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A Study of Eruptive Solar Events with Negative Radio Bursts

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Abstract—Solar events of June 15/16, 2000, June 1/2, 2002, February 6, 2002, and February 7, 2002, have been studied. These events probably belong to a poorly studied class of explosive eruptions. In such events disintegration of the magnetic structure of an eruptive filament and dispersing of its fragments as a cloud over a considerable part of the solar surface are possible. The analysis of SOHO/EIT extreme ultraviolet images obtained in the 195 Å and 304 Å channels has revealed the appearance of dimmings of various shapes and propagation of a coronal wave for June 1/2, 2002. In all the events the Nobeyama, Learmonth, and Ussuriysk observatories recorded negative radio bursts at several frequencies in the 1–10 GHz range. Most likely, these bursts were due to absorption of solar radio emission in clouds produced by fragments of filaments. Absorption of the solar background radiation can be observed as a depression of the emission in the 304 Å channel. A model has been developed, which permits one to estimate parameters of absorbing plasma such as temperature, optical thickness, area of the absorbing cloud, and its height above the chromosphere from the radio absorption observed at several frequencies. The obtained values of the temperature, 8000–9000 K, demonstrate that the absorber was the material of an erupted cool filament. The model estimate of the masses of the ejecta in the considered events were $\sim 10^{15}$ g, which is comparable to masses of typical filaments and coronal mass ejections.

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1. INTRODUCTION

Negative radio bursts in the microwave range are rather infrequent phenomena. It is supposed that they are related to eruptive events on the solar disk and can bear information on parameters of the eruption. One of probable causes of negative bursts is a temporary occultation of a radio source by an absorbing screen. This explanation of a negative burst observed on May 19, 1951, was proposed by Covington and Dodson [1]. Observations of negative bursts, their interpretation, and relation to optical observations in the Hα line were summarized in paper [2], where it was noted that the concept of a cool screen could apply to the absorption both in the Hα line and in microwaves.

Coronal dimmings, i.e.,regions of reduced brightness in the extreme ultraviolet and soft X-ray emissions, are also associated with eruptive events. After their appearance, long-lived quasi-stationary dimmings expand a little, their depth increases and then slowly decreases on a time span of hours or days [3, 4]. The main interpretation of such dimmings is the depletion of the corona as a result of eruption of a magnetic structure [5].

In addition to quasi-stationary dimmings, short-lived migrating darkenings are observed on the solar surface. Some of them can be due to occultation of bright coronal structures by the absorbing material of eruptions [6]. Dimmings are usually observed in images obtained by ultraviolet telescopes on the SOHO and TRACE spacecraft in several channels (FeIX/X 171 Å, FeXII 195 Å, FeXV 284 Å, HeII 304 Å). In different extreme ultraviolet lines the form and position of such dimmings can be different.

Before developing dimmings or irrespective of them, disturbances in the form of a bright expanding diffuse (seldom sharp) front having a ringlike or a more complicated form and propagating from the eruption center at a velocity of several hundreds of kilometers per second are frequently observed [7]. Such disturbances observed in the 171, 195, and

284 Å channels, and sometimes also in soft X-rays [8] are called "EIT waves".

Eruptive events are often accompanied by coronal mass ejections (CMEs) and type II and IV radio bursts in the metric and decimetric ranges [9]. If a CME is obviously associated with the eruption of a filament, the eruptive filament or its remnants are frequently observed in white light images as a CME's bright core. However, the filament is not always erupted, and after the ascent to some height it can return back to the Sun [10]. Such returning ejecta (returning prominences) are also called quasi-eruptive, or it is spoken not about eruption of a filament but its activation [9].

Observations in the Hα line with a high spatial resolution permitting one to trace the motion of an eruptive filament are not always available. In such cases it is possible to find out, whether the event was eruptive using observations in the soft X-ray and extreme- ultraviolet emissions. In [11] the connection between disappearing filaments (disparition brusques) and coronal activity was studied, and characteristics of eruptive and quasi-eruptive events were revieved. The conclusion was drawn that the events with eruption of filaments are associated with two-ribbon flares in the Hα line and are characterized by formation of arcades and (or) dimmings in the extreme ultraviolet and soft X-ray ranges. This suggests a large-scale restructuring of the coronal magnetic field. The events with quasi-eruptive filaments are related to compact flares in the Hα line and are accompanied by local changes in the soft X-ray and extreme ultraviolet ranges without any signs of opening of the coronal magnetic field (see also [12]). The local changes are visible as a compact flare or bright loop; weak brightenings along the filament channel can also be observed at 195 Å.

To reconstruct an authentic picture of eruptive events it is necessary to use observations in different spectral ranges. A detailed analysis of the eruptive event of July 13, 2004, for which an exhaustive set of experimental data was available, has revealed a picture of an explosive eruption of a compact filament in an active region, which resulted in the destruction of the magnetic structure of the filament and dispersing of its fragments as a cloud over a huge area on the solar surface [13]. Accordingly, a CME in this event did not have a three-component structure. The well-known event of April 29, 1998, probably had the same character [14] (a negative radio burst and a large-scale darkening in the SOHO/EIT 304 Å channel was also observed in that event) as well as the event of November 18, 2003 (in which a moving large-scale darkening was detected in the 304 Å channel of the CORONAS-F/SPIRIT telescope) [4, 15]. For these two events we do not have high-quality multifrequency records of radio bursts, which would allow us to estimate parameters of the eruptions from radio absorption.

In this paper we examine four events with negative microwave bursts categorized as a "post-burst decrease." Negative bursts were revealed from total flux records of the Ussuriysk Astrophysical Observatory at a frequency 2.804 GHz. Images available for these events do not allow us to establish unambiguously whether we deal with quasi-eruptions or explosive eruptions of filaments. However, we have radio data that offer an opportunity of the multifrequency analysis of radio absorption and model calculations. In Section 2 we analyze observations of the events in different spectral ranges. In Section 3 we briefly address a model used to estimate parameters of absorbing plasma and masses of ejecta. Section 4 is dedicated to the discussion of the analysis of observations and obtained results.

