UNUSUAL TYPE III BURSTS AT THE DECAMETRE WAVELENGTHS

V. V Dorovskyy*, V. N. Melnik*, A. A. Konovalenko*, H. O. Rucker†,
E. P. Abranin*, and A. Lecacheux‡

Abstract

It is currently accepted that the dependences of frequency drift rate and instant duration of type III bursts on frequency follow a monotonic function. The observations carried out during summer months of 2002-2006 by the world largest decameter wavelength radio telescope UTR-2 in frequency band 10-30 MHz show that sometimes these dependences may have a jump at some frequency, when the steepness of the dependence changes step-wise. In this paper the results of observations of such unusual type III bursts are given. Since the dynamic spectrum of such bursts resembles a dog's leg we call them "dog-leg" type III bursts. More than a hundred of these "dog-leg" bursts were observed during 5 years. The parameters of the 41 bursts observed in 2002 were defined and statistically analyzed. The fact that "dog-leg" type III bursts are observed on the background of standard type III bursts allows to exclude any instrumental component of the observed phenomena.

1 Introduction

Type III bursts were first identified by Wild [1950]. Since that time these bursts were deeply studied by many scientists (see, e.g., Wild and Smerd [1972], Smith and Davis [1975], Utrecht group [1975], Suzuki and Dulk [1985], Pick and Vilmer [2008] and in different frequency bands (from 1 GHz to some tens of kHz). All authors interpret these bursts as radiation produced near the electron plasma frequency f_p and/or near its harmonic $2f_p$ by electron beams moving along open magnetic field lines with superthermal velocities $\approx 0.3c$, where c is the speed of light.

According to all existing corona models [Allen, 1947], [Newkirk and Gordon, 1961], [Abranin et al., 1990], [Mann, et al., 1999] the coronal plasma density monotonically decreases

---

* Institute of Radio Astronomy, Ukrainian Academy of Sciences, Chervonopraporna 4, 61002, Kharkiv, Ukraine

† Space Research Institute, Austrian Academy of Sciences, Schmiedlstrasse 6, A-8042 Graz, Austria

‡ LESIA, Observatoire de Paris, UMR CNRS 8109, 92195 Meudon, France

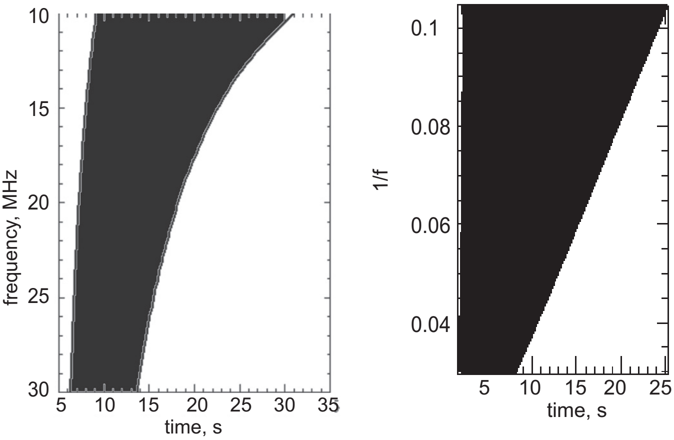

Figure 1: Modeled type III burst dynamic spectrum (left) and 1/f-t spectrum (right).

with distance from the Sun. As a result the frequency of radio emission of type III burst (taking into account plasma emission mechanism) should monotonically decrease with time, forming the dynamic spectrum of well known appearance.

Summarizing many observational results Alvarez and Haddock [1973] have proposed empirical dependence of the frequency drift rate on frequency for type III bursts in wide frequency band.

$$df/dt = -0.01 \cdot f^{1.84} \tag{1}$$

where frequency f is in MHz.

Taking into account the dependence of the type III bursts half-power duration on frequency $T = 220/f$ proposed by Suzuki and Dulk [1985] we can calculate the idealized dynamic spectrum of the type III burst. The result of calculation is shown in figure (1a). Cairns et al. [2009] suggested the model where solar bursts form straight line on the $1/f - t$ plane. For the calculated spectrum in figure (1a) it is also true (see figure (1b)).

Observations show that in the vast majority of cases real dynamic spectra of type III bursts are very similar to the calculated spectrum shown in figure (1). This fact speaks in favor of the model of type III bursts generation where superthermal electrons move with constant speed through the uniform corona with monotonically decreasing density.

