Frequency drift rates of powerful decameter Type III bursts

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We report on the observations of powerful (fluxes are larger than 10^{-19} W m^{-2} Hz^{-1}) solar Type III bursts at frequencies $10-30$ MHz. Recordings of 163 bursts, observed in July 2002 and of 231 bursts observed in August 2002 are investigated. The main properties of these Type III bursts (frequency drift rate, duration, flux, frequency bandwidth) are analyzed. In present report we pay more attention to consideration of frequency drift rate. A great difference between the observed and the well-known empirical frequency dependencies of Type III bursts drift rate is determined. A linear approximation for the drift rate versus frequency is found. It indicates, that solar corona above active regions has exponential density distribution. We consider that drift rate value depends on the position of an active region on the solar disc.

Introduction

Wild in his paper [5] first selected Type III bursts as individual type of solar bursts. He found the linear approximation for frequency drift rate via frequency dependence in the range of $70-130$ MHz. More detail analysis of Type III bursts was made by Alvarez and Haddock [1]. They determined drift rate dependence on frequency by equation $df/dt = -0.01f^{1.84}$ (df/dt is in MHz/s, f is in MHz) in the wide frequency band of 50 kHz – 1 GHz. We report on the analysis of the solar Type III bursts drift rates at frequencies $10-30$ MHz.

Observations

Powerful Type III bursts were registered with the radio telescope UTR-2 (Kharkiv, Ukraine) during summer 2002 observational campaign. Three sections of the radio telescope UTR-2 with a total area of 30 000 m^2 were used. It provides a beam of $1^\circ \times 13^\circ$. Detection was carried out by the 60-channel receiver with the frequency resolution of 300 kHz, the time resolution of 10 ms, and by the DSP (Digital Spectral Polarimeter) with the frequency resolution of 12 kHz, the time resolution of 100 ms [2].

Data of powerful solar Type III bursts have been obtained for 163 bursts in July 2002 and for 231 bursts in August 2002 which are matter of the present investigation. The majority of powerful Type III bursts are observed, as we discovered, at the days when their occurrence is associated with active regions (see e.g. http://www.gao.spb.ru/) on the solar disc located near the central meridian or at the medium longitudes ($40^\circ-60^\circ$). The two maxima (Figure 2b) in the burst distribution (on 17 and 26 August 2002) correspond to the intersection of the central meridian with two active regions. The maximum on 21 August is associated with 2 active regions located not in the center on the solar disc (60° to the East, 50° to the West). A similar situation occurs during the July storm (Figure 2a).

An example of a powerful Type III burst time profile against background of usual Type III bursts is shown in Figure 1. The time profiles of these bursts are not symmetrical and has fast rise and slow decay, like usual Type III bursts. In the range of $10-30$ MHz all these bursts have negative frequency drift rates (burst drift from high to low frequencies), it is true in the most cases for the standard Type III bursts. For the statistical analysis we divided the whole frequency band from 10 to 30 MHz into the frequency sub-bands $10-13$, $13-15$, $15-20$, $20-25$ and $25-30$ MHz. We mark all the characteristics on the average frequencies of these sub-bands.

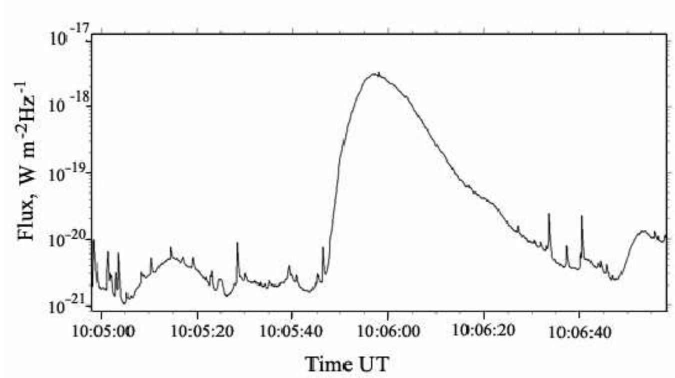

Figure 1: The powerful Type III burst (10:05:50 UT on August, 17, 2002) time profile.

