SPORADIC SOLAR RADIO EMISSION AT DECAMETER WAVELENGTHS

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Abstract

Results of observations of solar sporadic radio emission with the UTR-2 radio telescope in 2001 – 2003 are presented using the new back-end facilities. The DSP and the 60-channel spectrometer allowed us to obtain data with time resolution up to 2 ms and frequency resolution of 12 kHz in the frequency bandwidth of 12 MHz. Usual Type III bursts, Type IIIb bursts, U– and J–bursts, spikes as well as unusual bursts at the decameter wavelength band are presented. Special attention is paid to the detection and the analysis of Type II bursts and their properties, fine structure of Type III bursts, new observational features of drift pair bursts, "absorption" burst and statistical analysis of solar radio bursts.

1 Introduction

Radio telescope UTR–2 (Kharkov, Ukraine) is nowadays the world largest radio telescope operating in decameter wavelengths band [Braude et al., 1978]. It was involved in solar observations since the beginning of the seventies of the previous century. Usually the observations were carried out using the filter bank spectrometers with only 6 or 8 channels. These limitations did not allow us to investigate properly the various components of the solar sporadic radio emission. By the end of the nineties our research activity was limited to the investigation of Type III and IIIb bursts, drift pairs and the quiet Sun.

The collaboration of the Austrian, French and Ukrainian scientists resulted in the creation of the new generation spectrometer (Digital Spectro-Polarimeter, DSP) [Lecacheux et al., 1998]. The DSP provided observations with high time and frequency resolution in a rather wide frequency band up to 12 MHz (or 50% of the working frequency). The DSP observations were supplemented by the 60-channel filter bank spectrometer which increased the capability of investigations in the field of solar radio emission. The present paper introduces the first results of the solar sporadic radio emission observations obtained with the new back-end facilities as well as the obtained results.

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2 Radio telescope and associated equipment

The broadband T-shaped radio telescope UTR-2 consists of two antenna arrays: "North-South" (1800 m along the North-South direction) and "East-West" (900 m along the East-West direction). The antenna "North-South" is in its turn divided in two separate arrays each of which includes 720 broadband dipoles (6 rows with 120 dipoles). The "East-West" antenna consists of 6 rows with 100 dipoles. The discrete phasing system allows to cover the sector $\pm 50°$ in right ascension plane and $\pm 50°$ in declination plane. The effective area of the "North-South" antenna amounts to 100 000 m^2 and for the "East-West" antenna it equals 40 000 m^2 when pointing to the zenith. The telescope beam can be as narrow as 25' at 25 MHz. The wide dynamic range and the linearity of the amplifiers, as well as their optimal distribution, almost exclude the intermodulation interference.

At the end of the nineties the new 60-channel filter bank spectrometer was created. It has 60 identical channels with selectable bandwidth from 3 to 10 kHz. The central frequency of each channel can be chosen in the range 10 – 30 MHz depending on the observational program. The spectrometer has variable time resolution from 20ms to several minutes with data accumulation and averaging. The dynamic range is 40 dB with sensitivity about 10^{-25}Wm^{-2}Hz^{-1}.

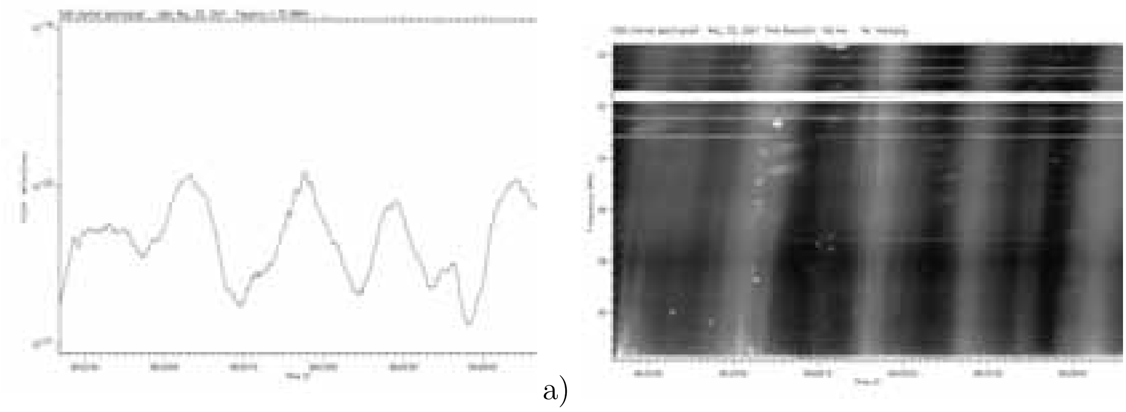
In 1999–2002 joint observations of the solar sporadic radio emission have been carried out at the UTR-2 radio telescope with the assistance of the scientists from the Space Research Institute (Graz, Austria), the Paris-Meudon Observatory (Paris, France) and the Institute of Radio Astronomy (Kharkov, Ukraine). During these observations the DSP was used as the back-end facility.