Nevertheless observations carried out at the radio telescope UTR-2 in 2002-2006 in wide frequency range discovered rare cases when type III bursts have unusual dynamic spectra with a kind of jump point where the drift rate changes step-wise. From the specific appearance of the dynamic spectra of such type III bursts we called them “dog-leg” type III bursts. To reliably distinguish these “dog-leg” type III bursts among other type IIIs

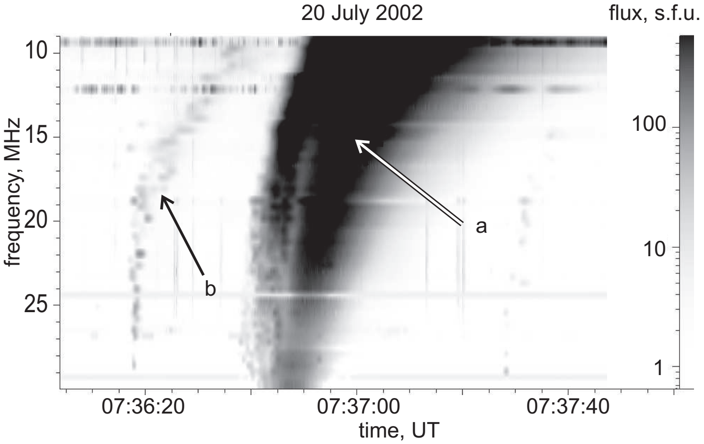

Figure 2: Ordinary type III burst (a) and dog-leg type IIIb burst with knee-point at 19 MHz (b)

we analyzed the dependence of the drift rate on frequency as well as $1/f - t$ spectra for each candidate. This paper introduces the results of observations and analysis of such "dog-leg" type III bursts in frequency range from 10 to 30 MHz.

2 Instruments

All observations were carried out with the 4 sections of the Northern branch of the UTR-2. This configuration provided the effective area of about 50,000 m^2 and wide and flat antenna beam (15° × 1°). In mentioned years the radio telescope was equipped with 60-channel filter-bank receiver and the FFT-based digital polarimeter DSP. In the present paper only data of the first receiver was used since the bandwidth of the DSP was insufficient to observe this kind of events.

3 Observations

As mentioned above ordinary type III bursts are characterized by the frequency drift rate monotonically decreasing with time. The example is the burst (a) in figure (2).

Our observations show that sometimes type III burst demonstrate unusual shape of dynamic spectrum with a kind of jump points. An example of such burst is shown in figure (3). One can clearly see that at frequency around 15 MHz the drift rate of the burst is decreased rapidly. To prove the reliability of the knee-point detection we additionally

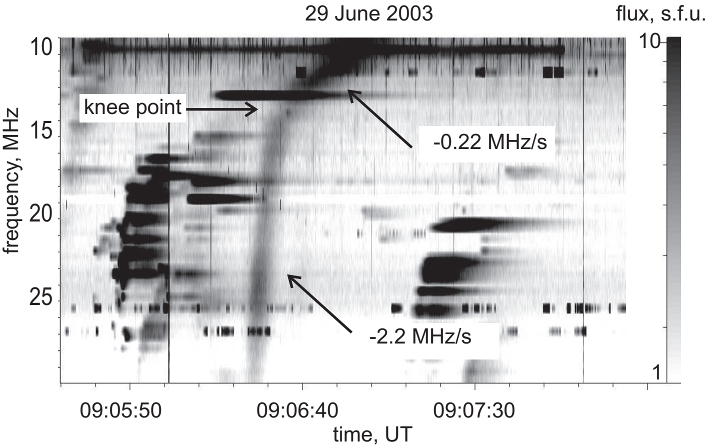

Figure 3: Dog-leg type III burst observed on 29 June 2003.

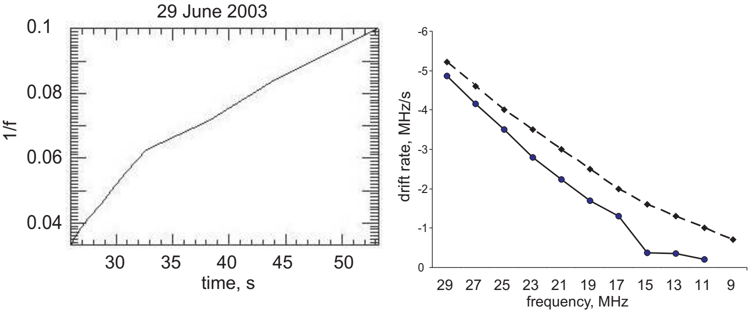

Figure 4: Dog-leg burst (figure (3)) on the $1/f - t$ plane (left) and its drift rate dependence on frequency (right). Here the UT in the left picture is 9^h 06^m + seconds on the time axis. The dash line in the right picture represents the Alvarez and Haddock [1973] dependence (1).

