Interferometer Observations of Solar Type III Bursts by the Radio Telescope UTR-2

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Abstract Results of solar radio emission observations by radio telescopes UTR-2 and URAN-2 in May-June 2014 are discussed. Observations by the radio telescope UTR-2 were carried out in the interferometer mode using West-East arm of the UTR-2 on 29 May and North-South arm on 2 June at frequencies 20 and 25 MHz. On 29 May some powerful simple type III bursts and groups of type III bursts were observed against type IV burst. There were only isolated weak type III bursts on 2 June. Analysis of visibility functions of radio emission sources at these frequencies was allowed to find spatial sizes of bursts sources, which changed mainly from 20\` to 22\` at 25 MHz and from 24\` to 27\` at 20 MHz. Also sources distances at these frequencies were obtained. In most cases radio emissions at frequencies 20 and 25 MHz escaped at distances 2.9Rs and 2.6 Rs, respectively. At these distances the radio emission at frequencies 10 and 12.5 MHz are generated in the Newkirk corona so we conclude that the observational radio emission occurred at the second harmonic. This fact is confirmed by the low polarizations of discussed type III bursts. Brightness temperatures of these bursts were in the range from 2.1 10^9 K to 4.5 10^{10} K for bursts on 29 May and only about 10^8 K for the burst observed on 2 June.

Keywords: type III bursts, interferometer observations, sizes of radio bursts sources, heights of radiation sources, solar corona.

Introduction

In 60th - 80th number of observations for definition of sizes of different solar burst sources in the decameter range from 12.5 MHz to 40 MHz were conducted (Weiss and Sheridan, 1962; Erickson, 1963; Malitson and Erickson, 1966; Gergely and Kundu, 1975; Abranin et al., 1976; Chen and Shawhan, 1978; Dulk and Suzuki, 1980; Abranin et al., 1980). Heliographic and interferometer methods were used for that. According to some authors type III bursts had core-halo structures. But others did not find such structures. Sizes of cores, if they were detected, were about 10\` and sizes of halos were up to 40\` at different frequencies. The least sizes, 15\`, were revealed at 40 MHz and the largest ones, not more than 40\`, at 12.5 MHz. At intermediate frequencies the sizes were from 15\` to 30\` mainly. In some of these observations the distances of radiation places were defined. They were changed in the range 1.75 R_S - 2.5 R_S at frequency 40 MHz and in the range 1.55 R_S - 2.9 R_S at frequencies 25 MHz, 26.3 MHz and 30 MHz. It was registered that radio emissions of discussed type III bursts occurred predominantly at the second harmonic of the local plasma frequency.

In this paper the results of type III bursts observations by radio telescopes UTR-2 (Braude et al., 1978) and URAN-2 (Brazhenko et al., 2005) on 29 May and 2 June, 2014 are discussed. The radio telescope UTR-2 worked in the interferometer mode at frequencies 20 and 25 MHz and the radio telescope URAN-2 observed the solar radio emission in the standard spectrographic mode in the frequency band 8-32 MHz. Sizes of type III bursts sources as well as their distances at frequencies 20 and 25 MHz from the centre of the Sun were found.

Observations

The bases 225 m, 450 m and 675 m between sections of West-East arm on 29 May and the bases 208 m, 416 m, 624 m, 885 m, 1301 m and 1509 m between sections of North-South arm on 2 June were used in the interferometer mode of observations by the radio telescope UTR-2 (Figure 1). Single type III bursts and their groups were observed against type IV burst (from 9:00 to 10:20) on 29 May (Figure 2). 8 most powerful type III bursts at 9:41, 10:07, 10:08, 10:14, 10:15, 10:16, 11:13 and 11:14 registered on 29 May (Figure 3a,b,c) were chosen for analysis. On 2 June there was practically the quiet Sun in the frequency band 8-32 MHz with some single weak type III bursts. We obtained sizes and distances of type III burst source occurred at 6:59 (Figure 3d).

The dynamic spectrum of solar radio emission in the frequency range 8-32 MHz from 9:00 to 12:00 UT on 29 May 2014 is shown in the Figure 2. This time interval corresponds to that when the radio telescope UTR-2 worked in the interferometer mode this day.