3 Observations

The observations with the new recording devices have been started in 2001 [Konovalenko et al. 2002]. During this period we have observed not only the well known bursts typical in the decameter band, such as Type III and IIIb bursts and drift pairs, but also bursts which have not been observed yet in our spectra in this frequency range: Type II bursts, U–, J– and S–bursts, decametric spikes and bursts in absorption. Moreover we have obtained new information about the well known events, in particular, we have found fine structures in Type III, Type II bursts and drift pairs. Let us briefly describe the main properties of these events.

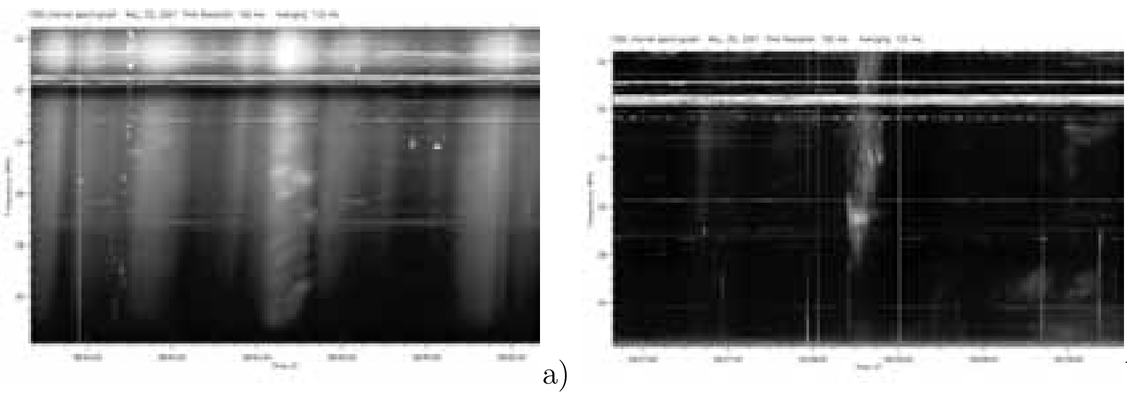
3.1 Type III bursts

Type III bursts in the decametric band show drift rates of about -3 MHz/s, their duration is close to 10 s. Their time profiles are smooth, that apparently inform us about the uniformity of the electron beams generating these bursts. Type IIIb bursts are shorter (3s) and drift slightly faster (-4 MHz/s). Usually they are slightly stronger. Apart the



a) b)

Figure 1: Type III burst with fine structure: profile (a) and dynamic spectrum (b)



a) b)

Figure 2: Type III bursts with sub-bursts drifting slower then the host burst (a) and drifting in both directions (b)

ordinary Type III bursts we have observed also fine structured ones [Mel'nik et al., 2004a]. During the observations in 2001–2002 more than 50 such bursts were recorded. Usually fine structures have a form of short and narrow band sub-bursts with their own drift rates.

The sub-structures can be classified due to their drift rates into four groups:

- sub-bursts drifting faster than the host burst (the highest observed drift rate was about 12 MHz/s), (Figure 1);
- sub-bursts drifting slower with drift rates around 1 MHz/s;
- sub-bursts drifting slower than 100 kHz/s (Figure 2a);
- combination of sub-bursts with positive and negative drifts (Figure 2b).