2. ANALYSIS OF THE OBSERVATIONS

2.1. Event of June 15/16, 2000

The event occurred in active region NOAA 9040 (N19 E17) of magnetic class β. It was associated with an Hα flare of importance 1N (maximum at 23:42 UT) according to the Solar-Geophysical Data bulletin (SGD, http:// sgd.ngdc.noaa.gov/sgd/jsp/solarindex.jsp) and with a soft X-ray flare of M2.0 importance according to the GOES classification. Several stations recorded type II and III radio bursts in the decimetric and metric ranges. A CME with a central position angle of 42° corresponding to the position of the active region on the solar disk is listed in the SOHO/LASCO catalog.

For the analysis of observations in the extreme ultraviolet we have used SOHO/EIT images in the channels 195 Å (intervals between images 12 min) and 304 Å (intervals 6 h). The source files in the FITS format were taken from the EIT catalog (http://umbra.nascom.nasa.gov/eit/eit-catalog.html). Figure 1 presents fixed-difference images of the northeast quadrant of the solar disk in the 195 Å channel with restricting pixel values by ±300 counts/pixel and of the entire solar disk in the 304 Å channel with restricting pixel values by ±20 counts/pixel as well as the CME image obtained at 00:50 UT by SOHO/LASCO/C2. The difference images have been obtained by subtracting the frame taken before the event from all subsequent frames; before it compensation of the solar rotation has been done. In AR 9040 of our interest flare brightenings and dimmings 1 and 2 (Fig. 1b, 1c) were observed. The dimmings

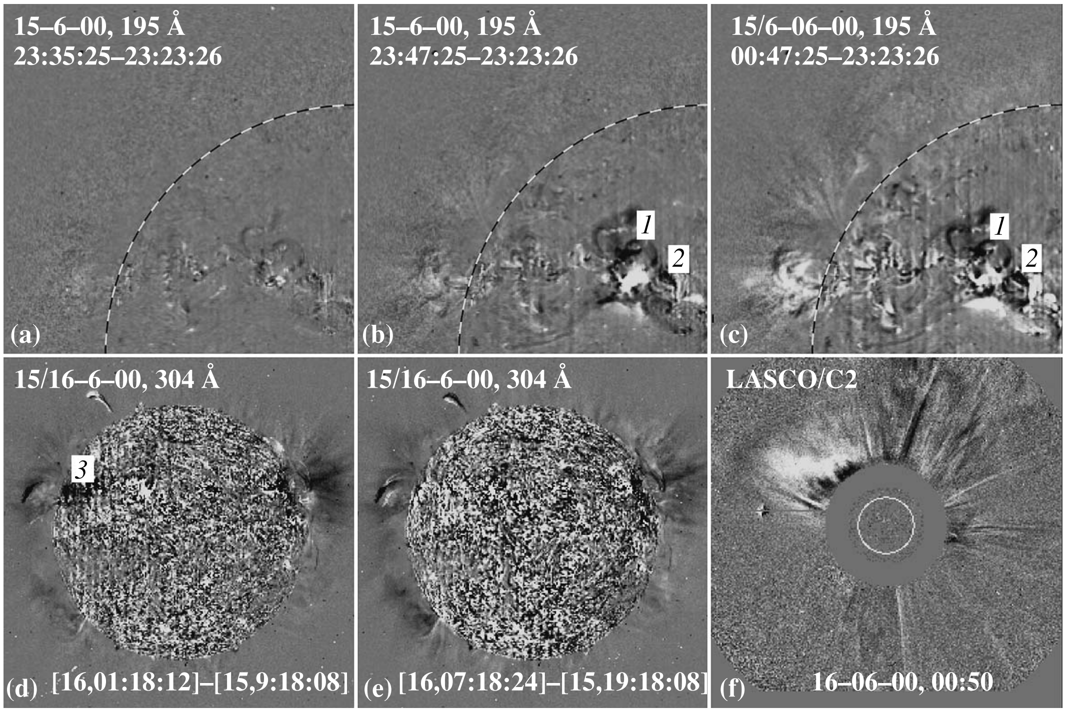

Fig. 1. Event of June 15/16, 2000. Solar-rotation-compensated fixed difference images ofthe northeast quadrant of the solar disk in the 195 Å channel (a–c) and of the entire solar disk in the 304 Å channel (d, e) according to SOHO/EIT data (the dashed circle shows the solar limb); (f) CME in the SOHO/LASCO difference image for the event of June 15/16, 2000. The gray disk is the occultor of the coronagraph; the white circle shows the white-light solar disk.

exist also after 01:30 UT, though they considerably decrease their sizes. Darkening 3 in frame "d" of Fig. 1, which is located eastward of AR 9040, can be due to absorption of the background emission by the erupted material.

For the analysis of the integrated radio emission at different frequencies we have used the data from the Ussuriysk Astrophysical Observatory, Nobeyama Radio Observatory, and Hiraiso Solar Observatory. Processing of calibrated flux records included subtraction of the pre-burst radio emission level, normalization of the obtained values to the level of the quiet Sun, and smoothing of the time profiles over 200–300 s. A negative radio burst was observed after an impulsive burst at frequencies ≤ 9.4 GHz (Fig. 2a). Its duration was minimum at 9.4 GHz and increased toward lower frequencies. One can distinguish at all frequencies two maxima of absorption at 00:01 and 00:10 UT. The depth of the depression was maximum at 00:10 UT at 1.0 GHz, 19%.

The cause of negative bursts in the microwave range can be absorption in the ejected material of the emission of the quiet Sun and of the radio sources located above the active region 9040 and eastward of it (judging from the position of the darkening in Fig. 1d). The fluxes of these sources estimated from solar images obtained at 17 GHz on the radioheliograph of the Nobeyama Observatory (http:// solar.nro.nao.ac.jp/norh/images/10min/) were in total 7–10 sfu.