The main parameters of discussed type III bursts are represented in Table 1 (25 MHz) and Table 2 (20 MHz). All type III bursts registered on 29 May had fluxes from 10^2 *s.f.u* to 10^3 *s.f.u* Type III burst observed on 2 June was essentially weaker, its flux was about 10 *s.f.u*

The frequency drift rates of discussed bursts between 20 and 25 MHz are not so much as for standard decameter type III bursts (Melnik et al., 2005) at these frequencies, only 1÷2 *MHz/s*. Such drift rates are characteristic to decameter type III bursts at lower frequencies (Melnik et al., 2011, Brazhenko et al., 2015) if radio emission happened at the fundamental harmonic.

The burst durations τ at frequencies 20 and 25 MHz are in the range 11-17s and only the burst at 9:41 UT was a little shorter. Again such durations are more typical for bursts at low frequencies (Brazhenko et al., 2015).

The polarizations of all analyzed type III bursts are not higher than 11%. It says that such decameter bursts seem to be generated at the second harmonic of the local plasma frequency (Dulk and Suzuki, 1980; Brazhenko et al., 2015).

Sizes of type III sources were derived by writing in the visibility function (Thompson, Moran, and Swenson, 2001)

$$\gamma = \exp[-(\frac{\pi\theta L}{2\sqrt{\ln 2}\lambda})^2] \qquad (1)$$

where θ is the angle size, λ is the wave length, at which observations were carried out, and L is the interferometer base, in experimental data (Figure 4). Derived sizes are presented in the Tables 1 and 2. In most cases type III source sizes are in the ranges 24`-27` and 20`-22` at frequencies 20 and 25 MHz respectively. The sizes of two bursts at 10:07 and 10:08 at 25 MHz are visibly larger than for others. We connect this feature with high level of background radio emission in the form of type IV burst (Figure 2) that increases effective sizes of type III bursts. At the same time this background level of radio emission at 20 MHz is not so high and as consequence the effective sizes of bursts at this frequency do not differ so greatly. The sizes of type III burst at 6:59 at both 20 and 25 MHz are larger in comparison with those of type III bursts observed on May 29. Notice that in the last case type III electrons moved in equatorial plane (Figure 5) and measured sizes in West-East direction are prolonged sizes of electron beams d. At the same time measured sizes of type III burst source on 2 June in North-South direction are transverse sizes l. So we can conclude that transverse sizes are larger of prolonged sizes of type III bursts at frequencies 20 and 25 MHz. May be it is the common property but to be sure it is necessary to increase statistics of measured type III sizes.

In the theory of type III bursts fast electrons propagating through the solar corona generate radio emission at the local plasma frequency so electron beam with velocity v and prolonged size d radiate electromagnetic waves for a time $\tau = d / v$. Measuring duration of type III burst τ and prolonged size d everyone can derive velocity of electron beam $v = d / \tau$ responsible for the burst. We see (Table 1, 2) that these velocities at both frequencies are in the range 0.2-0.3c. These values are in good agreement with generally accepted theory for type III bursts.

Supposing that transverse sizes are not differed significantly from the prolonged sizes the brightness temperatures (Aubier, Leblanc, and Boischot, 1971) for different type III bursts

$$T_b = 5.5 \cdot 10^{29} \frac{\lambda^2 S}{\theta_W \theta_N} \qquad (2)$$

(S is the flux (in $Wm^{-2}Hz^{-1}$), θ_W, θ_N are diameters (in minutes) in equator and polar directions and λ is the wavelength (in m)) were derived. They changed from 2.1 10^9 *K* to 4.5 10^{10} *K* for type III bursts observed on 29 May. Such brightness temperatures are characteristic for the induced processes of transformation of Langmuir waves to electromagnetic waves (Melnik and Kontar, 2003). Type III burst observed on 2 June had brightness temperature smaller than 10^9 *K* at both frequencies 20 and 25 MHz. It means that this burst was generated in spontaneous processes (Melnik and Kontar, 2003).

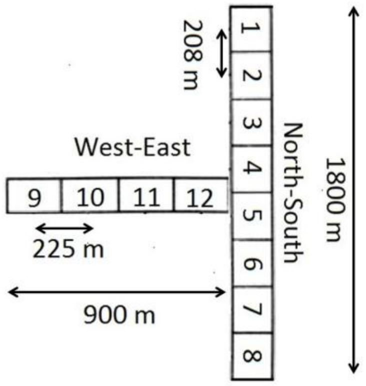

Figure 1. Scheme of the radio telescope UTR-2, which consists of 8 North-South sections and 4 West-East sections.