Besides the second group we can show cases when the drift pairs and the solar S-bursts were observed just on the background of a Type III burst. Apparently this is not a simple superposition of different bursts emitted from different sources in the corona since both

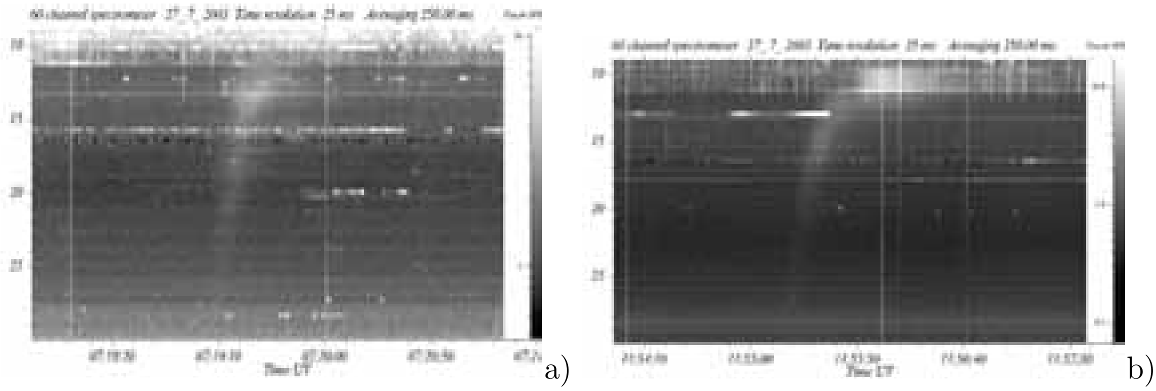


Figure 3: U–type (a) and J–type (b) bursts with reverse point at 10MHz

the drift pairs and the S-bursts are sharply bounded by the host Type III body. The lifetime of the sub-bursts belonging to the host burst usually lasts approximately 1 s. In our opinion fine structures are a manifestation of particle beams with parameters (density and/or velocity) which are different from the parameters of the host Type III electrons.

Inverted U- and J-bursts are also related to Type III bursts family. Examples of such bursts observed on 27 July 2003 are shown in Figure 3. The return points of these bursts were at the lowest frequency ever observed: −10 MHz. Thus if we believe that these bursts are generated by electrons moving along closed magnetic loops, it means that the height of these loops exceeds $R_\odot$.

3.2 Type II bursts

In 2001–2002 we have firstly observed Type II bursts in the frequency range 10–30MHz (Figure 4 and 5) [Mel'nik et al. 2004b]. At these frequencies they drifted with rate 30 − 70 kHz/s. Their instantaneous bandwidth was 1–3 MHz. They often consist of lanes similar to the ones at higher frequencies. The most important feature were fine structure in form of sub-bursts drifting towards lower and higher frequencies. This may mean that electrons were accelerated from the shock front in opposite directions, i.e. they moved towards and outwards the Sun. The observed sub-bursts drift rates were about 1–3 MHz/s, while their duration was 1–2 s.

A Type II burst with a particular herringbone structure was recorded on 7 July 2002 (Figure 5a). Its drift rate was approximately equal to zero, that mean that the shock wave was moving along a constant density region. As it can be seen from Figure 5a, the backbone had a wave-like shape. In our opinion that can happen when a shock wave intersects particular coronal structures. The characteristic parameters of these structures could be estimated by the "amplitude" and the "wavelength" of the backbone trace in the time-frequency plane. A very similar burst was recorded on 17 July 2003 (Figure 5b). Its average drift rate was 25 kHz/s and it also had a wave-like backbone. The sub-bursts drifting towards higher frequencies showed absolute drift rates that were several times higher than those drifting in the opposite direction. They also showed longer lifetime, that

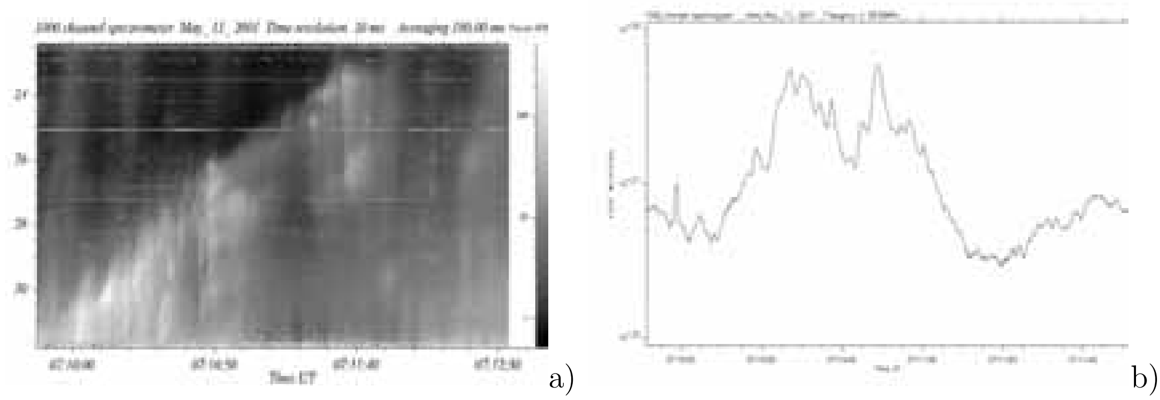


Figure 4: Type II burst: the dynamic spectrum (a) and time profile (b)