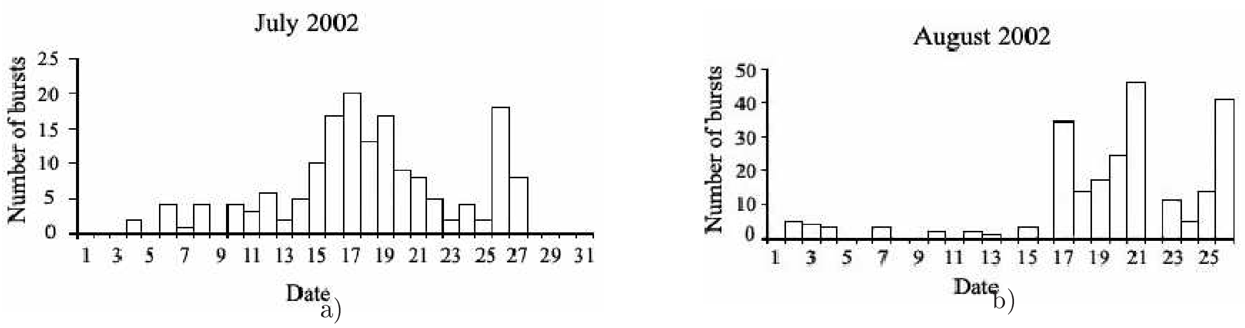

Figure 2: Distributions of powerful Type III bursts in July (a) and August (b) 2002.

According to [4] the duration of standard Type III bursts varies from 4 to 10 seconds. The derived duration value for powerful bursts is within the range of $4-12$ seconds. We obtained different kinds of flux dependence on frequency for these bursts. The flux of these bursts: increases with frequency, decreases with frequency, or has more complicated dependence. In the most cases powerful bursts have frequency drift rates in the range of $1-3$ MHz/s. In some cases the drift rate can be as small as 0.4 MHz/s and single bursts have drift rate up to 4 MHz/s. The drift rate histograms for bursts observed on August, 19 are shown in Figure 3. We can see the shift of the histograms maxima to small frequency drift values with decreasing frequency.

The drift rates versus frequency dependence for powerful Type III bursts is shown in Figure 4. We draw attention to the difference between derived and generally accepted dependence [1]. Drift rates were almost the same at frequencies $10-15$ MHz, but they considerably differ (by a factor of about 2) at frequencies $20-30$ MHz and also depend on the location of the active region on the solar disc. We propose a linear approximation between the drift rate and the frequency $df/dt=-A\cdot f+B$ [3], where A and B are coefficients depending on the day and the type of storm. This result is repeatable during all the observational time. For

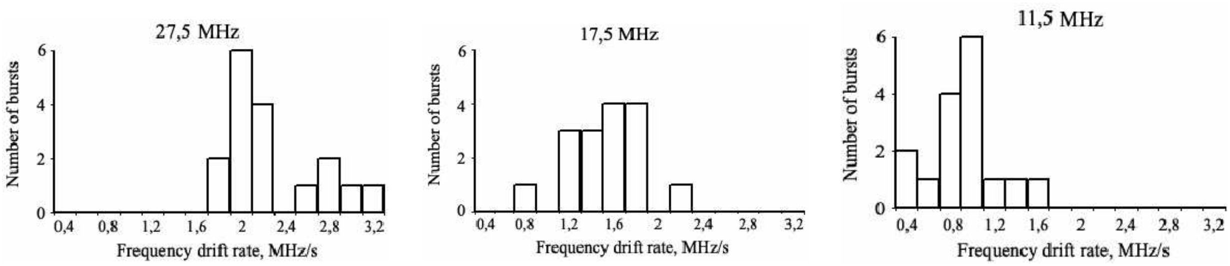

Figure 3: Drift rate histograms for powerful Type III bursts observed on August, 19, 2002 at different frequencies: 27.5 MHz (a), 17.5 MHz (b), 11.5 MHz (c).

