TRACKING TYPE III RADIO BURST SOURCES IN THE SOLAR CORONA BY HELIOGRAPHIC MEANS

A.A.Koval[1], A.A.Stanislavsky[1,2], A.A.Konovalenko[1], Ya.S.Volvach[1]

[1] Institute of Radio Astronomy of NAS of Ukraine, 4, Chervonopraporna Str., 61002, Kharkiv, Ukraine, *akoval@rian.kharkov.ua*

[2] V.N. Karazin Kharkiv National University, Svobody Sq. 4, 61022, Kharkiv, Ukraine

ABSTRACT. We present the preliminary results of heliographic measurements of solar type III radio bursts in the low-frequency range (16.5-33 MHz) using the UTR-2 radio heliograph. The radio astronomy tools permit us to obtain two-dimensional spatial structures of burst sources in dependence of frequency and time. Each heliogram consists of 40 pixels (beams) as a result of the serial sweep in *UV*-plane wherein signals of each beam are recorded in a dynamic spectrum with both high temporal (~ 2.482 ms) and top spectral (~ 4 kHz) resolutions. The rate of output heliograph is one image per 3 seconds. Over a session in April, 2013 many type III radio and IIIb-III bursts were observed. On the heliograms the source motion direction in the upper corona is clearly detectable. The heliogram features are discussed.

Key words: Sun: radio emission – bursts: radio heliograph: UTR-2 radio telescope

1. Introduction

Solar bursts are important manifestations of solar activity because they are related to sporadic acceleration of enormous flows of solar plasma matter caused by release of energy stored in magnetic fields. The radio observations of bursts provide valuable information about solar plasma properties in the corona through which the bursts propagate. Many solar bursts reliably are identified with their sources from the study of frequency-time characteristics of these bursts that gives an indirect opportunity to specify parameters of their emitters.

Vast population or "zoo" of solar bursts manifests themselves in ground-based and space-based observations within wide frequency band. Such radio bursts were classified into several different types on the basis of their frequency drift rates df/dt (Wild, 1963). Solar emission in decameter wavelengths range (3-30 MHz) is abundant in bursts too. Recall a brief description of solar bursts characteristic for the decameter range. The type II and type IV bursts are often associated with coronal mass ejections (CMEs) which are generally attributed to solar flares or filament eruptions (Subramanian and Dere, 2001). The II type bursts are slowly drifting emission ($df/dt < 0.1$ MHz/s within 10-30 MHz) which is believed to be generated by shock waves traveling through the solar corona (Melnik et al., 2004). The broad continuum radiation with varying the time structure relating to CME body itself is called the solar IV type burst.

The solar III type bursts are the most numerous events filling the low-frequency band (<100 MHz). In decameter wavelengths the type III bursts have typically drift rates about – (2−4) MHz/s (see, for example, Abranin et al., 1990). Such radio emission is associated with beams of fast electrons moving outward into interplanetary space along open magnetic field lines. Durations of these bursts can be up to 20 s, while the most are found in the range within 4-10 s in the frequency band 10-30 MHz. The energetic characteristics of decameter type III bursts is that their brightness temperatures can achieve to 10^8-10^9 K.

In many cases the conventional analysis of solar dynamic spectra is restricted by the determination of above-mentioned parameters of type III bursts. Unfortunately, there are no in-depth reports about spatial characteristics of type III bursts sources at low frequencies with the exception of space-based observations below 10 MHz (see, for example, Morosan et al., 2014). Particular estimations of spatial sizes of electron beams, which are sources of type III bursts, have been performed by Benz (2009). In decameter wavelengths the spatial structure of burst sources was studied by Abranin et al. (1976) as well as by Chen and Shawhan (1978). In general it was found that the angular width of type III burst sources increases inversely proportional to frequency.

One of the Ukrainian radio-astronomy projects developing on the basis of the UTR-2 telescope is a new radio heliograph aimed to study quiet-Sun radio emission and solar bursts activity in the wide low-frequency range 8-33 MHz. The instrument opens wide perspectives to fill the gaps in solar low-frequency data as applied to angular sizes of solar burst sources. In this paper we present preliminary results obtained by the UTR-2 radio heliograph to study the angular structure of type III radio bursts.

2. Instrument and observations

The radio heliograph based on the UTR-2 antenna system is an updated low-frequency instrument capable of measuring two-dimensional images of brightness distributions within 8-33 MHz (Stanislavsky et al., 2011). The dipoles (2040 units) of UTR-2 are divided on 12 sections forming three arms called North, South and West. The large total area of UTR-2 (~ 140000 m^2) permits us to investigate both sporadic solar radio emission and continuum radiation of the quiet Sun in complicated interference conditions (Konovalenko et al., 2013). Recently, the heliograph has successfully proved itself in getting maps of quiet-Sun corona in the decameter range (Stanislavsky et al., 2013). The powerful back-end facilities of UTR-2 give opportunities to carry out observations with high time (from 0.2 msec up to 1 sec) and top frequency (~ 4 kHz) resolutions under wide dynamic range (over 90 dB). The present configuration of the radio heliograph is based yet only on a serial mode, i.e. an antenna pencil-beam changes its position consecutively along declination and hour angle, forming *UV*-images. Each image element is spaced on 30 minutes in declination and hour angle at 25 MHz. The angular field of heliograph view is about 2.5°×4.0°, and each frame consists of forty (5×8) pixels as an image matrix (Konovalenko et al., 2012).