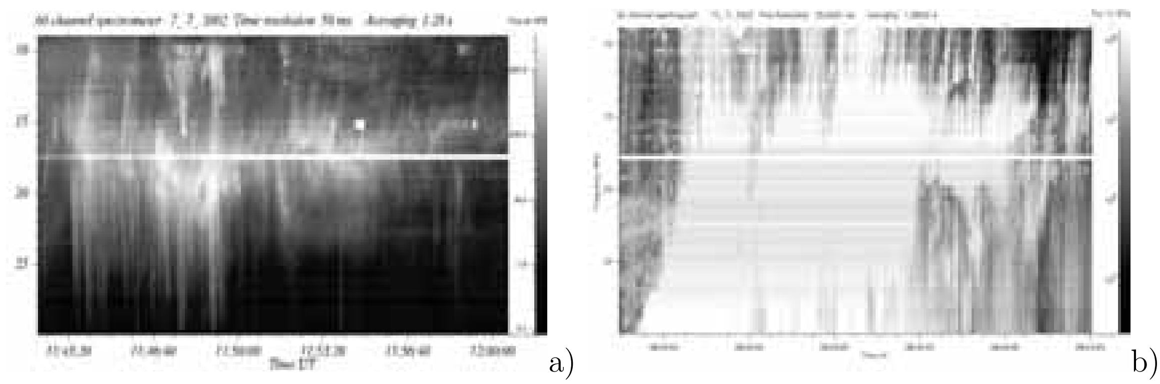


Figure 5: Type II bursts with "herringbone" structure and wave-like "backbone"

may be the result of different conditions for the propagation of the accelerated electrons at both sides of the shock wave.

3.3 The Drift Pair Bursts

This kind of sporadic solar radio emission was observed mostly during Type III storms and very often appeared as a storm of drift pair bursts [Mel'nik et al., 2005]. These events are rare as not every Type III storm was accompanied by them. "Forward" (drifting from higher to lower frequencies) and "reverse" (drifting in opposite direction) drift pairs were recorded. According to our observations [Mel'nik et al., 2005] their number was approximately equal, but their occurrence in the frequency range was different. The forward drift pairs occurred more or less uniformly in the frequency range down to 15 MHz, meanwhile the number of the reverse drift pairs decreased sharply below 25 MHz. Drift pairs normally extend over 3 – 4 MHz. The forward drift pairs show absolute average drift rate of about 0.8 MHz/s and the drift rate distribution was narrow. The reverse pairs in their turn showed a wider drift rate distribution with maximum at approximately 1.6 MHz/s. We should also note that the highest drift rate (more than 10 MHz/s) were detected only for reverse drift pairs. At the same time only the forward bursts were observed with anomalous low drift rates (up to 0.3 MHz/s). The average value of the time delay between the components of the pair was almost equal in all cases: 1.7 s for the forward and 2 s for the reverse drift pairs. The duration of each component was about 1 s for both types of drift pairs. The fluxes of the majority of drift pairs were in the range between 5 and 100 s.f.u. Sometimes we observed also "diffuse" drift pairs with duration 2 s, drift pairs with fine structures in form of clouds or sub-bursts, as well as "hook" bursts, combination of reverse and forward drift pairs, when the end of the first sharply coincided with the beginning of the second.