Thus, the event of June 15/16, 2000 was associated with a CME and a negative radio burst in the microwave range. The analysis of the observations in the extreme ultraviolet has revealed the appearance of dimmings; this can be related to the eruption of a filament [11]. Thus, the observational data confirm the supposition about the eruptive character of this event.

2.2. Event of June 1/2, 2002

The event of June 1/2, 2002 took place in active region NOAA 9973 (coordinates S16 E20) of class β/γ in the magnetic classification. It was associated with an eruptive Hα flare of importance 1F (maximum at 23:50 UT) according to the SGD data and with a flare of importance C5.1 in soft X-rays according to the GOES data. Type II and III radio bursts were recorded by several stations.

Figure 3a shows a close-up image of the vicinity of the active region in Hα obtained in the Big Bear Solar Observatory on June 1, 2002, at 20:00 UT. In active region there are some filaments, the largest of them is filament 1. In this active region, before the considered event (June 1, 2002, 03:50 UT [16]) and

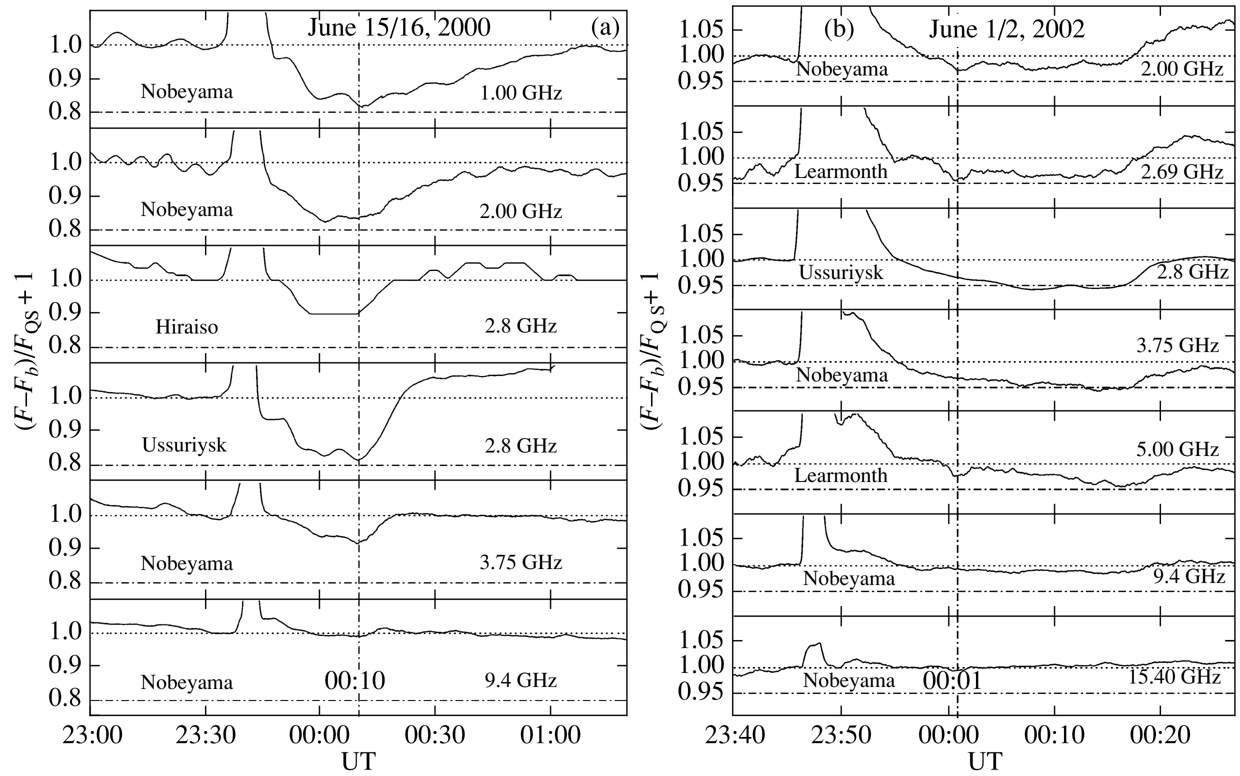

Fig. 2. Time profiles of the radio emission (normalized to the quiet Sun level) at different frequencies for the events of June 15/16, 2000 (a), and June 1/2, 2002 (b).

after it (June 2, 2002, 11:47 UT [16, 17]), there were homologous eruptive events observed in the Hα line and extreme ultraviolet; their duration did not exceed 10 min. In each of these events, very similar eruptions of dark filaments and bright magnetic ropes inside a dome-haped magnetic structure with a coronal zero point at its top, which resulted in the appearance of surges, were observed in the 195 Å channel [16].

The image analysis in the extreme ultraviolet was conducted in two SOHO/EIT channels. Figures 3b and 3c present fixed-difference images with compensation of the solar rotation in the 304 Å channel with a 6-h interval. These images demonstrate the appearance and expansion of a dark structure 2 above the southeast part of the limb. Its appearance can be interpreted as a brightness decrease in this region because of the plasma density depletion due to an eruption.

Figures 3d–3f present running-difference images of the southeast quadrant of the solar disk in the 195 Å channel with restricting pixel values by ±10 counts/pixel, which demonstrate changes in the brightness, position, and shape of the observed structures between two consecutive frames. In frames "e" and "f" of Fig. 3 the appearance and expansion of dimmings 3–4 at two sides from the eruptive center as well as a front of a coronal wave propagating above the southeast limb (indicated by the arrows) are visible. Dimmings and coronal waves evidence large-scale disturbances of coronal magnetic fields that are usually associated with a CME. However, no data about a probable CME are available, because SOHO/LASCO did not operate in this time interval, and the observations with the Mark4 coronagraph in the Mauna Loa Observatory had been terminated before the event occurrence.

