Astrophysical Letters, 1983, Vol. 23, pp. 95–101
0004-6388/83/2302–0095/$18.50/0

Absorption Bursts in the Radio Emission from the Sun at Decameter Wavelengths

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(Received April 1, 1982; in final form July 2, 1982)

We have detected sudden decreases in the radio emission from the sun at decameter wavelengths. Some characteristics of these ''absorption bursts'' are presented. Possible interpretations are discussed.

Key words: solar radio emission, absorption bursts.

INTRODUCTION

As part of an investigation of the microstructure of decameter solar radio bursts we have been observing the sun with high resolution in time and frequency and also with high sensitivity [Sastry *et al.* (1981)]. During our recent observations, we have detected on several occasions, sudden decreases, or absorptions, in the intensity of solar radio emission. Since the time structure of these features is quite similar to that of the emission bursts, we refer to them as absorption bursts. Some characteristics of these absorption bursts are presented here.

EQUIPMENT

These observations were made with the NS array of the Gauribidanur Radio telescope (Lat. 13° 36′ 12°N, Long. 77° 26′ 07″E) and a multichannel receiver. The NS array has a collecting area of approximately 9,000 m^2 and beam widths of 15° and 0.5° in the EW and NS directions respectively. The center frequency of the receiving system is 34.5 MHz. The separation between channels is 50 KHz, and the bandwidth of each channel is 15 KHz. The time constant used was 20 milliseconds. The minimum detectable flux density is $\approx$1 SFU. The data were recorded both in analog and digital forms. The present number of channels is sixteen. The radiometer was operated for about an hour around the local noon during periods of enhanced solar radio emission. Several hundred absorption bursts were recorded during the period March–July 1981. During the periods April 13–15 and June 23–25 the rate of occurrence of absorption bursts was maximum.

OBSERVATIONS

The absorption bursts occurred during periods of steady continuum emission and also during long duration emission bursts. The steady level of the continuum corresponded to about 10 to 15 solar flux units. The intensity of the long duration emission bursts

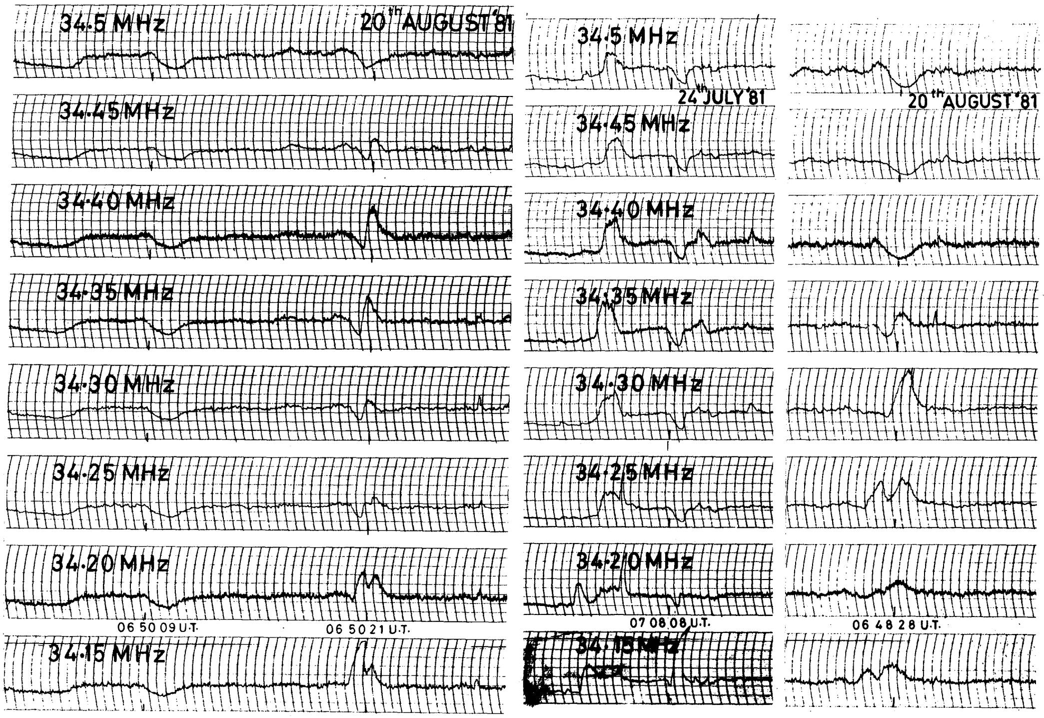

FIGURE 1a, b, c Typical examples of absorption bursts, with simple time profiles.