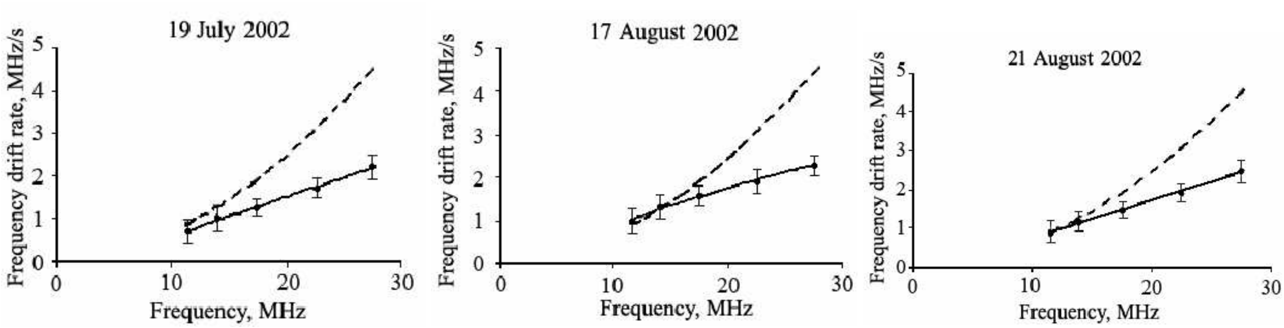

Figure 4: Drift rate dependencies on frequency for July, 19 (a), August, 17 (b) and August, 21 (c) 2002 (the solid line represents observational curve, the dashed line represents empirical dependence [1]).

the most cases the coefficient A is in the range of $0.08 - 0.09$ s^{-1}. The coefficient B does not exceed 10% of the measured drift rate. In such case we can use the equation $df/dt \approx -A \cdot f$

Our data allow us to find the linear velocity of powerful Type III bursts sources. Let us consider in what way the average drift rate of Type III bursts is changing from 10 to 16 July when the active region N249 got over the solar disk from the East to the middle of the Sun. The dependence of drift rate on location of the active region N249 is shown in Figure 5. The drift rate increases with the approach of the active region to the central meridian. Using known equation

$$\frac{df}{dt} = \frac{df}{dn} \cdot \frac{dn}{dr} \cdot \frac{c \cdot v_s}{c - v_s \cdot \cos\beta}, \tag{1}$$

where n is the plasma density, c is the speed of light, β is the longitude angle, the linear velocity of the radiation source v_s can be derived from observational data. In our case the velocity v_s is equal to $0.3c$, as usually supposed. The dashed curve in Figure 5 corresponds to this value of velocity.

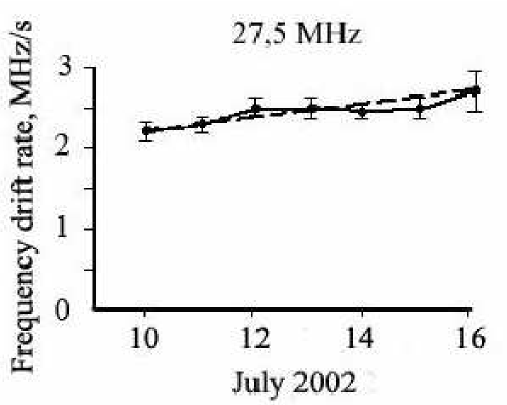

Figure 5: The variation of powerful Type III bursts drift rates depending on the active region N249 location on the solar disk (the solid line represents the drift rate dependence on the position of the active region N249, the dashed line corresponds to the equation (5) at $v_s = 0.3c$) .

Under the assumption that Type III radio emission is fundamental and occurs at the local plasma frequency $f = f_{pe}$, we have the equation $(df/dt)_F = f \cdot 1/(2 \cdot n) \cdot dn/dr \cdot v_s$. Comparing it with equation for linear approximation we derive the equation for coefficient A:

$$A = -\frac{1}{2 \cdot n} \cdot \frac{dn}{dr} \cdot v_s. \tag{2}$$

Taking into account that A is a constant value, which does not depend on frequency, and supposing that the source velocity is also constant, the density dependence on distance can be found as

$$n = n_0 \cdot \ exp(-2 \cdot A \cdot r/v_s), \quad (3)$$

where n_0 is the normalization factor. We conclude, that the solar corona above active regions has exponential density distribution.

We estimate the size of inhomogeneity $a = n/|dn/dr|$ for coronal plasma. It is equal to $a = 6 \cdot 10^{10}$ cm and $a = 5 \cdot 10^{10}$ cm above active regions N289 ($A = 0.08$) and N249 ($A = 0.09$) correspondingly at $v_s = 0.3c$.

Conclusions

The main result of our analysis of powerful Type III bursts is the discovery of a linear dependence between the frequency drift rate and frequency in the range of $10 - 30$ MHz. It indicates, that solar corona above active regions has exponential density distribution. We confirm that drift rate values depend on the position of an active region on the solar disc.

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