ABSORPTION BURST IN THE SOLAR SPORADIC RADIO EMISSION AT 10–30 MHz FREQUENCIES

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We report the results of UTR-2 radio telescope observations of an absorption burst at the decameter range. This event is associated with two consecutive M-class flares and happened after the second M-flare. The latter flare was accompanied by Type II, Type IV radio sweeps and a CME. The observed bandwidth of the burst is about 20 MHz. The size of the absorption region is compared with the solar radius. The frequency drift rate of the absorption burst is about −0.12 MHz/s. The features of this event are discussed.

INTRODUCTION

The radio emission of solar activity strikes by the variety of its features. Probably, this is connected with different emission processes and physical conditions. Important effects of solar activity are eruptive flares, coronal mass ejections (CMEs), and global coronal waves. Their *in situ* detection is impossible, but the radio emissions carry information on shocks, energetic electrons and their acceleration associated with the solar activity. As is well known, these processes play a major role in the space weather having terrestrial effects. So, CMEs are responsible for geomagnetic storms and disrupting the auroral particle belts. In view of space weather implications, the solar radio bursts have acquired a renewed interest, particularly in combination with observations at various wavelengths.

Among a great number of solar bursts observed there have been reported on the detection of absorption events [1, 4, 5, 11–14]. They are poorly stated in the scientific literature due to their rarity. Absorption features in solar radio spectra were firstly pointed out by Boischot *et al.* [1] based on single-frequency record. Wild *et al.* [14] mentioned also solar radio bursts showing themselves in absorption. To study a fine structure of the Type IV event on February 5, 1965, Malville and Aller [5] noticed an apparent absorption of the background radiation. Kai [4] described the Type II event on August 23–24, 1968, in which an absorption U-fold burst was visible at 80–120 MHz. Sometimes, the observed characteristics of such bursts resemble those of Type III radio bursts. Therefore, Kai [4] called the absorption bursts by "shadow" Type III events. Nevertheless, this similarity is enough illusory and deceptive. Slottje [13] reported sudden reductions in the intensity of a Type IV radiation at frequencies about 250 MHz. The essential difference between the aforesaid observations and the absorption bursts represented by Sastry *et al.* [12] from the observations at 34.15–34.5 MHz was the extremely low level of underlying continuum. The observations were not confined to any particular type of bursts like Type IV, Type III, *etc.* The results of Ramesh and Ebenezer [11] support the contrary point of view. There exists a close temporal association between such absorption events and the corresponding flares accompanied by the onset of a "halo" coronal mass ejection. The authors have concluded that coronal shock waves just give rise to favourable conditions for beginnings of absorption bursts. Besides, it should be recognized that not any shock wave causes the presence of absorption. Thus, the experimental features of the absorption bursts require a more comprehensive study that would be undoubtedly useful in understanding this phenomenon, its mechanism of initiation. Melrose [8, 9] conjectured that the absorption is the inverse of one of the familiar plasma emission processes. However, the experimental results known for such bursts badly fall into a pattern of the plasma theory describing the generation of Type III radio bursts from the Sun.

In this paper, we report a new observation of an absorption burst at decameter wavelengths. The observations have detected first the absorption of sporadic solar radio emission at the upper corona. This did not succeed to realize early. Moreover, the obtained results are really reliable. The capabilities of the UTR-2 telescope permits to discern the quiet-Sun emission, the Galactic background radiation and sporadic features of the solar activity.

OBSERVATIONS

The radio data reported here were obtained on August 19, 2003 with the 60-channel spectrometer operating at the UTR-2 radio observatory near Grakovo ([2] for details on the instrument, and [7] about the spectrometer). The frequency range of these observations was 9–30 MHz. Recall that the plasma levels of 30 and 10 MHz correspond to radial distances 1.78 and 2.94 of the solar radius, respectively, from the center of the Sun.