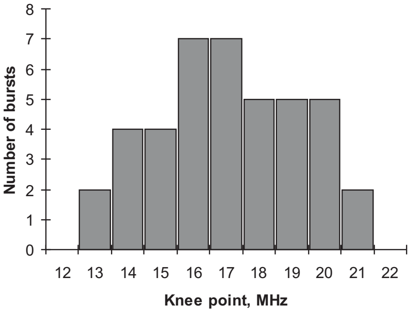

Figure 5: Knee point frequency distribution.

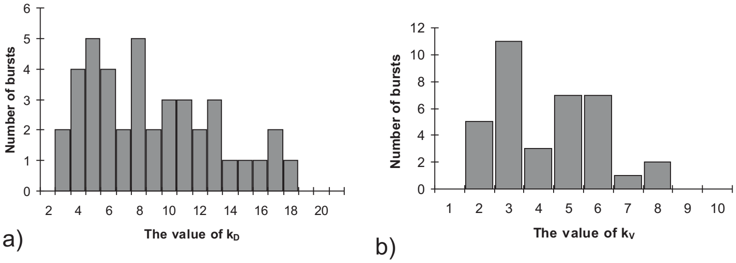

Figure 6: Distributions of the jump values at the knee-point: a) drift rate jump k_D and b) source velocity jump k_V.

analyzed the $1/f - t$ dynamic spectrum (figure (4a)) and drift rate vs frequency dependence (figure (4b)) of this burst. According to Cairns et al. [2009] type III bursts form straight line on the $1/f - t$ plane. In our case it is clearly seen that the discussed burst consists of two segments of straight line with different slopes connected around $1/f$=0.065 (or f=15MHz). Another evidence of the knee-point existence can be found on the drift rate dependence on frequency (figure (4b)). From 30 MHz down to 15 MHz our experimental dependence is monotonic and rather close to the well known dependence (1). But at frequency 15 MHz the drift rate falls step-wise with the slope of the dependence also changed. In our experiments all knee-points were found exclusively at the frequencies below 20 MHz as can be seen on the distribution in figure (5). The fact of knee points absence at frequencies below 13 MHz in figure (5) does not mean that they were not observed. We just excluded those cases from consideration because they were too close to the lower frequency of the equipment and we could not reliably conclude whether it was dog-leg, U or J burst.

The drift rate jump at the knee point in some cases reached an order of magnitude (see for example figure (4)). To analyze the value of this jump statistically we used the k_D

and k_V parameters. If $D_1 = (df/dt)_1$ is the frequency drift rate before the knee point and $D_2 = (df/dt)_2$ is the frequency drift rate after the knee point then $k_D = D_1/D_2$. For instance the k_D value for the burst in figure (4) equals 10. The k_D parameter distribution for 41 bursts registered in 2002 is show in figure (6a). According to the plasma generation model the frequency drift rate is defined by the fast electron velocity (under the conditions of known coronal density profile). Thus the value of the jump at the knee point can be also expressed in terms of the source velocity jump. If v_1 is the source velocity before the knee point and v_2 is the source velocity after the knee point then $k_V = v_1/v_2$. The k_V parameter distribution for the same set of bursts is shown in figure (6b).

4 Discussion

The observable frequency drift rate of type III burst df/dt (MHz s^{-1}) is defined by the equation (2)

$$\frac{df}{dt} = \frac{df}{dn} \cdot \frac{dn}{dr} \cdot v_s \cdot \cos\varphi, \tag{2}$$