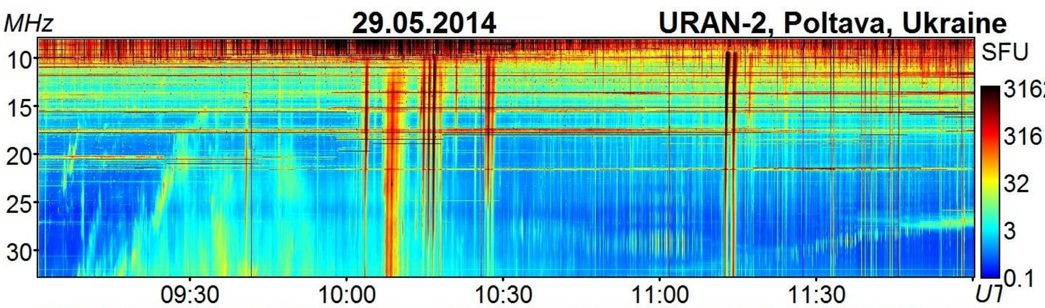

Figure 2. The dynamic spectrum of solar radio emission from 9:00 to 12:00 according to URAN-2 observations.

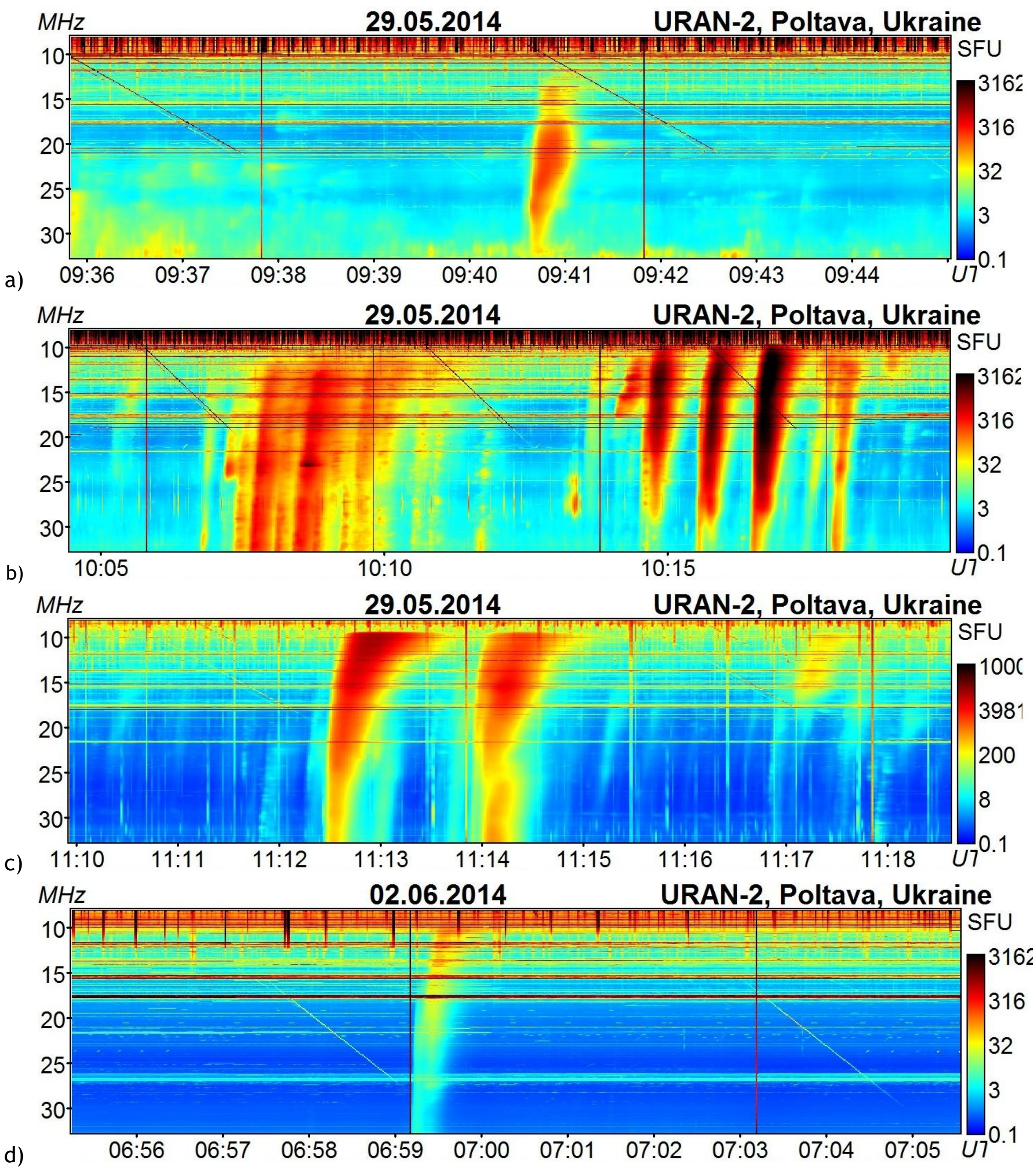

Figure 3. Discussed type III bursts observed by the radio telescope URAN-2 on 29 May (a, b, c) and on 2 June (d).

Table 1. Parameters of type III bursts at 25 MHz

Time UT	Flux s.f.u.	drift rate MHz/s	Duration s	Polarization %	Size arcmin	Velocity c	Distance arcmin	Brightness temperature K
9: 41	170	-1.2	7	-11	14	0.29	50	$7.5\ 10^{9}$
10:07	230	-0.9	13	-6	29	0.33	39	$2.4\ 10^{9}$
10:08	270	-1	14	-6	28	0.29	39	$3\ 10^{9}$
10:14	120	-2.5	12	-6	22	0.27	41.5	$2.1\ 10^{9}$
10:15	500	-1.6	11.3	-9	22	0.28	43	$8.9\ 10^{9}$
10:16	1000	-2.5	13	-9	22	0.25	41.5	$1.8\ 10^{10}$
11:13	710	-0.9	10.6	0	20	0.28	42.5	$1.5\ 10^{10}$
11:14	260	-0.9	13.5	0	21	0.23	41.5	$5.1\ 10^{9}$
6:59	6	-2	12	0	27	-	-	$7\ 10^{7}$

Table 2. Parameters of type III bursts at 20 MHz

Time UT	Flux s.f.u.	drift rate MHz/s	Duration s	Polarization %	Size arcmin	Velocity c	Distance arcmin	Brightness temperature K
9: 41	170	-1.2	11	0	16	0.21	55	8 109
10:07	255	-0.9	14.4	-4	26	0.26	49	4.7 109
10:08	316	-1	17.5	-1	27	0.23	49	5.4 109
10:14	600	-2.5	14.5	-5	27	0.27	47	1 1010
