulses in time showed that this pulsar has a class II periodic process (according to the classification in <sup>(2)</sup>) with an average period

$$P_2 = 0^s.053642 \pm 0^s.000002.$$

This period is not a multiple of the class I period ( $P_1 = 1.292241 = 24.09P_2$ ), and therefore the following picture is observed: in a group consisting on average of 11 pulses, sub-

**Table 1**

$f_1$ , MHz	$f_2$ , MHz	$f_1 - f_2$ , MHz	$R_{12}$	$\sigma_1$ , msec	$\sigma_2$ , msec
85.7	86.0	0.3	0.92	4.5	4.8
2.0	86.0	4.0	0.78	5.8	5.7
1.75	82.0	10.25	0.56	3.6	4.2

**Table 2**

$f$ , MHz	Diagram width $T_0$ , msec	Diagram width $\varphi_0$ , degrees	$d$ , m
62	104	29	19.2
86	77	21.4	18.8
110	61	17	18.4

pulses follow one another with an average period  $P = 1.2874 = 24P_2$ ; then the subpulses of this group gradually disappear, while the subpulses of the following group, displaced by 53.6 msec relative to the first, form a new sequence of pulses; thereafter the pattern repeats. This is clearly seen in Fig. 1.

In work <sup>(3)</sup> the complex structure of the pulses of pulsar CP 0808 was indicated, but no periodicity of the subpulses was detected. CP 0808 is the third pulsar in which class II pulsations have been found.

The variations of the time positions of the subpulses  $\Delta t_{2i}$  relative to the instants of time determined by the mean class II period  $P_2$  were studied in detail:

$$\Delta t_{2i} = t_i - mP_2$$

( $t_i$  is the time of appearance of a subpulse,  $m$  is an integer). Short-time variations of the quantities  $\Delta t_{2i}$  of smaller amplitude and long-time variations of larger amplitude were found. The correlation of the variations  $\Delta t_{2i}$  at different frequencies was investigated.

Table 1 gives  $\sigma_1$  and  $\sigma_2$ —the rms values of  $\Delta t_{2i}$ , respectively, at two frequencies, and the mutual correlation coefficients  $R_{12}$  of the quantities  $\Delta t_{2i}$  for the indicated frequencies. The table gives results for comparatively small series of pulses ( $n \sim 50$ ), for which the deviations in the time positions of the subpulses relative to the instants  $mP_2$  did not exceed  $\pm 15$  msec,  $\sigma = (3.6 \div 5.8)$  msec (see Fig. 2a). Good

the correlation of these short-period variations  $\Delta t_2$  at noticeably different frequencies shows that the main cause of their appearance is apparently true variations in the times of radio emission of the subpulses by the pulsar itself, and not the influence of other factors.

An analysis of a longer series of pulses shows that, in addition to the short-period variations  $\Delta t_2$ , there are also slower variations in time and of greater magnitude, reaching a value of 50 msec (see Fig. 2b). Thus, one can speak of the instability of the periodic pulsations of CP 0808 and estimate the quality factor of the system. From Fig. 2b it is seen that in approximately 200 pulses, i.e., in 4800 periods of class II, the phase of the variations  $\Delta t_2$  changes by  $2\pi$ , which corresponds to a quality factor of the system  $Q \approx 5000$ .

**Fig. 1.** Copy of a record of consecutive pulses of pulsar CP 0808, 17 XII 1968,  $f = 86.0$  MHz;  $\Delta f = 80$  kHz;  $\tau = 5$  msec. The positions of the subpulses are

Figure 1. Copy of a record of consecutive pulses of pulsar CP 0808

Figure 1: Figure 1. Copy of a record of consecutive pulses of pulsar CP 0808

counted from the period  $P$ , a multiple of the class-II period  $P_2$ ;  $P = 24P_2 = 1^s.2874$ , ( $\Delta t_2 = t_i - mP_2$ )

2. Starting from the model of the pulsar as a pulsating-rotating compact star, one can determine the width and, to some extent, the form of the radio-emission pattern of the pulsar subpulses. The average form of the radio-emission pattern can be found by constructing a histogram of the distribution of the amplitudes of the subpulses as a function of their time position, counted with respect to the instants of time determined by the mean class-I period, i.e., by studying the dependence:

$$\bar{I}_i = f(\Delta t_{1i}),$$

where  $\bar{I}_i$  is the mean value of the intensity for the position of the subpulse at the instant  $\Delta t_{1i}$ ;  $\Delta t_{1i} = t_i - mP_1$ .

Analysis of the results obtained at frequencies of 62, 96, and 110 MHz shows that the average form of the radio-emission pattern has rather sharp boundaries, contains several characteristic maxima with a certain general decrease (minimum) in the middle of the pattern. This is especially clearly seen from the data at 86 MHz, part of which is shown in Fig. 3. Noteworthy is the constancy of the width of the radio-emission pattern at the zeros (designation  $T_0$ , corresponding angle  $\varphi_0$ ) over many days.

