Astrophysical Letters, 1972, Vol. 11, pp. 47–51

The Frequency Drift and Time Splitting of Decameter Solar Radio Bursts

Ch. V. SASTRY *Indian Institute of Astrophysics, Kodaikanal, India*

The frequency drift and time splitting of solar radio bursts are observed with a multi-channel radiometer and a polarimeter at frequencies around 25 MHz. It is found that a majority of noise storm bursts have drift rates between +1.0 and −1.0 MHz/sec. Two types of unusual bursts with frequency drift are described. The two components of a double burst are found to be polarized to the same degree and in the same sense.

INTRODUCTION

Extensive observations on the frequency drift of noise storm bursts have been made at very high frequencies. De Groot (1966) came to the conclusion that storm bursts do not show any frequency drift in the range 200 to 400 MHz. Eckhoff (1966) found drift rates between +17 and −17 MHz/sec at 200 MHz. So far no measurements on the frequency drift of noise storm bursts at significantly low frequencies are reported. This paper presents results of observations at high time and frequency resolution around 25 MHz. We also present observations on the polarization characteristics of double bursts of the type previously reported by Sastry (1971).

OBSERVATIONS

The antenna system and the multi-channel radiometer have already been described by Sastry (1971). The antenna system for the polarimeter consists of 8 pairs of half-wave dipoles and the recorded output is the difference between the RH and LH circular components. The polarization and spectral data are recorded on a four-channel pen oscillograph with a response time of 15 msec and paper speeds of 0.75 to 3 cm/sec.

The equipment was operated during noise storms and most of the bursts recorded were of short duration. The observations reported here were made during the period March 1969 to August 1971. The analysis of frequency drift of storm bursts was based mainly on the observations made during two noise storms in the period July 15–19 and August 19–25, 1971. We have measured the differences in starting times in various channels for individual bursts and the drift rates df/dt were derived. The sign of df/dt is taken to be positive if the drift is from low to high frequencies. The total number of bursts recorded in all channels was 9996 and it was possible to measure the differences in only 2378 cases, because of the complex time profile of a majority of the bursts and the lack of perfect correlation of the time profile in adjacent channels. Out of these, 1800 bursts showed irregular drifts in sign and magnitude from channel to channel. The present study uses only those bursts for which the drift is in the same direction in all channels and the rate of drift is approximately the same from one channel to another. The number of such bursts is 578 and the number of values of df/dt derived is 206. The measured values of df/dt are from −4.0 to −0.2 MHz/sec and +0.2 to +4.5 MHz/sec. Typical examples of bursts with frequency drift are shown in Figure 1. The distribution of the number of occurrences of various values of df/dt is shown in Figure 2a. It can be seen that a majority of the observed drift rates lie between −0.2 to −1.0 MHz/sec and +0.2 to +1.0 MHz/sec, and also that there is an excess of positive drifts. The difference between the total number of occurrences of positive and negative drifts is significant at the 95 per cent confidence level. Elgaroy (1960) also found a similar asymmetry at 200 MHz. The histogram varies in character from one storm to another, as illustrated in Figures 2b and 2c, which show that during the July 1971 storm the total number of occurrences of the positive drifts is significantly more, while during the August 1971 storm this is not the case. The histogram in Figure 2d shows the distribution of the durations of the 578 bursts, and that the most probable duration is about 2 sec. These bursts are probably different from the fast-drift storm bursts detected by Ellis (1969) in the frequency range 30 to 50 MHz, since the duration of the fast-drift storm bursts is significantly