In the radio range at a number of frequencies negative radio bursts were recorded. For the analysis of the total radio flux we have used the data from the Nobeyama, Learmonth, and Ussuriysk observatories. We have subtracted pre-burst levels of the radio emission from calibrated flux records at all frequencies and smoothed over 100 points the time profiles recorded with a 1-s sampling. Figure 2b presents the total flux time profiles at different frequencies normalized to the quiet Sun's levels. The negative radio burst was observed at frequencies $\leq$9.4 GHz. The burst duration was minimum at 9.4 GHz; it increased up to a frequency of 2.8 GHz, and then decreased again. At frequencies 2.8–5.0 GHz the absorption depth was approximately the same, about 5–6%; at other frequencies it was somewhat less.

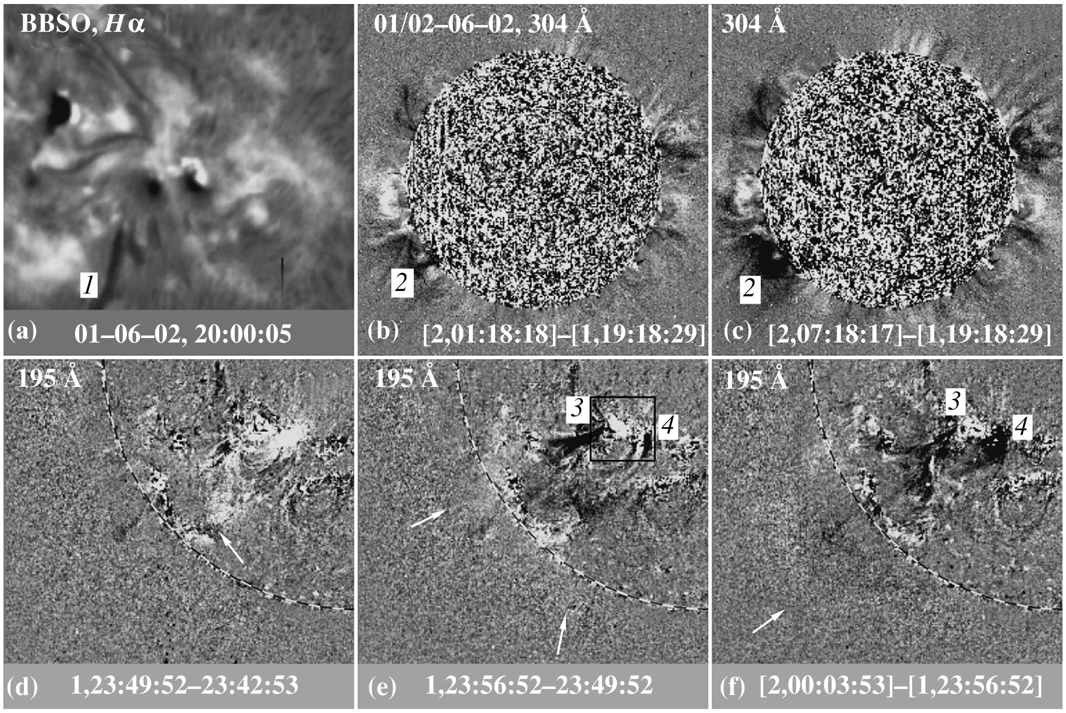

Fig. 3. Event of June 1/2, 2002. (a) A vicinity of AR 9973 visible in the BBSO Hα image; the frame in image (e) shows its location; (b, c) solar-rotation-compensated difference images of the Sun in the 304 Å channel; (d–f) running-difference SOHO/EIT images of the southeast quadrant of the solar disk in the 195 Å channel for the event of June 1/2, 2002. The dashed circle: solar limb; the arrows: the "EIT wave" front.

Using solar images from the Nobeyama Radioheliograph, the flux of a thermal radio source located above an active region was found to remain almost invariable during the event. This suggests the absence of a substantial occultation of this radio source by the ejected material. Judging from the observations in the extreme ultraviolet, the ejected material moved in the plane of the sky toward the limb, screening the radio emission from quiet solar regions.

The dimmings and the coronal wave observed during the June 2, 2002 event in the extreme ultraviolet, the negative burst in the microwave range, as well as the striking similarity of a number of manifestations in homologous eruptive events observed in the same active region before and after the June 2, 2002 event suggest its eruptive character.

2.3. *Events of February 6 and 7, 2002*

The events of February 6, 2002 (coordinates S12 W60) and February 7, 2002 (S11 W72) occurred in the same active region NOAA 9816, magnetic class β. Several observatories recorded type III radio bursts in both events and also a type II radio burst in the event of February 6.

The event of February 6, 2002, was associated with an eruptive Hα flare of importance 1N (maximum at 04:40 UT, SGD data) and with a flare of importance C8.2 in soft X-rays (GOES data). Figure 4a shows the vicinity of the active region in the Hα line before the event (Big Bear Solar Observatory). Near the active region there were two large filaments 1 and 2. Smaller filaments within the active region were less visible because of its proximity to the limb. For this event we have no solar images either in the Hα line or extreme ultraviolet emission lines; hence we cannot confirm the association of the event with eruption of a filament. However, in the report of the Learmonth Observatory about this flare its eruptive character is indicated (SGD).

In the event of February 7, 2002, there was an eruptive Hα flare of importance SF with a maximum at 00:56 UT (SGD) and a flare of importance C4.1 in soft X-rays (GOES). For the analysis of the event in the extreme ultraviolet we have used SOHO/EIT data in the 195 and 304 Å channels. Figures 4b–f present fixed-difference images in these channels with the compensation of the solar rotation; pixel values are restricted by ±50 counts/pixels. In frame "b" of Fig. 4 a small brightening in active region 9816 is visible. It is also notable that a dimming above it is deeper and more pronounced as compared to frame

