Astrophysical Letters, 1971, Vol. 8, pp. 115–119

The Time Splitting of Decameter Solar Radio Bursts

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Solar radio bursts were observed with a multi-channel receiver with frequency separations of 100 to 200 kHz, at a center frequency of 25 MHz. The time resolution was 15 msec. Some properties of double bursts are described.

INTRODUCTION

Several investigators have found that solar radio bursts of short period sometimes occur in pairs. The double humped bursts first observed by Payne-Scott (1949) were explained by Jaeger and Westfold (1950) as the result of reception of direct and reflected rays from the solar corona. But the observations of Wild *et al.* (1954) revealed that these bursts may be of spectral Type III, the second part of the burst being the second harmonic and not the delayed repetition of the first. Roberts (1958) described a double burst known as the reverse drift pair and suggested that the second element of the burst was the echo of the first. Elgaroy (1961) found several pairs of bursts around 200 MHz which he interpreted as possible echo events. Yoh and James (1967) reported observing double short-lasting bursts at 38 MHz. Ellis (1969) described a forward drift pair of bursts in the frequency range 25 to 40 MHz. Sastry (1969) observed double bursts at 25 MHz. So far no convincing evidence has been put forward for the existence of echoes in the solar corona. Elgaroy (1969) suggested that the splitting in time may be the result of propagation via two different magneto-ionic modes. In this paper we present some of our results of high time and frequency resolution on the double bursts around 25 MHz.

OBSERVATIONS

The antenna system used is an array of 72 full-wave dipoles. The received signal is fed to a preamplifier of bandwidth 1.5 MHz centered at 25 MHz. The output of the preamplifier is split into two or three channels and is fed to main receivers. The separation between adjacent channels ranged from 100 to 200 kHz. The bandwidths of the main receivers are either 6.5 or 13 kHz. The linearly detected outputs are simultaneously recorded by an Ediswan pen oscillograph with a response time of the order of 15 msec and paper speeds of 0.75 to 3 cm/sec.

The receiving system was operated during times of enhanced solar radio emission and all the three types of noise storms are recorded. These are (1) background continuum enhancement only with irregular variations, (2) short period and narrow band bursts superimposed on the enhanced background, and (3) short period and narrow band bursts without accompanying continuum enhancement.

The double bursts occurred with and without accompanying background enhancement. Figure 1 shows typical examples of these bursts. They occurred in many cases as single isolated bursts. The time interval at a single frequency between the occurrence of two double bursts is usually of the order of a few tens of seconds although in rare cases it can be very much less. During the period May-August 1970, the total number of double bursts recorded was 88. The ratio of the amplitude of the earlier element to that of the later element R, the total duration T, and the time interval between the two elements Δt, were measured for each one of the 88 double bursts. The three quantities R, T, and Δt are illustrated in Figure 1. A histogram depicting the distribution of R is shown in Figure 2a. It can be seen that the value of R is less than or equal to one, in a majority of cases. This implies that the intensity of the earlier element is less than or equal to that of the later element. Figure 2b shows the distribution of the total duration T, and that the most probable duration lies between 2 and 8 sec. Figure 2c shows a histogram of the distribution of the time interval Δt between the two elements. It is clear that in most cases the value of Δt lies between one and two sec. In order to study the relationship between T and Δt, the two