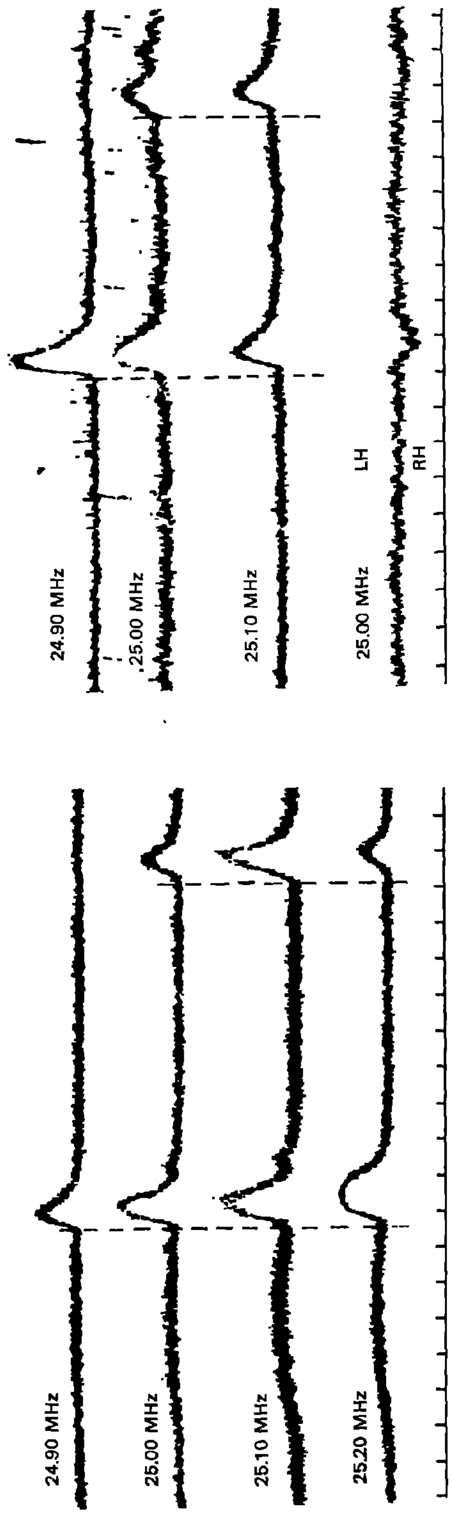

FIG. 1. Typical examples of bursts with frequency drift. *Left*: 1971 July 21 06.54.00 UT. *Right*: 1971 August 25 05.59.45 UT. The bottom channel gives polarization information; the time markers are at intervals of one second.

different, being about 0.6 to 0.8 sec, and also their sign of drift is always negative. According to Malville (1962) the duration of Type III bursts at 25 MHz is 5 sec; therefore it is reasonable to assume that the contamination due to Type III bursts is negligible. We have also measured the drift rates and durations of 62 narrow-band bursts. These bursts appeared in the central two channels only and the estimated bandwidth is ≤ 150 KHz. The average drift rate and duration are found to be ± 1 MHz/sec and 2 sec respectively. This shows that the rate of drift and the duration are not dependent on the bandwidth of the bursts.

We have recorded two types of unusual bursts with frequency drift. Figure 3a shows examples of spike bursts with negative frequency drift. The rate of drift is 0.5 MHz/sec and is remarkably constant for all the bursts. The duration of the spikes varied from 175 to 260 msec. The time interval between the occurrence of two successive bursts at the same frequency varied from 11 to 18 sec. The amplitude of the bursts varied in an irregular way and is not frequency dependent. The delayed arrival of the spikes at the lower frequency is not due to dispersion in the intervening medium since it can be shown that the value of $\int n_e \, dl = 10^{24}$ cm^{-2} (where n_e is the number of electrons and l is the total path length), which is very high. Figure 3b shows another type of unusual burst. Here the intensity at the higher frequency abruptly increases and exhibits high speed oscillations of about 10 to 12 Hz before it comes back to the base level, equally abruptly. The oscillatory nature of the burst is clearly visible in example 4 of Figure 3b. The same pattern is repeated at the lower frequency after a few seconds of time. The smallest time interval between the occurrence of the bursts in the two channels is 3.2 sec and the largest time interval is 6.1 sec. These correspond to drift rates of 0.06 and 0.03 MHz/sec respectively. The occurrence of these two types of bursts is rare and we have recorded them on only three different occasions.

About 200 double bursts of the type described by Sastry (1971) were observed with the multi-channel radiometer and the polarimeter, and 30 per cent of them were found to be polarized. In these bursts the two components are always polarized in the same sense and to the same degree. Typical examples of double bursts with and without polariza-