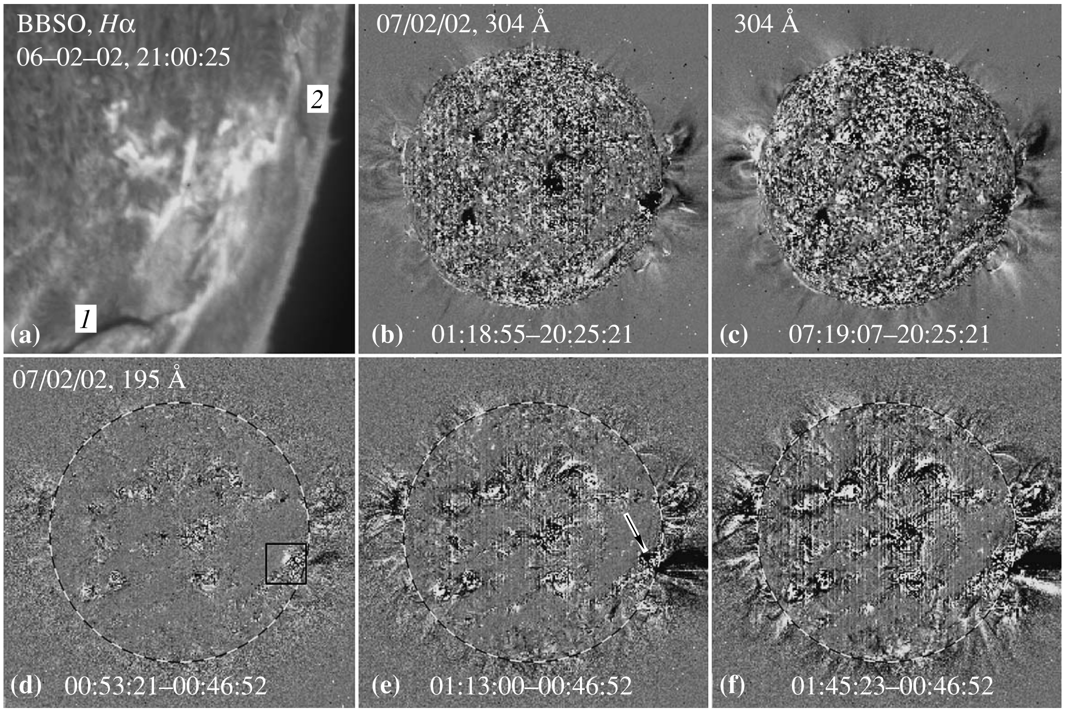

Fig. 4. Events of February 6 and 7, 2002. (a) A vicinity of AR 9816 visible in the BBSO Hα image; the frame in image (d) shows its location; (b–c) fixed-difference images of the Sun in the 304 Å channel; (d–f) solar rotation-compensated fixed-difference SOHO/EIT images of the southeast quadrant of the solar disk in the 195 Å channel for the event of February 7, 2002. The dashed circle: solar limb; the arrow in frame (e): short-lived dimming above the active region.

"c," but the 6-h interval between the frames does not allow us to trace its development.

A sequence of images in Figs. 4d–4f demonstrates initially the appearance of brightenings, and then the development of a small dimming above the active region (indicated with the arrow in frame "e") as well as the expansion of a dark feature and the appearance of a bright structure (probably, a jet) above the limb. The appearance of a short-lived dimming could be caused by temporary absorption of the emission from a part of the solar surface by the erupted material which covered it; the dimming at the limb could be due to the brightness decrease because of plasma density depletion as a result of the eruption.

From February 5 to 10, 2002, there were no observations with SOHO/LASCO coronagraphs; therefore, in the events of February 6 and 7 no CMEs could be recorded. Before 14:30 UT February 6 there were neither SOHO/EIT observations. Observations with the Mark4 coronagraph in the Mauna Loa Observatory had been terminated at about 23 UT, before the onset of the event.

For the analysis of the total radio flux at different frequencies we have used the data from the Nobeyama and Ussuriysk observatories. The calibrated flux records were processed in the same way as done for the event of June 1/2, 2002. Figure 5 shows the total flux time profiles recorded in the two events at different frequencies and normalized to the quiet Sun's levels. The negative radio burst of February 6, 2002 was recorded at frequencies $\leq$9.4 GHz, and that of February 7, 2002 at frequencies $\leq$3.75 GHz. In both events the maximum depth of the absorption was 10%. The radio flux from a thermal radio source above an active region estimated from 17 GHz solar images did not exceed 6 sfu. The material of the ejection could absorb solar radio emissions; this was the cause of the negative bursts at a number of frequencies in the microwave range.

Both events were associated with small eruptive flares. In the event of February 6, 2002, a type II burst, probable evidence of a shock wave, was recorded; this indirectly confirms the possibility of an energetic eruption of explosive character. In the event of February 7, 2002, in the extreme ultraviolet a vast dimming and a jet above the limb (both testifying to a CME) were observed as well as short-term local brightenings, and a short-lived dimming probably caused by the absorption that produced also the negative radio burst. These facts suggest that both events, February 6 and 7, 2002, were most likely related to explosive eruptions of filaments; however, we cannot rule out the possibility that these events could be quasi-