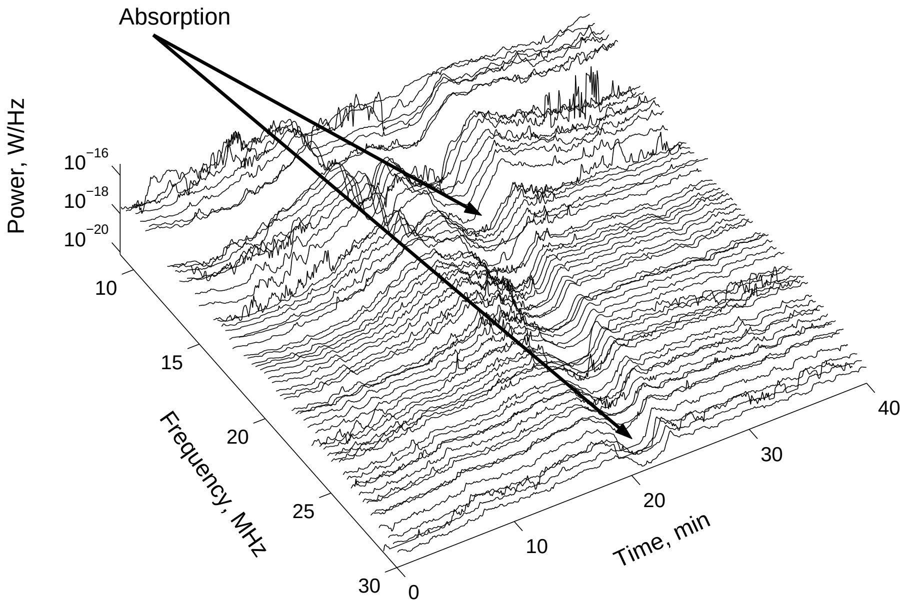

Figure 1. Time profiles of the absorption burst on August 19, 2003. Time zero corresponds to 11:00:40 UT

On this day the solar activity was moderate with observing two M-class flares from Region 431 (S13, $L = 194$) [3]. The first M-flare was impulsive (M2/1n) at 07:59 UT. The second M-flare (M2.7/2f) was at 10:06 UT with associated Type II burst (614 km/s), Type IV radio sweeps and a coronal mass ejection that was not Earth directed. Each of these events was registered in the form of a sporadic decameter radio emission by means of the UTR-2 telescope. Starting from 07:55:37 UT to 07:55:42 UT at 30–10 MHz the solar flux density increases suddenly of 10^4 times with slow relaxing to a lower level. At 08:08:44 UT and 10:01:34 UT the two decameter Type II bursts were observed. Next, about 10:40 UT the solar flux density begins again slowly to increase almost at all frequencies of the observation. Finally, a sudden reduction in intensity was started at 11:20 UT. The absorption event lasted until 11:26 UT. It characterizes by clear negative frequency drift. Figure 1 shows the time profiles obtained with the 60-channel spectrometer in the range from 11:00:40 to 11:40:40 UT.

ANALYSIS AND RESULTS

The drift rate value of the absorption burst equals to –119±8 kHz/s at the frequency range 14–30 MHz. It is four times more than the frequency drift rate associated with Type II burst for which it was about –0.03 MHz/s. This shows that probably the absorber moved quicker than the shock wave generating the Type II burst. Moreover, it follows from the spectrogram that the absorber ran to catch up with the shock wave. It should be noticed that early the drift rate of an absorption burst was mentioned only in [4] (∼ –10 MHz/s at the single frequency 80 MHz). Let us estimate the radial velocity of the absorber traveled into the solar corona. Assume that the bursts were conditioned by the plasma mechanism, *i.e.*, the radio radiation is emitted/absorbed near the local electron plasma frequency. As a density model of the corona, we use a special Parker solution [10]. Mann *et al.* have shown its good agreement with observations for corona heights up to 5 AU [6]. Then the electron number density N_e as a function of the radial distance r is expressed in the form

$$N_e(r) = N_s \exp[A_s(R_s/r - 1)], \tag{1}$$

$A_s = 13.83$, $N_s = 5.14 \cdot 10^9\ \mathrm{cm}^{-3}$, R_s is the solar radius. The frequency drift rate D_f of a burst on a spectrogram is connected with the radial velocity V_r of the corresponding source by the relation

$$D_f = \frac{df}{dt} = \frac{f}{2}\frac{1}{N_e}\frac{dN_e}{dr}V_r, \tag{2}$$

where f is the frequency. Substituting the density model Eq. (1) into Eq. (2), the radial shock speed $\sim$640 km/s is obtained. In this assumptions the absorber advanced with the velocity about 2 550 km/s. What object, absorbing radio emission, can moved in the solar corona with such high velocity? It is not clear.

The maximum of absorption on the time profiles (Fig. 1) corresponds to the most reductions of emission in intensity. In this connection the first crucial question to answer is just connected with the maximum of absorption. How much is the solar radio emission absorbed? For that aim we compare the minimum power of the absorption burst with the emission power of the quiescent Sun. It should be remembered that the quiet-Sun flux varies considerably within a solar cycle. This is understandable, since the eruptive flares and CMEs warm the corona in all times, and their intensity depends on time. According to the solar data, available from NOAA [3], it has been known that on August 18, 2003 the solar activity was at low level. Therefore, for our aims it was chosen the initial period of the observation records on August 19 before the first M-flare at 7:59 UT. We hope that by this time the corona had settled down more or less. The Sun moves $2.5''$ relative to the background sky per minute; the UTR-2 array tracked the Sun, and the array beam covered almost fully the solar corona at the corresponding plasma frequency. Strictly speaking, the emission contains not only the proper emission of the quiescent Sun, but also the Galactic background emission. The two parts were not separated specially. Nevertheless, their ratio may be estimated.