10:15	1150	-1.6	12.3	-6	25	0.3	45.5	2.3 1010
10:16	2600	-2.5	16.7	-7	27	0.24	44.5	4.4 1010
11:13	2090	-0.9	12.5	-5	24	0.28	47	4.5 1010
11:14	790	-0.9	16	-5	23	0.21	46	1.8 1010
6:59	18	-2	14	0	29	-	-	2.6 108

Distances of type III sources was defined by the phase differences of signals coming to sections of interferometer

$$\sin\Delta\theta = \frac{\Delta\varphi\lambda}{2\pi L} \qquad (3)$$

where $\Delta\theta$ is the angle distance, $\Delta\varphi$ is the phase difference, λ is the wavelength and L is the interferometer base (Thompson, Moran, and Swenson, 2001). Sources of type III bursts at 20 and 25 MHz were situated from 45\` to 49\` and from 39\` to 43\` from the solar centre respectively. On supposition that electron beams propagated in the Newkirk corona we found that at these distances local plasma frequencies were two times smaller than the frequency of type III radio emissions. It says in favor of radio emission of these type III bursts at the second harmonic. This ties in with polarizations, drift rates and durations of discussed bursts. A little higher altitudes for type III burst at 9:41 can be indicated that corresponding electrons propagate through the corona with temperature higher than $1.4\ 10^6\ K$ (see, for example, (Mann et al., 1999).