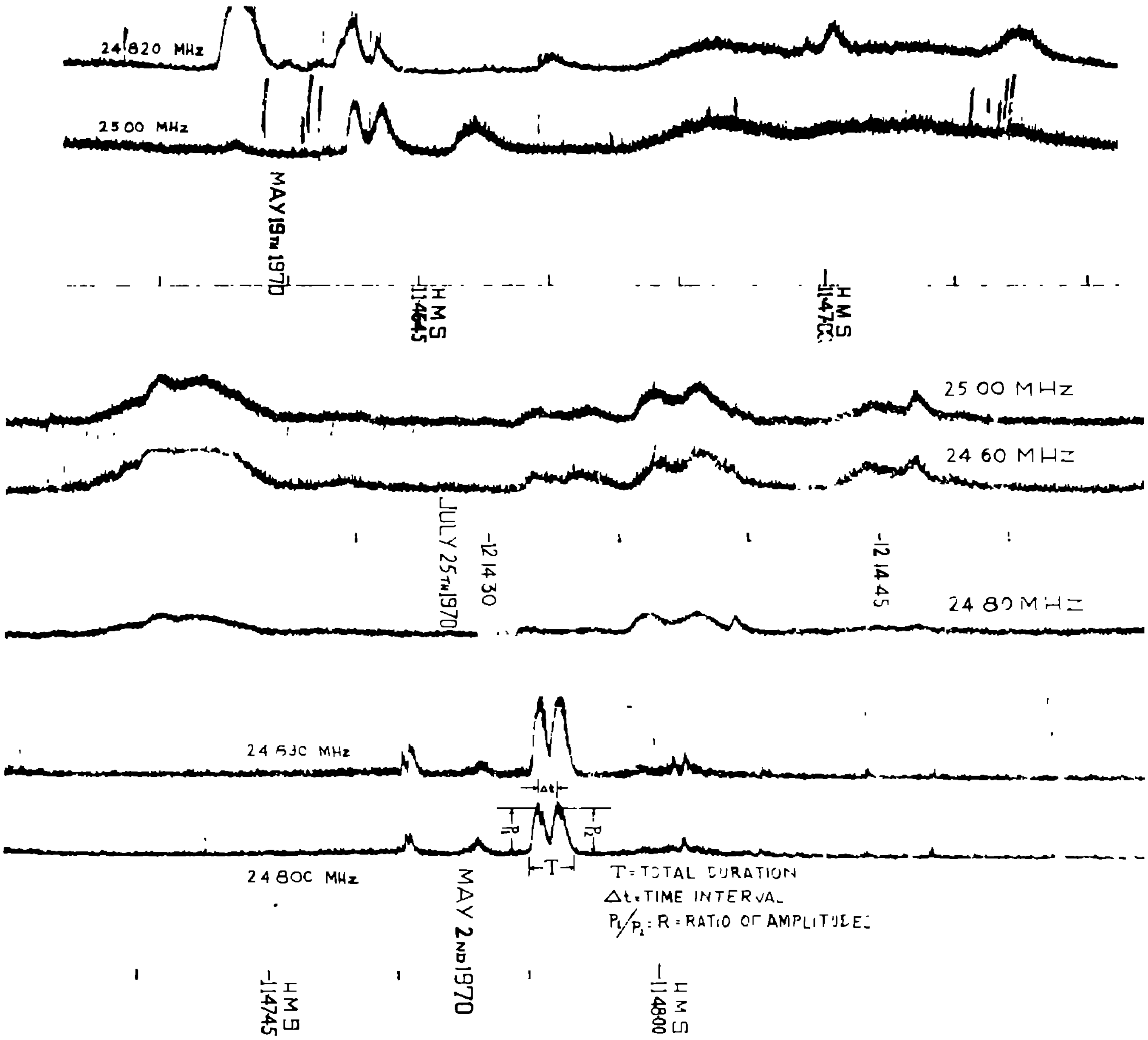

FIG. 1. Typical examples of double bursts. The three quantities R, T, and Δt are illustrated in the lowest two records. The time markers are at intervals of 5 sec. The sharp spikes are due to atmospherics.

quantities are plotted in Figure 3. It can be seen that for bursts whose total duration is less than about 8 sec the time interval Δt is directly proportional to the total duration T. There is no such relation between the two when T is greater than about 8 sec.

The bandwidth of about 10 per cent of the total number of the bursts is less than or equal to 200 KHz. In about 20 per cent of the cases, the time-profile of the bursts in adjacent channels is completely different. Figure 4a shows an example of bursts which appear in only one channel and Figure 4b shows an example where at 24.82 MHz there is double burst, while at 25.00 MHz a single burst appeared. In all the remaining cases the bandwidth is greater than 200 kHz. The frequency drift of these relatively broad band bursts can be zero, positive, or negative. The drift rate of both positive and negative drift bursts is of the order of 1 to 2 MHz/sec.