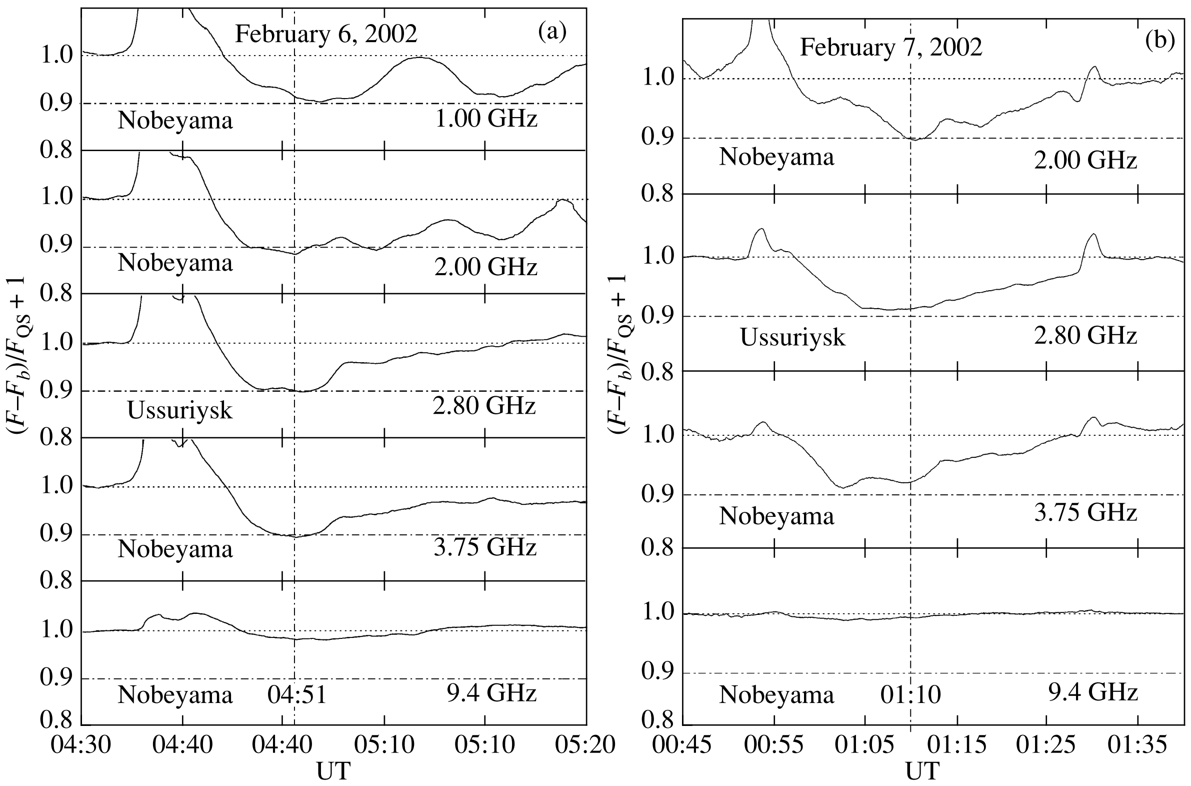

Fig. 5. Time profiles of the radio emission (normalized to the quiet Sun level) at different frequencies for the events of February 6, 2002 (a) and February 7, 2002 (b).

eruptive. In this case the absorption could be caused by surges.

3. ESTIMATES OF PARAMETERS AND MASS OF OUTFLOWS

Our analysis has shown that all considered events were related to eruptions of filaments in active regions. This fact confirms the possibility of the appearance of a negative radio burst due to shielding of solar radio emission by the material of the eruption, though it does not warrant it. Assuming that a negative burst is caused by absorption, let us attempt to estimate characteristics of the ejected material in each of these events from the spectrum of radio absorption using a model we have developed [13].

The model (Fig. 6) consists of (1) the chromosphere, (2) a screen placed in the corona, with area A_S, kinetic temperature T_S, and optical thickness τ_S at height z above the chromosphere, (3) a coronal layer with optical thickness τ_1 between the chromosphere and screen, (4) a coronal layer with optical depth τ_2 between the screen and observer. The temperature of the corona $T_C = 1.5 \times 10^6$ K, and that of the chromosphere $T_{Chr} = 10^4$ K. Then the ratio of the total flux of a negative burst to the total flux of the quiet Sun is

$$\frac{F}{F_{QS}} = \frac{T^B_{QS}(A - A_S) + T^B_S A_S}{T^B_{QS} A}. \qquad (1)$$

Here F_{QS} is the total radio flux of the quiet Sun, T^B_{QS} and T^B_S are the brightness temperatures of the quiet Sun and occulting screen, A and A_S are the areas of the solar disk and the screen. The brightness temperature of the screen is

$$T^B_S = T_{Chr} e^{-(\tau_1 + \tau_S + \tau_2)} + T_C e^{-(\tau_S + \tau_2)}(1 - e^{-\tau_1}) + T_S e^{-\tau_2}(1 - e^{-\tau_S}) + T_C(1 - e^{-\tau_2}),$$

where $\tau_2 = \tau_C \exp(-2z/H)$, H is the scale height (for the corona $H = 8.4 \times 10^9$ cm), $\tau_1 = \tau_C - \tau_2$, and τ_C is calculated from the formula $T^B_{QS} \approx T_{Chr} + T_C \tau_C$.

The frequency dependences of the brightness temperature of the quiet Sun T^B_{QS} and radio radius have been taken from [18]. For the model to be self-consistent, we have used in the calculations the values of the brightness temperatures and radio radii, and the fluxes were calculated from them. Parameters A_S/A, T_S, $\tau_{S(17\,\mathrm{GHz})}$, and z were chosen to fit the curve calculated with formula (1) to the observed depths of the radio absorption.

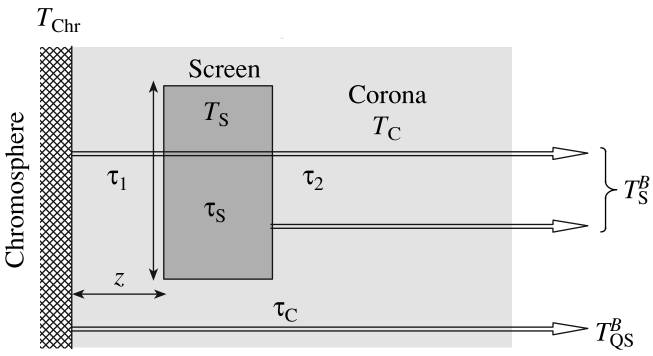

Fig. 6. Model for the estimation of parameters of the screen occulting a region of the quiet Sun.

Screening is possible not only of a part of the quiet Sun but also of compact bright sources. In this case the thickness of the compact source is also important, and expression (1) becomes cumbersome. For simplification we use a virtual temperature calculated from its measured total flux as the temperature of a uniform source with an area equal to the area of the screen. In the model we take into account occultation of a source radiating thermal bremsstrahlung. Its flux in the optically thin region of the spectrum can be measured using images from the Nobeyama Radioheliograph (17 GHz). In our modeling we vary the optically thin and thick components of the thermal source emission.