The data for different frequencies, summarized in Table 2, show that the width of the radio-emission pattern (at the zeros) is, within the errors, directly proportional to the wavelength.

If one constructs a model of the radio-emitting region consisting of a series of cells (of the phased-array type), and if the principal factor determining the pulsar radiation pattern is the pattern of a single cell, then its characteristic size is  $d = 2\lambda/\varphi_0$ ; the values of  $d$  are given in Table 2.

As can be seen, the size of the radio-emitting cells proves to be one and the same for all frequencies, with a high degree of constancy. The obtained dependence of the width of the radio-emission pattern on wavelength explains the fact that, at a frequency of 60 MHz, three subpulses are often observed in pulsar CP 0808,

**Fig. 2.** Variations in the positions of the centers of subpulses of pulsar CP 0808 relative to positions with period  $P_2$  ( $\Delta t_{2i} = t_i - mP_2$ ). Measurement errors are shown for broad and symmetric subpulses. *a*—5 XII 1968,  $1-f = 86.0$  MHz,  $2-f = 82.0$  MHz; *b*—22 XII 1968,  $f = 86.0$  MHz.

whereas at a frequency of 110 MHz usually one, and rarely two, subpulses are

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Figure 2: Fig. 2. Variations in the positions of the centers of subpulses of pulsar CP 0808 relative to positions with period  $P_2$  ( $\Delta t_{2i} = t_i - mP_2$ ). Measurement errors are shown for broad and symmetric subpulses.  $a-5$  XII 1968,  $1-f = 86.0$  MHz,  $2-f = 82.0$  MHz;  $b-22$  XII 1968,  $f = 86.0$  MHz.

observed. According to observations at Jodrell Bank [4], at frequencies of 151 and 408 MHz no even two subpulses are observed in CP 0808, which can be explained by the narrow radio-emission pattern at these frequencies. If our data are extrapolated toward these higher frequencies, then the width of the pattern at 151 MHz will be about 45 msec, which is less than the separation between subpulses. The presence of a minimum approximately in the middle of the radiation pattern must be attributed to the radiation pattern of the cell (for example, its “biphasic” nature).

3. In pulsar CP 0808, in the meter-wavelength range, a regularly recurring fine structure of the subpulse spectrum in frequency is detected. The observations show fairly clearly expressed maxima of emission at nearby frequencies  $\Delta f$ , the positions of which do not change over

observation session, i.e., over a time of about 3 min. The separation  $\Delta f$  between the maxima is  $(0.7 \pm 0.07)$  MHz at a frequency of 86 MHz, while at a frequency of 60 MHz  $\Delta f = (0.2 \pm 0.02)$  MHz. Thus, in the indicated part of the range the dependence  $\Delta f \sim f^3$  is satisfied.

If by  $B_\eta$  we denote the frequency band for which the modulation depth decreases to 0.5, then we obtain  $B_\eta = (0.4 \pm 0.1)$  MHz at a frequency of 86 MHz and  $(0.12 \pm 0.03)$  MHz at a frequency of 60 MHz. According to measurements at a frequency of 408 MHz <sup>(5)</sup>, for the pulsar CP 0808  $B_\eta = 20$  MHz, which gives the dependence in the range 408–86 MHz

$$B_\eta \sim f^{2.5}.$$

4. The measurements showed that in the range 60–110 MHz, on average, the quadratic dependence of the delay times of the subpulses on wavelength is satisfied fairly accurately. The total number of electrons

$$\int N dx = 5.757 \pm 0.002 \text{ pc} \cdot \text{cm}^{-3},$$

which agrees with the data of measurements at frequencies of 151 and 408 MHz <sup>(4)</sup>, but is almost 2 times smaller than according to the measurements in <sup>(3)</sup>.

5. Records with a narrow band and a small time constant made it possible to analyze the shape of the subpulses. It turned out that about 35% of the subpulses (frequency 86 MHz) have a symmetric shape, for which the pulse rise time  $\tau_1$  and decay time  $\tau_2$  are the same. About 45% of the subpulses have an asymmetric shape, and for them  $\tau_1 > \tau_2$ . Subpulses with clearly pronounced saturation are observed, in which the top is cut off; in this case, apparently, saturation effects of the coherent mechanism of radio emission are manifested.

**Fig. 3.** Histogram of the dependence of the amplitudes of subpulses  $I$  on their positions within the radio-emission diagram of the pulsar CP 0808 ( $\Delta t_{1i} = t_i - mP_1$ ),  $f = 86.0$  MHz.  $a$ —5 XII 1968,  $n = 28$ ;  $b$ —17 XII 1968,  $n = 45$ ;  $v$ —18 XII 1968,  $n = 31$ ;  $g$ —averaged dependence over 3 days,  $n = 104$ .  $n$  is the number of subpulses.

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