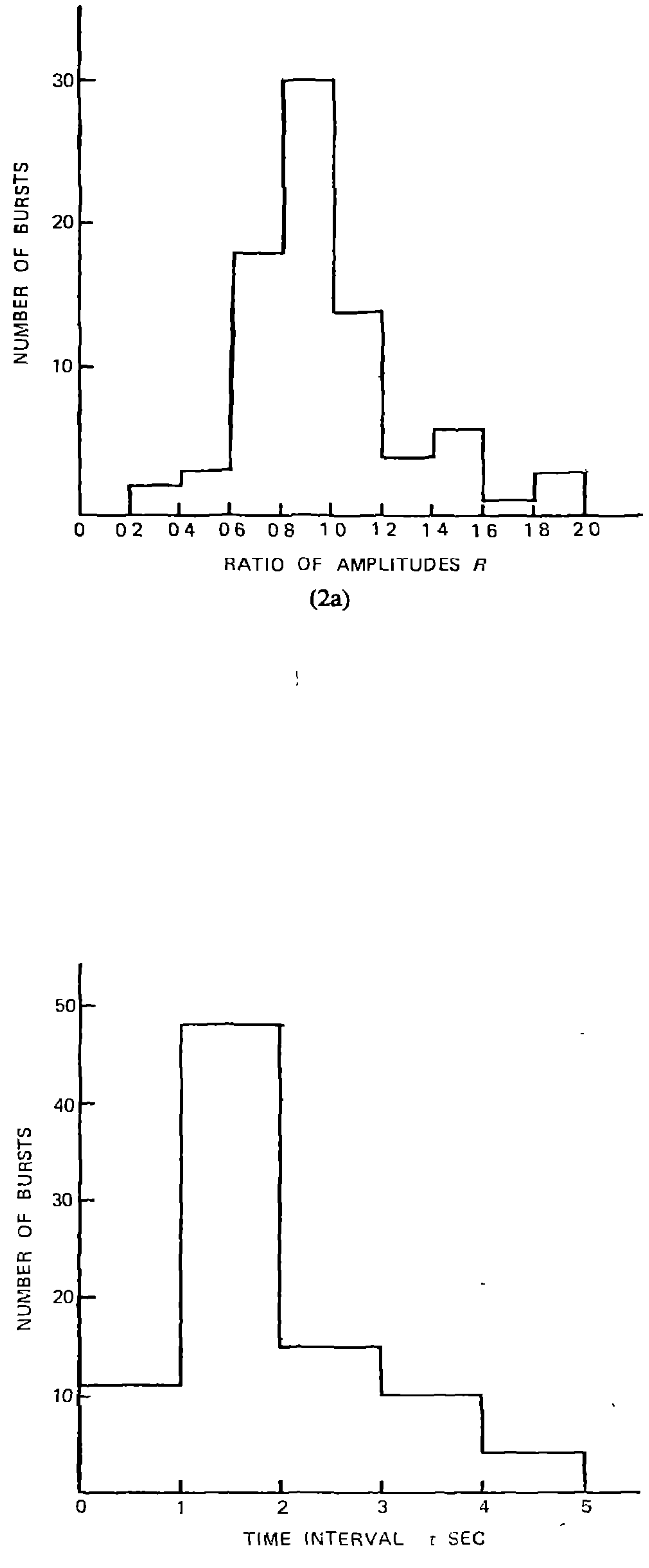

FIG. 2. (a) Distribution of the ratio of amplitudes R. (b) Distribution of the total duration T. (c) Distribution of the time interval Δt.