varied over a range of 10 to 300 SFU. Sometimes the long duration emission bursts themselves were superimposed on the steady continuum. We found that the time and frequency structure of the absorption bursts can take a variety of forms. The most common type is the one in which the fall in the intensity and the subsequent rise are smooth and structureless. Typical examples of this type of burst are shown in Figures 1a, b and c. In Figure 1a one can see a broadband absorption bursts of about 4 sec. duration with smooth fall and rise in intensity. It is followed by another burst in which there is considerable structure in frequency. During this burst the absorption is seen only in the 34.5 MHz channel, while in the channels in the frequency range 34.45 MHz to 34.25 MHz, the absorption is followed by emission. At 34.20 MHz and 34.15 MHz there is only emission. In Figure 1b one can see a short duration (≈2 sec.) absorption burst in the frequency range 34.50 MHz to 34.20 MHz, and a strong emission burst at 34.15 MHz at the same time. Another absorption burst with complex frequency structure is shown in Figure 1c. Here there is absorption in the frequency range 34.50 MHz to 34.40 MHz; at 34.35 MHz the absorption is followed by emission and in the lower frequency range 34.30 MHz to 34.15 MHz there is only emission.

A statistical analysis of about 300 absorption bursts with simple time profiles showed that the distribution of the total duration peaks around 2 to 3 sec. It is also found that the fall time, i.e. the time taken for the intensity to reach the minimum level, and the rise time, i.e. the time taken to reach the preabsorption level, can take values between 0.2 to 2 sec. We have observed both symmetric and asymmetric time profiles, for this type of burst. In the asymmetric profiles the fall times can be larger or smaller than the rise times. The bandwidth of these bursts ranges from 200 KHz to ≥500 KHz. The frequency drift, if it exists, is more than 5 MHz/sec.

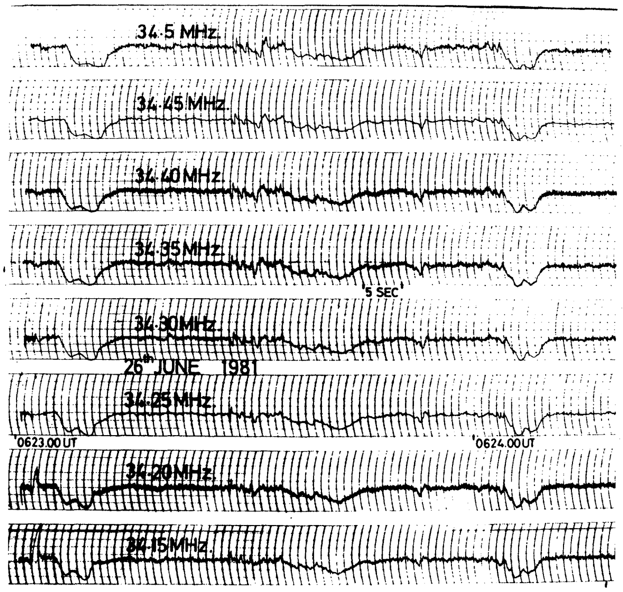

FIGURE 2 Typical examples of absorption bursts with split time structure.

Another type of absorption burst is shown in Figure 2. These bursts are mainly characterized by their split time profiles. In Figure 2 one can see a broad-band burst with two absorption peaks immediately after the narrow-band spike bursts in the last two channels. A similar burst occurred again after a delay of about one minute. In Figure 3a, b and c are given the distributions of the total duration (T), the time interval (ΔT) between the two peaks of absorption, and the ratio of amplitudes of the two peaks of absorption (I_1/I_2). It can be seen that the total duration lies between 3 and 6 sec. The time interval between the two peaks of absorption is about 2 sec. and the amplitude ratio is <1 indicating that the amplitude of the later peak is greater than the earlier one. On some occasions we have recorded this type of burst both in emission and absorption occurring at the same time in different frequency channels. The characteristics of such split time profiles of emission bursts have been already studied in detail [Sastry (1971)]. It is interesting to note that values of T, ΔT, and I_1/I_2 are the same for both emission and absorption bursts of this type. It was found that the splitting in time in the case of emission bursts is not a propagation effect such as echoes in the corona or magnetoionic splitting, but is inherent to the emission process [Sastry (1972)].

A third type of absorption burst, with long duration, is shown in Figure 4. In this case the total duration exceeds 10 to 15 sec. The fall and rise in the intensity can either be gradual or sudden. The bandwidth of this type of bursts is invariably >500 KHz.

A histogram showing the distribution of the ratio of the depth of absorption to the level of the continuum for all types of bursts is shown in Figure 5. It is clear that the continuum is reduced by 30 to 40 percent from the preabsorption level in a majority of cases. Some other characteristics of the absorption bursts observed by us are: (1) The band width of the absorption bursts tends to be larger than the associated emission bursts (2) The amplitude of the emission bursts is much larger than the depth of absorption bursts, when they occur simultaneously in different channels (3) Normally, the number of emission bursts is much larger than that of absorption bursts, although on rare occasions we have seen storms of absorption bursts only.