The relative depths of the absorption during the maximum depression measured at different frequencies from Figs. 2 and 5 for all events were renormalized to the sum of radio fluxes from the quiet Sun and occulted compact radio source. Figure 7 shows these values with asterisks along the results of the model fit represented by the solid curve. The calculated curves for the studied events have been obtained with the parameters of the absorbing material listed in the table. The average electron density n_e and mass of the absorbing material m can be found using the expressions

$$\tau = \frac{0.2n_e^2 L}{\nu^2 T^{3/2}}, \quad m = m_{\rm p} n_e A_{\rm S} L,$$

where ν is the radio frequency, L is the geometrical thickness of the absorber, and $m_{\rm p}$ is the mass of proton. The observational data do not allow us to determine the shape of an absorbing cloud in any of the events; as the first approximation we can accept that its geometrical thickness $L = \sqrt{A_{\rm S}}$. Densities of particles (n_e) and masses of ejections (m) estimated for the studied events are also listed in the table.

For comparison, the estimated CME mass given in the SOHO/LASCO catalog for the event of June 15/16, 2000, is 6.3×10^{14} g. The geometrical thickness can be significantly less if the cloud is a thin layer; therefore, the obtained values of the mass in the considered events are maximum estimates; however, the dependence of the mass on the geometrical thickness is rather weak (as $\sqrt{L}$).

4. DISCUSSION AND CONCLUSION

The conducted analysis has shown that all considered events were related to eruptions of filaments from active regions and to flares in the Hα line and soft X-rays. In three of the four events type II radio bursts were observed, which are attributed to shock waves in the corona. No type II burst was recorded in the event of February 7, 2002; however, note that at the time when it could be observed there were interruptions in observations at the Learmonth Observatory (with 00:54 to 01:29 UT) as well as at fixed frequencies (200, 500 MHz, and 2.8 GHz) at the Hiraiso Observatory (from 00 to 01 UT), and the sensitivity of the Hiraiso spectrograph could be insufficient for the detection of this faint burst.

In the event of June 15/16, 2000, a CME was observed; the remaining three events occurred when observations on SOHO/LASCO and Mark4 (MLSO) coronagraphs lacked. However, evidence of CME, i.e., dimmings or coronal waves, were present in all events except for the event of February 6, 2002, for which we no images are available in the Hα line, in the extreme ultraviolet, or in the white light from coronagraphs. Even with the incomplete information on the considered events the presence of a type II radio burst and (or) large-scale disturbances observed in the extreme ultraviolet (or both) indicates that CMEs most likely occurred in each of these events.

The most probable cause of the microwave depression is shielding of the solar radio emission coming from below by a moving cloud of absorbing cool material. The appearance of a negative burst owing to a decrease in the emission of the radio source due to other causes in the considered events seems unlikely. The conformity of the spectrum of depression

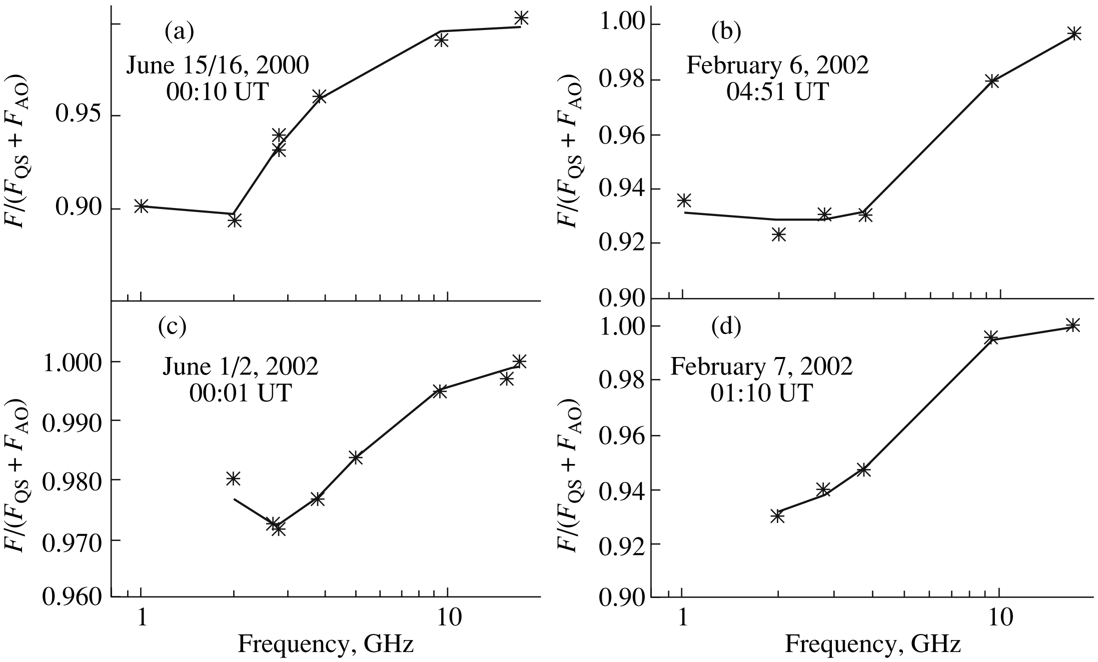

Fig. 7. Spectra of the microwave absorption depth in the events of June 15/16, 2000 (a), February 6, 2002 (b), June 1/2, 2002 (c), and February 7, 2002 (d). The absorption depths have been normalized to the sum of the fluxes from the quiet Sun and radio source. Asterisks: measured values; solid curve: model fit.

in negative bursts to the expected spectrum of the absorption depth (Fig. 7) does not leave a possibility of an alternative interpretation.