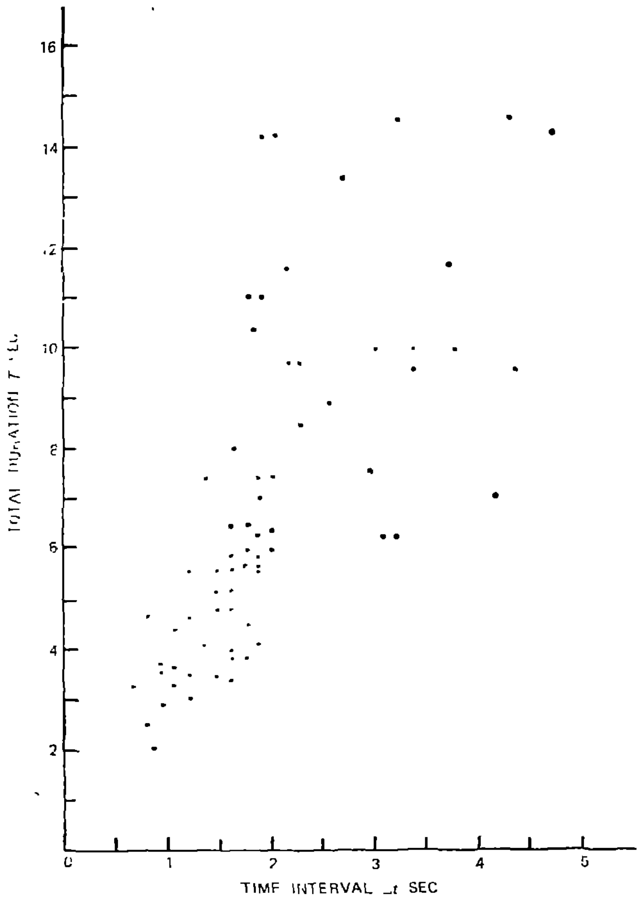

FIG. 3. Plot of total duration T versus the time interval between the two elements Δt.