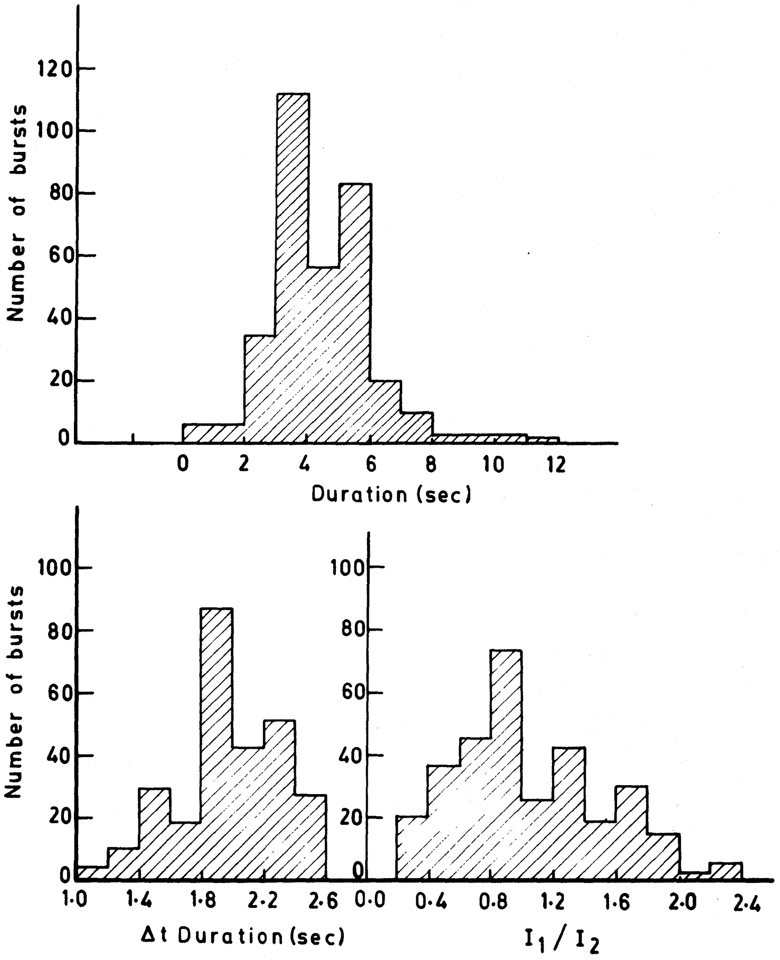

FIGURE 3a, b, c Distribution of (a) total duration T, (b) time interval ΔT and (c) the ratio of the amplitudes I_1/I_2 of absorption bursts with split time profiles.

DISCUSSION

Sudden reductions in the intensity of the Type IV radiation from the sun have been reported earlier by Slottje (1972) at frequencies around 250 MHz. Kai (1973) described absorption of a Type II burst by shadow Type III burst. The essential difference between these observations and the absorption bursts presented here is the extremely low level of the underlying continuum (10 to 15 SFU), and the long durations. Also, our observations are not confined to any particular type of burst like Type IV, Type III etc. We have rarely observed the absorption features when the background continuum level is very high (10^3 SFU). The occurrence of emission and absorption bursts simultaneously in different frequency channels implies (1) the presence of an additional electron beam and (2) that short duration emission and absorption can arise in the same region of the corona. The absorptions can be due to the complete quenching/partial interruption of the instability responsible for the generation of the non-thermal continuum, or the mutual interaction