Conclusions

The first interferometer observations of the solar radio emission by the radio telescope UTR-2 showed that the sizes of the radio telescope and its construction are very good for the definition of type III sources sizes and their distances. Measured visibility functions for type III sources had practically Gaussian distributions, which were defined by the only size, i. e. sources did not show core-halo structure. Of course this statement should be confirmed on the more statistical sampling. At both frequencies 20 and 25 MHz type III sources had prolonged sizes between 20\` and 30\`. The velocities of electron beams responsible for type III bursts had values 0.2-0.3c mainly that agreed with type III bursts theory. Brightness temperatures of type III bursts with fluxes $10^2 \div 10^3$ *s.f.u* are in the range $10^9\ K \div 5.10^{10}\ K$ that corresponds to the induced processes of type III bursts generation. The discussed bursts occurred in the plate plane and in this case distances from the Sun corresponded to the generation of the second harmonic of the local plasma frequency. This fact is supported by low polarizations of discussed type III bursts.

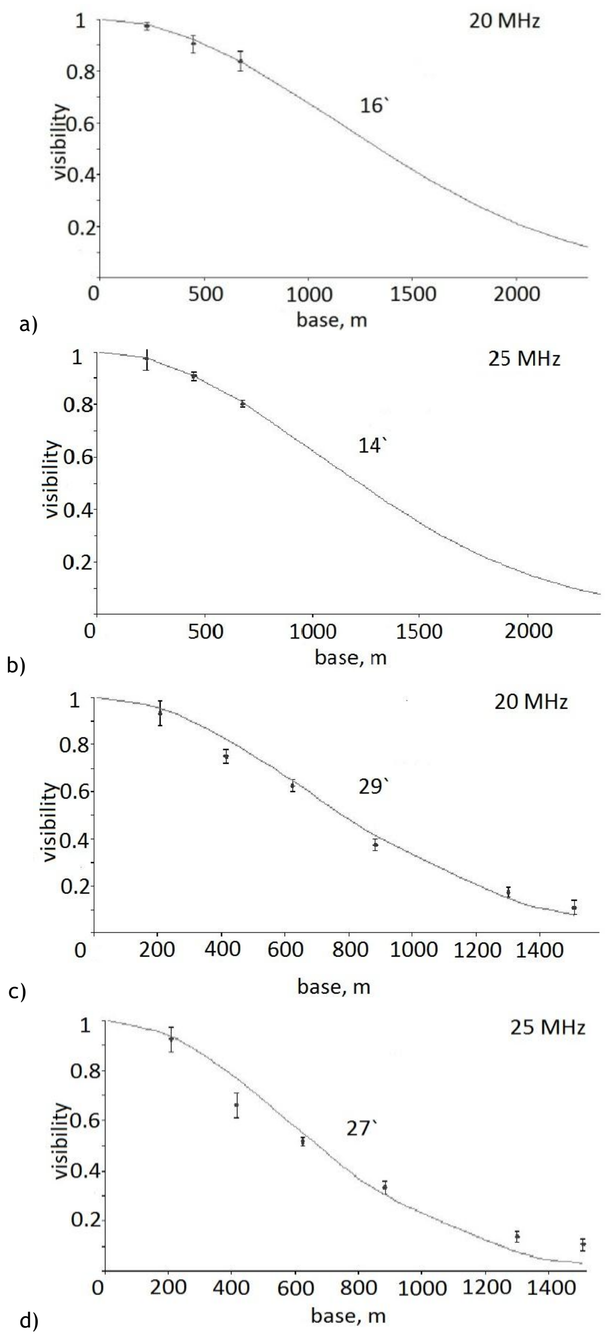

Figure 5. Visibility functions for type III bursts observed at 9:41 on 29 May (a,b) and at 6:59 on 2 June at frequencies 20 and 25 MHz.

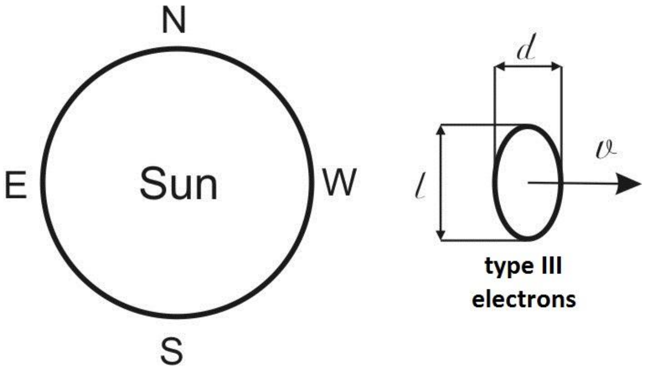

Figure 6. Sketch for type III electrons propagating in equatorial plane with velocity V outward the Sun.

Acknowledgements

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