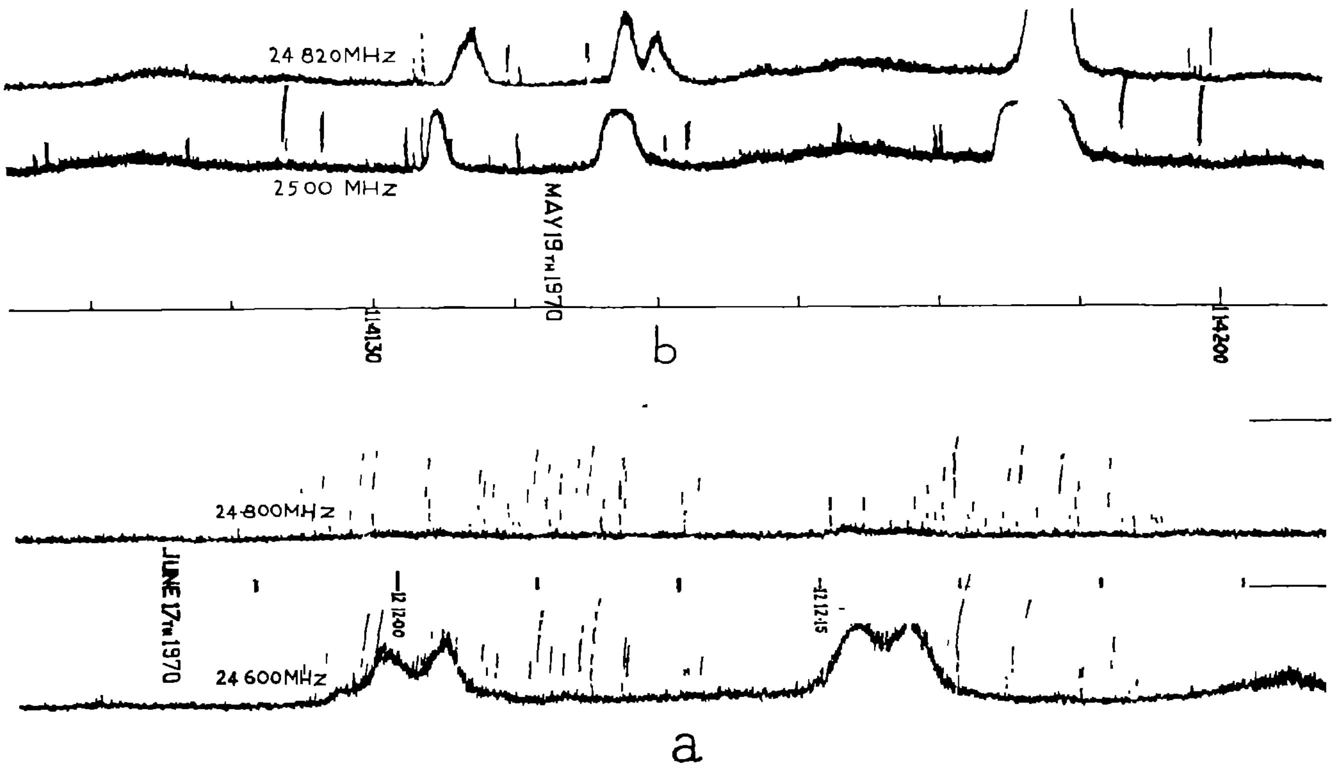

FIG. 4. (a) Example of narrow band double bursts. (b) Example of a record showing the occurrence of a double burst at 24.82 MHz and a single burst at 25.00 MHz at the same time. The sharp spikes in both (a) and (b) are due to atmospherics. The time markers are at intervals of 5 sec.

DISCUSSION

It is possible to explain the occurrence of the double bursts as an echo phenomenon. In the echo theory of Roberts (1958) and others it was shown that the intensity of the second element should be less than that of the first. It was subsequently suggested by Smerd *et al.* (1962) that the reverse can be true under certain circumstances of burst generation. However, as pointed out by Roberts (1958), if the sources are located at all accessible distances from the center of the disk then one should observe a wide range of values for the time interval Δt. But the observations show that there is a peak in the distribution of Δt around one to two sec. This would require that all the observed sources lie at the same distance from the center of the disk, which is rather improbable. The range of values of Δt at 25 MHz, as observed in the present study, and at 40 to 70 MHz, as reported by Roberts (1958), are about the same. But note that all the bursts observed by him are 5 to 10 MHz wide, whereas for at least 10 per cent of the bursts reported here the bandwidth is less than 200 KHz. This probably implies that the double bursts reported here are different from those studied by Roberts.

Another possibility is that these bursts are similar to the correlated bursts reported by Kai (1969) and others. The time delay between the correlated bursts at 80 MHz is of the order of 10 sec, which is about 5 to 10 times the value of Δt we have observed. According to Wild (1968) and Kai (1969), fast electrons accelerated and ejected in one active region excite a Type III burst, travel along the magnetic field, and stream into another region where they again excite a reverse drift Type III burst. The two bursts are expected to be polarized in opposite senses. It is possible to understand on this basis a general reduction in the value of Δt as the observing frequency is decreased. Further observations on position and polarization of these bursts are clearly necessary to come to a definite conclusion. The same additional information is also necessary to confirm Elgaroy's (1969) suggestion of magneto-ionic splitting. Position and polarization observations on the double bursts are at present being made at this observatory.

The fact that the correlation between the time interval Δt and the total duration T breaks down when T exceeds about 8 to 10 sec might mean that the doublets with $T > 10$ sec are different from those with $T < 10$ sec. It should be mentioned here that a fraction of the total number of double bursts, particularly those with large values of T, may be due to chance coincidence of single bursts. It might be possible to eliminate the bursts due to chance coincidence when position and polarization information is available on a large sample of these bursts. In any case, the linear proportionality observed between T and Δt must be taken into account in the theoretical interpretation of the double bursts.

I thank Dr M. K. Vainu Bappu for his advice and encouragement and Messrs A. T. Abdul Hameed and K. S. Ramamurthy for their help in collecting and analysing the data.

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Received in final form 1 March 1970