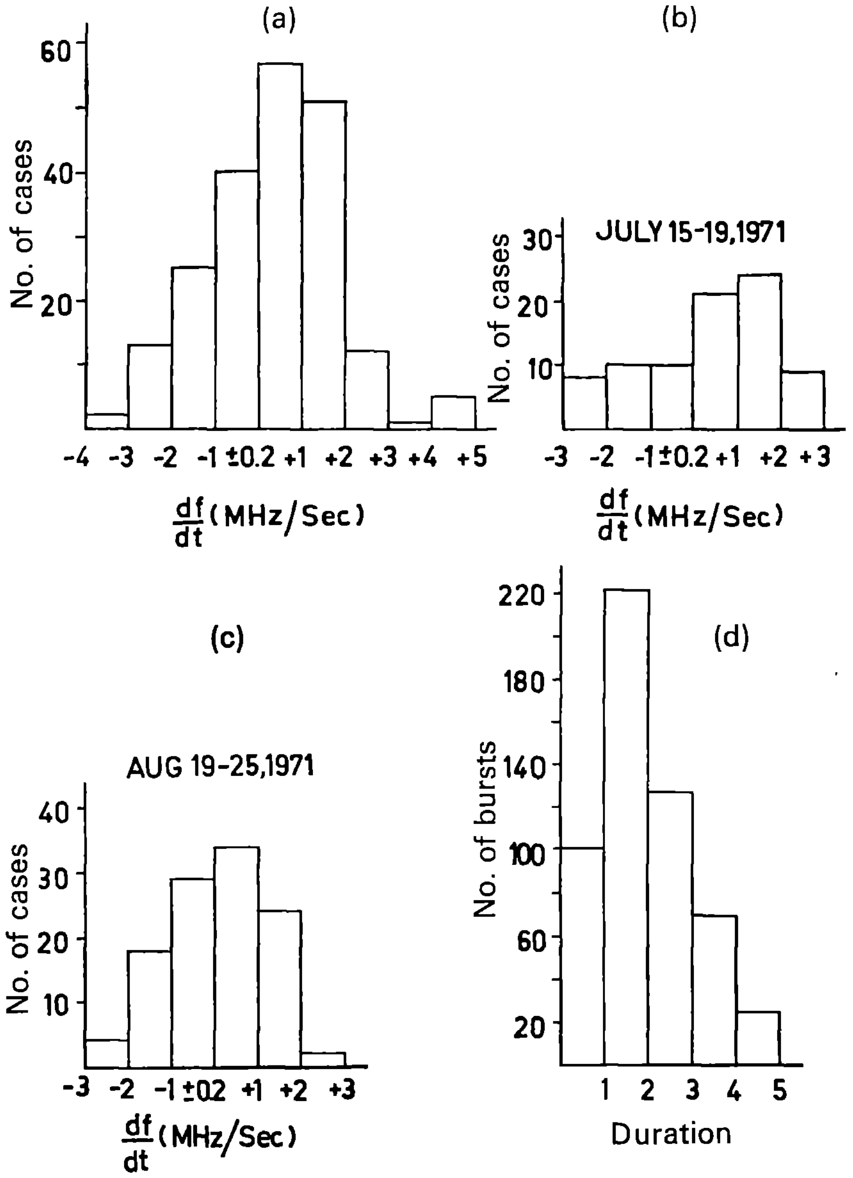

FIG. 2. (a) Drift rates of bursts. Total no. of bursts = 206; positive drifts = 126; negative drifts = 80. (b) Drift rates for storm of 1971 July 15–19. Total = 84, positive drifts = 55; negative drifts = 29. (c) Drift rates for storm of 1971 August 19–25. Total = 111, positive drifts = 60, negative drifts = 51. (d) Durations for 578 bursts.

tion are shown in Figure 4. We have also observed a few cases of double bursts with frequency splitting similar to that described by Ellis (1969) in the case of single bursts.

DISCUSSION

Several theories have been proposed to explain the various characteristics of the storm bursts. The theory of radio emission from coherent plasma waves may explain some of the observed characteristics. Takakura (1963) suggested that the storm bursts are generated by a beam of high speed electrons that excite coherent plasma waves. The duration t of a burst of this type is given by Takakura (1963) as

$$t = 2.0 \times 10^{-3} \frac{m^2 v_0^3}{e^4 N},$$

where m and e are the mass and charge of the electron, N is the electron density of the excited plasma and v_0 is the electron beam velocity. The