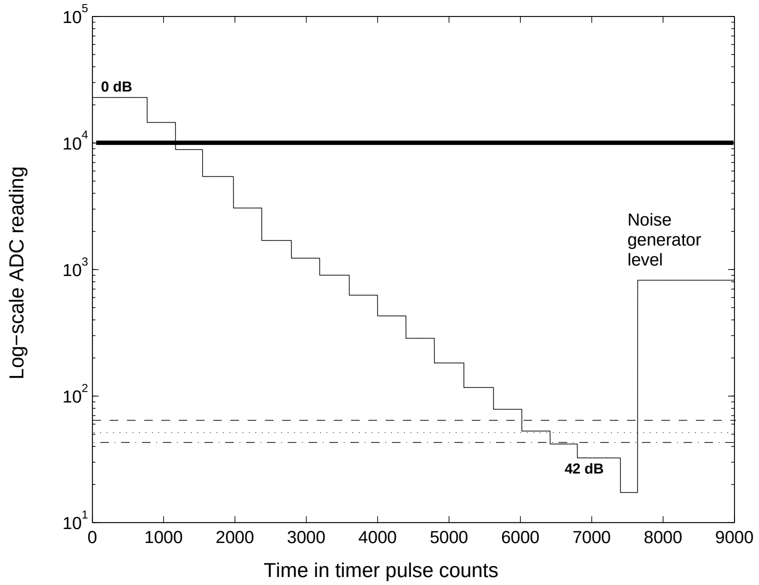

Figure 2. Curve for calibrating a power scale in the radio observational data on August 19, 2003 at 25 MHz. The dashed line corresponds to the absorption burst emission in minimum, the dotted line shows the sum level of the quiet-Sun emission and the background emission, the dash-dotted line notices only the background emission level. The black heavy line is the largest value of sporadic radio emission at 11:16:15 UT. ADC means an analog-to-digital converter

As a concrete example, we consider the observations of the absorption burst at 25 MHz. In this case the absorption burst minimum in spectral power is $3.6\cdot10^{-20}$ W/Hz, the galactic background plus the quiescent-Sun level is $2.7\cdot10^{-20}$ W/Hz, the proper galactic background level is $2.0\cdot10^{-20}$ W/Hz. These power levels are represented in Fig. 2, where for the convenience they are plotted on the calibration curve. In particular, the quiet-Sun flux of 10^3 Jy is assumed as typical for the solar emission at 25 MHz, then the galactic background has the temperature 26 400 K. In this figure it is clearly seen that all these levels lie within the limits of the calibration curve, and thus their accuracy of measurement is beyond doubt. The calibration scale covers 42 dB with the step of 4 dB from 0 dB to 20 dB, and next with the 2 dB step up to 42 dB. The minimum of the absorption burst corresponds to 36.9 dB according to this scale, whereas the galactic background together with the quiescent-Sun emission and the only galactic background had 38.1 dB and 39.6 dB, respectively. The similar situation takes place for other observation frequencies. It should be emphasized that formerly such detailed analysis of the emission components received by radio astronomical instruments for absorption events was not carried out.

For the sake of simplicity hereinafter the sum of the galactic background and the quiescent-Sun emission will be called simply by the background emission. The results of the frequency comparison of the minimum power of the absorption burst with the power of the background emission derived from the Sun clearly shows that the most reductions of emission reached background levels on the corresponding frequencies, but they did not fall down lower. The correlation coefficient between the background emission levels and the minima of the absorption burst tends to 0.95, and their spectral index comes to -1.93 ± 0.1. The latter is found in a good agreement with the solar measurements fulfilled early by means of the UTR-2 telescope.

All this allows us to define the absorbing region size. As the almost full absorption was observed, the cross-section of the region must be certainly more than the source size of the Type II burst at 11:20 UT. Though the solar radiogeliograph did not take part in our observations, it has been known that, for example, at 80 MHz the source size of Type II bursts comes to $12'\times7'$ [4]. At decameter wavelengths it will be still more. The simultaneous frequency band of the absorption burst exceeds 20 MHz that speaks about the longitudinal size of the absorber. It was more than one solar radius. The absorbing region must be optically thick for the radiation before absorption to be absorbed significantly.

SUMMARY

We observed a transient reduction of solar sporadic radio emission at decameter wavelengths on August 19, 2003. The observations have been stated that during the absorption the sporadic radio emission decreased almost to a background emission level. The drift rate value of the absorption burst is more than the drift rate of Type II solar bursts, but considerably less than one for Type III bursts at the same frequencies. The geometric size of the absorber is comparable with the solar size. A more detailed analysis of this event will be carried out elsewhere.

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