where f - frequency, n - plasma electron density, r - distance from the Sun, v_s - linear source velocity and φ - angle between the electron beam direction and the plasma density antigradient. Apparently the monotonicity of the drift rate dependence on time is predetermined by the monotonicity of all factors in the equation (2). Consequently the jump in the drift rate dependence on frequency can be caused by the jump either in dn/dr factor (due to coronal inhomogeneity on the path of superthermal electrons), or in v_s factor (due to sudden electrons slowing down), or in $\cos\varphi$ factor (due to sudden change of the electron beam direction). In fact it is rather difficult to explain such considerable drift rate jumps by the step-wise change of only one factor. For example to obtain drift rate jump of an order of magnitude the electrons which move along the density antigradient should become 10 times slower or should deflect from initial direction by about 80° almost instantly. So the effect is probably caused by the combination of parameters jumps in all factors in equation (2). Or in other words it may be the results of aggregate effect of plasma inhomogeneity, magnetic field structure change and variation of the electron beam parameters. According to our estimation the sizes of regions where such sudden changes take place do not exceed 30,000 km. Our observations show that the electrons responsible for the dog-leg type III bursts generation are in general slower then 0.3c (the speed of ordinary type III electrons)[1]. This fact is well illustrated by the electrons velocity distribution shown in figure (7) and may be explained by initial deflection of the electrons from the antigradient direction. One of possible regions in the corona where such inhomogeneities can take place is the coronal streamer region.

---

[1] The electron speed is estimated under the Newkirk model conditions.

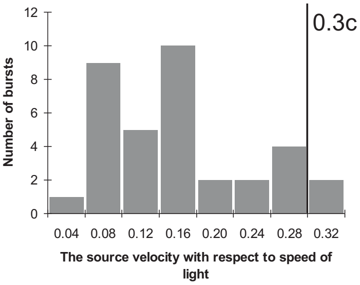

Figure 7: Distribution of the initial velocities of electrons responsible for the dog-leg type III bursts generation

5 Conclusion

Unusual "dog-leg" type III bursts were observed at frequencies 10-30 MHz. In our opinion the step-wise changes of the drift rate at the knee point can be the result of the coronal inhomogeneities which appear on the path of fast electron beams, responsible for type III bursts generation and/or a sudden slowing down and/or deflection of the electron beam. It is found that electrons responsible for "dog-leg" bursts generation are in general slower than 0.3c (characteristic speed of normal type III burst sources). The characteristic scale of regions where this sudden change takes place according to our estimation does not exceed 30,000 km. It can be the regions of coronal streamers, where plasma and magnetic inhomogeneities are most noticeable.

References

Abranin, E. P., L. L. Bazelyan, and Y. G. Tsybko, Stability of the Parameters of Decameter Type-III Bursts Over the 11-YEAR Solar Activity Cycle - Rates of Frequency Drift of Radio Burst, *Soviet Astr.*, **34**, 74–78, 1990.

Allen, C. W., Interpretation of Electron Densities from Corona Brightness, *Mon. Not. Roy. Astron. Soc.*, **107**, 426–432, 1947.

Alvarez, H., and F. T. Haddock, Solar wind density model from km-wave Type III bursts, *Solar Phys.*, **29**, 197–209, 1973.

Cairns, I. H., V. V. Lobzin, A. Warmuth, B. Li, P. A. Robinson, and G. Mann, Direct Radio Probing and Interpretation of the Sun's Plasma Density Profile, *Astrophys. J. Lett.*, **706**, 2, L265–L269, 2009.

Mann, G., F. Jansen, R. J. MacDowall, M. L. Kaiser, and R. G. Stone, A heliospheric density model and type III radio bursts, *Astron. Astrophys.*, **348**, 614–620, 1999.

Newkirk Jr., G., The Solar Corona in Active Regions and the Thermal Origin of the Slowly Varying Component of Solar Radio Radiation, *Astrophys. J.*, **133**, 983–1013, 1961.

Pick, M. and N. Vilmer, Sixty-five years of solar radioastronomy: flares, coronal mass ejections and Sun Earth connection, *Astron. Astrophys. Rev.*, **16**, 1–153, 2008.

Smith, D. F. and W. D. Davis, Type III Radio Bursts and Their Interpretation, *Space Sci. Rev.*, **16**, 91–144, 1975.

Solar Radio Group Utrecht, Type III Bursts, *Space Sci. Rev.*, **16**, 45–89, 1975.

Suzuki, S. and G. A. Dulk, Bursts of type III and type V, in *Solar Radiophysics* edited by D. J. McLean and N. R. Labrum, Cambridge University Press, Cambridge, 289–332, 1985.

Wild, J. P. and L. L. McCready, Observations of the Spectrum of High-Intensity Solar Radiation at Metre Wavelengths. III. Isolated Bursts, *Austral. J. Sci. Res.*, **3**, 541–557, 1950.

Wild, J. P., and S. F. Smerd, Radio Bursts from the Solar Corona, *Ann. Rev. Astron. Astrophys.*, **10**, 159–196, 1972.