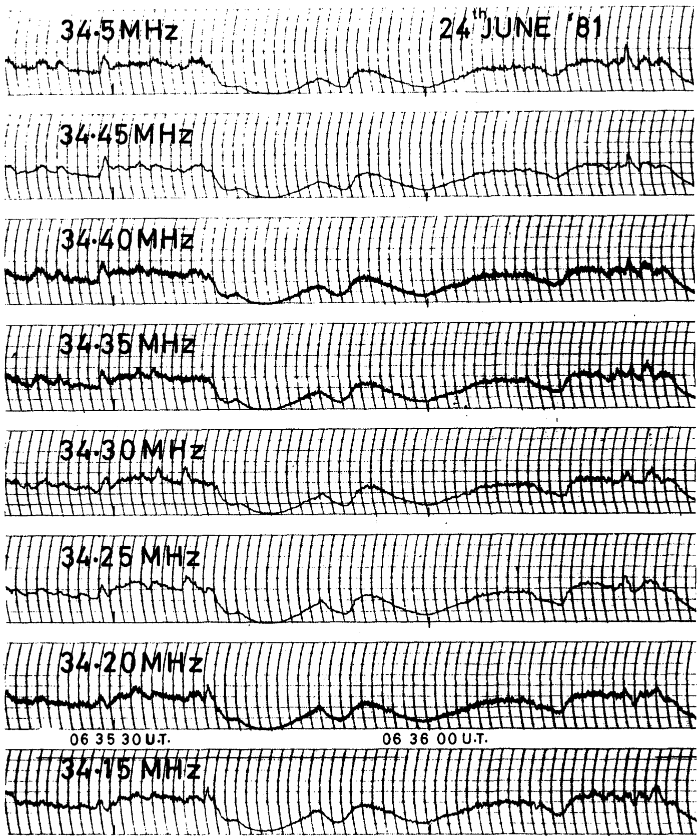

FIGURE 4 Typical examples of long duration and broad band absorption bursts.

of waves causing the transfer of energy from one wave to another in the presence of turbulence.

It was suggested by Zaitsev and Stepanov (1975) and Benz and Kuijpers (1976) that the excitation of coherent plasma waves due to loss cone instability and their subsequent conversion into electromagnetic waves by induced scattering is responsible for Type IV dm continuum emission. The occurrence of sudden reductions or absorptions can be due to the quenching of the loss cone instability by the injection of new electrons. This will result in a reduction or complete extinction of non-thermal continuum. It is also possible that the sudden reductions are due to the absence of conditions required for conversion of the Langmuir waves into electromagnetic waves by induced scattering. In the case of inhibition of the loss cone instability by the presence of additional electrons, the observed flux will decay in a time determined by the local collision time (1 to 2 Sec. at 30 MHz) or by Landau damping on the beam particles. The restoration time of the initial radio intensity is composed of (1) the injection time of the particles, (2) the time for the beam particles to escape from the source region and (3) the rise time of the plasma waves to reach the critical energy density level for the onset of induced scattering. The observed restoration times can be interpreted in this way. According to Benz and Kuijpers (1976) the effect of a adiabatic compression of the source region is to reduce the conversion efficiency through induced scattering, and thereby reducing the observed flux. The

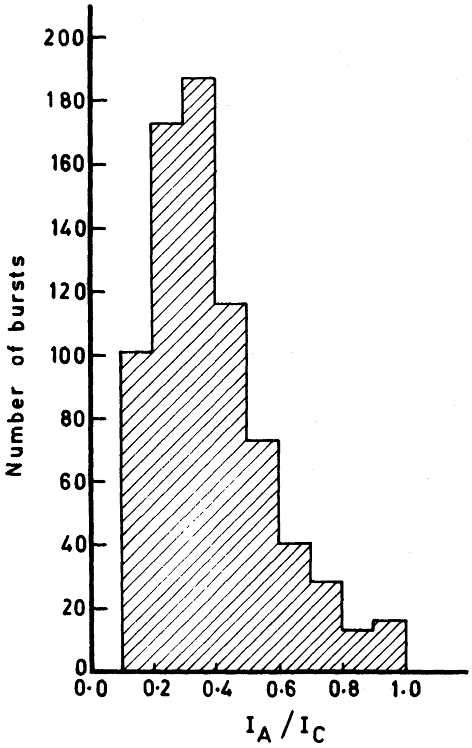

FIGURE 5 Distribution of the ratios of the depth of absorption I_A to the level of the continuum I_C of all types of absorption bursts.

compressions can be due to standing MHD waves in a flux tube, Rosenberg (1970). At low frequencies ($\approx$30 MHz) the assumed periods of the standing waves and the time scale of reductions are about the same order. Also the expected increase of the radio flux relative to the mean level during the expanding phase of the MHD wave cycle is sometimes observed at low frequencies. These characteristics appear to be different from what is observed at high frequencies. But it should be noted that the predicted periodicity in the reductions is not present even at low frequencies. The mechanism involving transfer of energy from one spectral region to another through wave—wave interaction in the turbulent medium, can lead to amplitude modulated absorption bursts [Sastry *et al.* (1981)]. In this case, e.g. during the interaction of Langmuir waves among themselves as well as with ion-acoustic waves, one of the waves grows at the expense of the other. It is well known that the three wave and the four wave interaction processes introduce nonlinear complex amplitude and frequency changes [Weiland and Wilhelmsson (1977)]. These changes can appear in the form of either regular oscillations, or random fluctuations in the profiles of the absorption bursts.

ACKNOWLEDGMENT

We would like to thank M. K. V. Bappu and V. Radhakrishnan for their continued support of the low frequency radio astronomy project at Gauribidanur. We would also like to thank V. Radhakrishnan for useful discussions.

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