The pilot heliographic observations of solar bursts have been fulfilled on 9-11 April 2013 in the frequency band 16.5-33.0 MHz. At that time the solar activity is accompanied by a large number of solar bursts, mainly IIIs type. In the observations the radio heliograph beam was formed with help of multiplying knife-pattern beams of North-South and West arms. The low-frequency operating range enables to study upper layers of the solar corona. Therefore, we can observe spatial and temporal peculiarity of coronal processes, particularly the evolution of angular structure of burst sources, in about 2-3 radii from the center of the Sun. At these heights the angular dimensions of type III burst sources correspond to about one solar radius and even more. The preliminary analysis of heliograms was performed for several III and IIIb-III bursts. The dynamic spectrum example of a type III burst is shown in Figure 1a. On Figure 1b the dynamic spectrum of this event recorded from the radio heliograph is presented. The consecutive record has the brightest vertical stripes being noise generator markers that indicate start/end instances of frames. The time between such two neighboring stripes (time of frame composition) is equal to 3 seconds. In the data processing the serial record was converted into a set of two-dimensional images. Consequently, the three-dimensional angular structure evolution of the type III solar burst source (*UV*-plane frames at selected frequencies in dependence of time) is obtained. It is quite visible that the burst duration expands with decreasing of frequency (see Figure 1a). Besides, the burst intensity peak moves towards low frequencies, i.e. the electron beam travels away from Sun to high altitudes in solar corona (see Figure 1c). The peak-in-time evolution from frame to frame indicates source-motion directions for this burst.

3. Summary and future work

The angular dimensions of sources of solar radio bursts are still not explored profoundly at low frequencies. Using the two-dimensional heliograph of UTR-2, we have shown that the tools allow us to get spatial information about sources of type III radio bursts within 16.5-33.0 MHz. Consequently, the three-dimensional evolution in time (so-called **3D+1** representation) of type III bursts spatial structures is obtained. A next step in the analysis of spatial features of IIIs bursts is the statistic estimation of angular sizes of their sources. The further researches will be focused on investigations of solar type II, IV bursts sources attributed to CMEs.

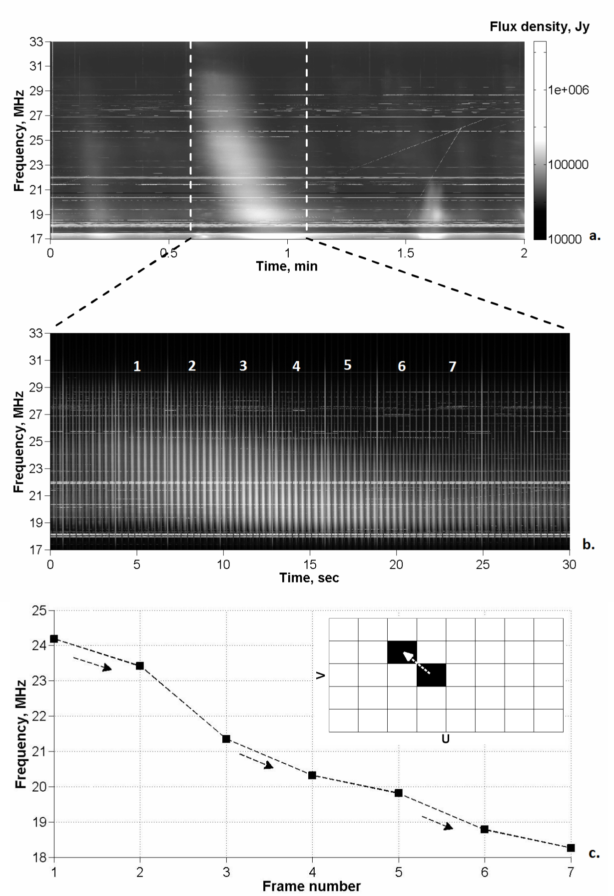

Figure 1: a) Dynamic spectrum recorded by UTR-2 at April 9, 2013. Time zero corresponds to 10:33:59 UT; b) Serial record obtained from heliographic measurements; c) Source position drift in *UV*-plane, frequency and time.

It should be also noticed that the measurement of burst source sizes can be carried out by two methods: either scanning by a radio telescope narrow beam or using interferometer tools. The facilities of UTR-2 enable to realize both methods simultaneously. This work plans to perform in the future too.

Acknowledgements. This research was also partially supported by Research Grant "Synchronized simultaneous study of radio emission of solar system objects by low-frequency ground- and space-based astronomy" from the National Academy of Sciences of Ukraine.

References

Abranin E.P. et al.: 1976, *SvA*, **19**, 602.
Abranin E.P. et al.: 1990, *SvA*, **34**, 74.
Benz A.O.: 2009, *LanB*, **4B**, 148.
Chen H.S., Shawhan S.D.: 1978, *Sol.Phys.*, **57**, 205.
Konovalenko A.A. et al.: 2012, *RPRA*, **3**, 1.
Konovalenko A.A. et al.: 2013, *Exp. Astr.*, **36**, 137.
Melnik V.N. et al.: 2004, *Sol.Phys.*, **222**, 151.
Morosan D.E. et al.: 2014, *A&A*, **568**, A67.
Stanislavsky A.A. et al.: 2011, *RPRA*, **2**, 197.
Stanislavsky A.A. et al.: 2013, *AN*, **334**, 1086.
Subramanian P., Dere K.P.: 2001, *ApJ*, **561**, 372.
Wild J.P.: 1963, *IAU Symp. Proc.*, **16**, 115.