The obtained estimates of temperatures (8000–11 000 K) demonstrate that in all events the absorber could be the material of erupted filaments. The areas of the absorbing clouds (2–6% of the solar disk area) are sufficient for shielding both the bright radio source and regions of the quiet Sun. In [2] estimated parameters of the microwave screen occulting a local radio source are reviewed: $\tau_{2.8\,\mathrm{GHz}} = 5$, $\tau_{\mathrm{H}\alpha} = 6 \times 10^{-4}$, $n_e = 1.3 \times 10^8$ cm^{-3}, screen area $\sim 10^4$ Mm^2 ($\sim$1% of the solar disk area), its thickness $\sim$100 Mm, and height from 20 to 200 Mm. The characteristics of the absorbing screen obtained in our study (table) have the same order of magnitude, and the scatter of the values probably reflects the individuality of each event.

The absorption of the extreme ultraviolet radiation in the cool material of the ejection can be considered by analogy with its absorption in filaments and prominences (see, e.g., [19, 20]). One of the causes is photoionization of hydrogen ($\lambda < 912$ Å), neutral helium ($\lambda < 504$ Å), and ionized helium ($\lambda < 228$ Å). For a cloud consisting of 92% of hydrogen and 8/for the emission at 195 Å is $\sigma_{195} \approx 7 \times 10^{-20}$ cm^2, which is by an order of magnitude less than at 304 Å ($\sigma_{304} \approx 5.5 \times 10^{-19}$ cm^2) [13, 19]. The darkening in coronal lines can also be due to the absence of coronal emission from the cloud volume (volume blocking effect). This effect depends on the height and line-of-sight extent of the cloud in comparison with the scale height at the given wavelength ($\sim$70 Mm for 195 Å).

In the 304 Å channel (the temperature sensitivity maximum is 80 000 K), the emission of the HeII line dominates and a small contribution from SiXI and MgVIII coronal is present in the 0.8–3 MK range. As stated in [6], darkenings at 304 Å are caused by absorption of the emission from the solar surface by the material of an eruptive filament and can be completely different from dimmings observed in coronal channels, in particular, not to coincide with them positionally. The absorption at 304 Å can be expected even when the absorbing layer is located below coronal loops radiating at 195 Å. In this case the absorption in the 195 Å channel is not observed, and at 304 Å it will take place as long as the absorbing layer is above the transition region.

The absorption of the emission in the 304 Å channel can be a consequence of photoionization of hydrogen and neutral HeI at low temperatures of the absorbing gas (of the order of 10 000 K or below) or resonant absorption (scattering) in helium if the gas temperature is in the range of excitation of the HeII line (20 000–80 000 K). The decrease in brightness due to the resonant scattering cannot be more than twofold [13]; furthermore, estimates demonstrate that

Parameters of the absorbing cloud estimated in the framework of the model

Event	T_S, K	$\tau_{17\,\mathrm{GHz}}$	$\tau_{2.8\,\mathrm{GHz}}$	A_S/A	z, Mm	L, Mm	n_e, cm^{-3}	m, g
June 15/16, 2000								
00:01	10 000	0.025	0.96	0.033	80	220	0.35×10^8	6.4×10^{14}
00:10	9000	0.025	0.96	0.06	20	300	0.28×10^8	1.3×10^{15}
June 1/2, 2002								
00:01	8000	0.2	7.4	0.022	40	180	0.92×10^8	9.4×10^{14}
00:11	8000	0.28	10.3	0.02	60	170	1.1×10^8	9.8×10^{14}
February 6, 2002	9000	0.3	11.1	0.035	50	230	1.1×10^8	2.2×10^{15}
February 7, 2002	11 000	0.07	2.6	0.038	80	240	0.6×10^8	1.4×10^{15}

the temperature of the material in the absorbing cloud is much lower than the temperature of excitation of the HeII line; therefore, in the considered cases the dominating mechanism of absorption should be photoionization by the continuum.

Explosive eruptions of filaments have been poorly studied for obvious reasons. The material scattered over a large area quickly becomes invisible in the Hα line because of loss of the optical depth and displacement of the absorption line from the filter passband due to the Doppler effect at considerable line-of-sight velocities. As a rule, 304 Å images are obtained with an interval of 6 h (or even 12 h); therefore, the probability of observing such phenomena is small.

In the considered event of June 15/16, 2000, a dimming observed in the 304 Å channel had an area of about 3% (at a level of a 20% brightness decrease) of the solar disk area. During its observation negative microwave bursts had already finished; this can mean that the cloud that absorbed emission in the 304 Å line was at lesser heights than the previously occulted radio sources. The absorbing material descended; however, it is unlikely that it followed the trajectory of its ascent, because the cloud area well exceeded the size of the filament and its position differed from the eruption site.

It is still unclear what happened to the filaments after the eruption in the events of June 1/2, 2002,February 6 and 7, 2002: either explosive dispersing over a large area or a surge with a subsequent fallout of material back to the eruption site (quasi-eruption). In both of these probable scenarios negative radio bursts and appearance of surges in the Hα line and in the extreme ultraviolet are possible. Surges and sprays are probably most similar by their nature to clouds of fragments that are formed during the disintegration of filaments in explosive eruptions, though they have a much smaller scale.

The analysis of the observations results in a conclusion that the studied events could belong to the poorly studied class of explosive eruptions or were associated with quasi-eruptions of filaments ("failed eruptions"). Using the depths of radio absorption measured at several frequencies in the 1–10 GHz range together with the previously developed model, we have estimated for all considered events parameters of the absorbing plasma (temperature, optical thickness, area of the occulting screen, and its height above the chromosphere). This has allowed us to estimate the ejected masses, $\sim 10^{15}$ g; this is comparable to masses of typical filaments and CMEs. In spite of some simplifications, the model enables us to obtain realistic estimates of parameters of the ejected mass.

The cause of negative radio bursts in the studied events could be absorption of the emission from quiet solar regions and local radio sources by the ejected material of a filament. During the motion of the ejections there could be absorption of the background solar radiation by cold hydrogen contained in a cloud of fragments of the filament; this was observed as a short-lived depression of the extreme-ultraviolet emission, in the 304 Å channel.

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