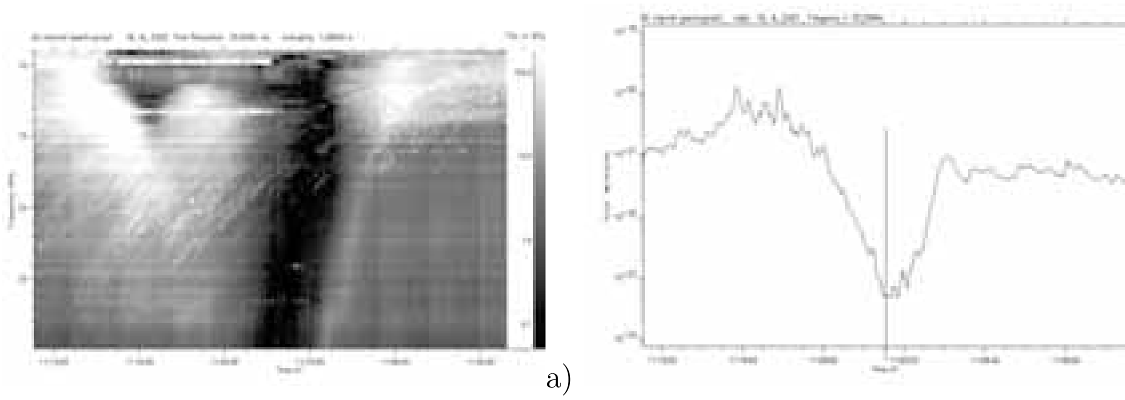
The constant value of the drift rate may be explained by the fact that these bursts are generated by excitation of fast magnetosonic waves having equal phase and group velocities. In this case the Cherenkov resonance condition is satisfied ($v_{ph} = v_{gr}$, where v_{ph} and v_{gr} are phase and group velocities of the fast magnetosonic wave, respectively). On the other hand these waves propagating together with the particle beam at the same speed ($v_{gr} = v_b$, where v_b is the speed of the beam particles) can obtain energy from them for a long period of time. The following interaction of the excited magnetosonic waves with the existing Langmuir waves can give rise to transverse waves, which were recorded as drift pair bursts. The limited frequency band of the drift pairs occurrence and the existence of the bursts with drift of opposite signs may be connected with the coronal plasma inhomogeneities, as was noted in [Zheleznyakov,1965].

3.4 Solar S–bursts

Solar S–bursts, as well as the drift pair bursts, are mostly observed during Type III storms and appear in groups forming a kind of S–burst storms [Dorovsky et al., 2005]. The main properties of these bursts are discussed more in detail in the separate presentation, which is published in these proceedings. Here we would like to note that some of the parameters of the S-bursts are very close to those of the drift pairs. First of all it is the drift rate, which for the S–bursts equals 1 MHz/s. However, if for the drift pairs their drift rate remains constant along a separate burst, for the S–bursts it noticeably decreases with decreasing frequency. Moreover the dependence of the drift rate as function of frequency is very similar to that of the Type III bursts. This apparently indicates that (as for Type III bursts) the dependence of the S–bursts drift rate versus frequency is the manifestation of similar coronal structures, i.e. we can assume that the source of the S–bursts moves through the plasma just as it happens for Type III bursts. S–bursts have negative drift rate and apparently do not form pairs. Their duration in the decameter band (0.3 s) appear to be larger than at frequencies > 40 MHz/s (≈ 0.1 s). This looks natural taking into account that the Type III bursts duration also increases at lower frequencies. The emission mechanism of the S–bursts may be analogous to that of the drift pairs, but it is realized in coronal conditions similar to what happen to Type III bursts.

3.5 Absorption Burst

A number of papers [Kai, 1973, Sastry et al., 1983] reported bursts in absorption on an enhanced continuum. Such absorption events drifted rapidly towards lower frequencies.



a) b)

Figure 6: Absorption bursts: dynamic spectra (a) and time profile at frequency 22.25MHz (b)

Such a phenomenon was called absorption burst or Type III absorption burst [Kai, 1973]. All previous observations were carried out at frequencies > 34 MHz. On 19 August 2003 at $11^h19^m10^s - 11^h25^m00^s$ we have recorded an absorption burst at frequencies lower than < 30 MHz, (Figure 6a) [Konovalenko et al., 2005]. We have observed its evolution in the frequency range 10–30 MHz. This burst drifted with rate of about 120 kHz/s, that corresponded to a linear velocity of more than 2000 km/s. The Type II burst, on the background of which the absorption burst was seen, drifted slower — about 30 kHz/s. Approximately four minutes earlier (from $11^h15^m00^s$ to $11^h18^m20^s$) there was another absorption event at frequencies 10–14 MHz. It was difficult to estimate its drift rate. The time profile of the burst in absorption (Figure 6b) showed that the decay was faster than the recovery phase; the ratio between them was ≈ 1.5.

4 Conclusion

New back-end facilities installed at the world largest decameter radio telescope UTR-2 allowed us to observe for the first time newly discovered phenomena in the frequency range 10–30 MHz, such as: particular Type II bursts, fine structures in Type II and Type III bursts. New information about the properties of Type II and Type III bursts, solar S–bursts, drift pairs and bursts in absorption were obtained too. One should expect that the LOFAR radio telescope, being presently built, would give new information regarding the solar sporadic radio emission.

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