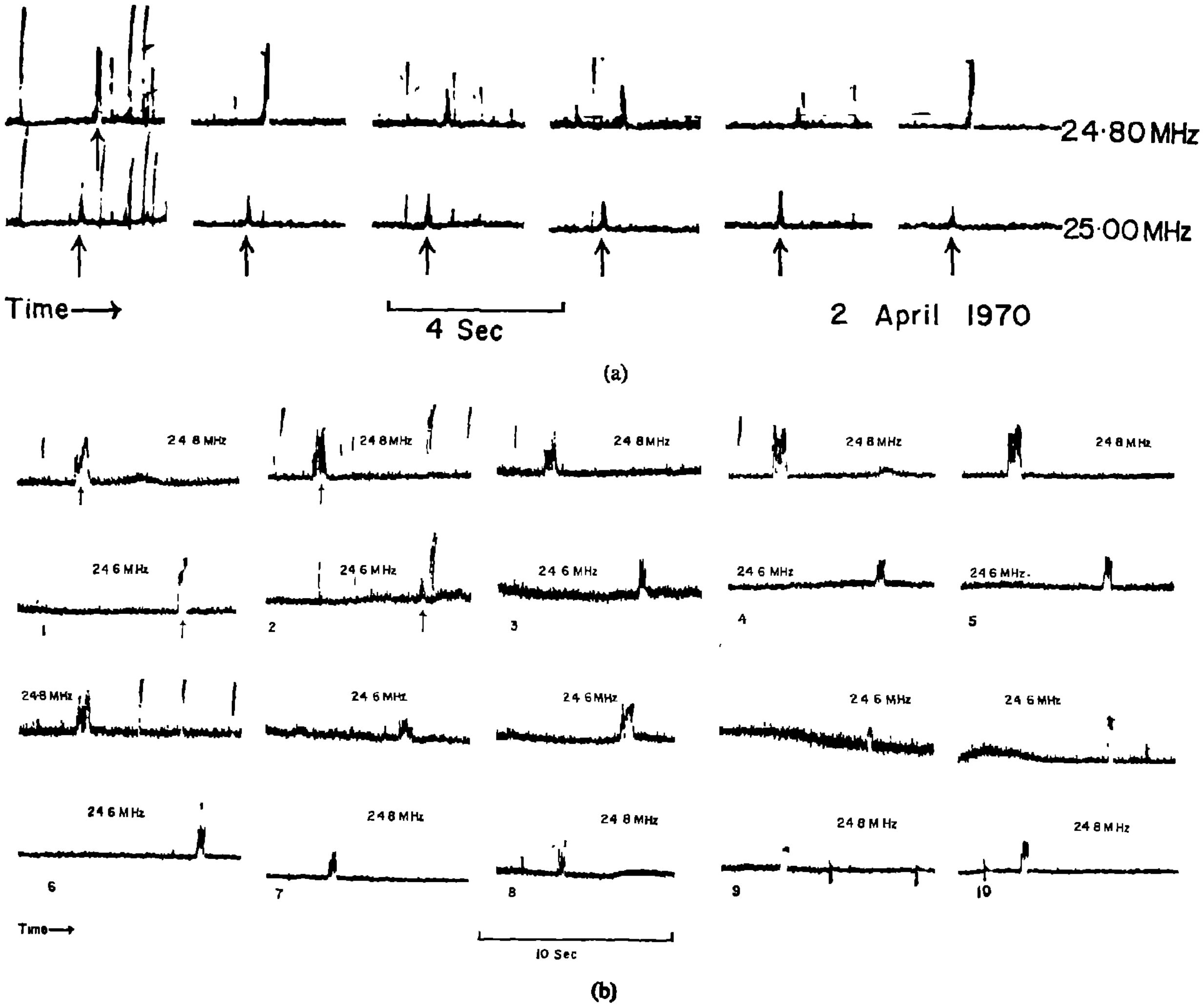

FIG. 3. (a) Examples of spike bursts recorded on 1970 April 2 between 06.10.45 and 06.15.00 UT. The spikes not indicated by arrows are due to atmospherics. (b) Examples of slow-drift oscillatory bursts recorded on 1970 June 17–25 between 06.00 and 07.00 UT. Note that the channel frequencies are interchanged in examples 7 to 10.

frequency of emission f of the radio bursts is given by the well-known dispersion relation

$$f^2 = f_p^2\left[1 - \frac{3}{2}\left(\frac{v_t}{v_0}\right)^2\right]^{-1},$$

where f_p is the plasma frequency and v_t is the speed of thermal electrons. As shown above, the average duration of the bursts is about 2 sec and so v_0 will be about 8.0×10^3 km/sec. To propagate, the waves must satisfy the condition $v_0 \geqq 3v_t$ and so the temperature of the corona at the place of generation of the bursts should be 0.1×10^6 K. As pointed out by Elgaroy (1966) a variation of f_p or v_t along the path of the exciting beam will produce a variation of the emitted frequency with time. Assuming that the electron density above an active region is given by 10 times the Baumbach-Allen model, we can show that

$$\Delta f_p/\Delta t = -10^2 v_0 \text{ Hz/sec.}$$

With the value of v_0 given above the frequency drift is -0.8 MHz/sec. It can also be shown that a temperature gradient of about 10 K/km would also produce the observed frequency drift. If this kind of explanation is correct then it can account for both positive and negative drifts, since the gradients

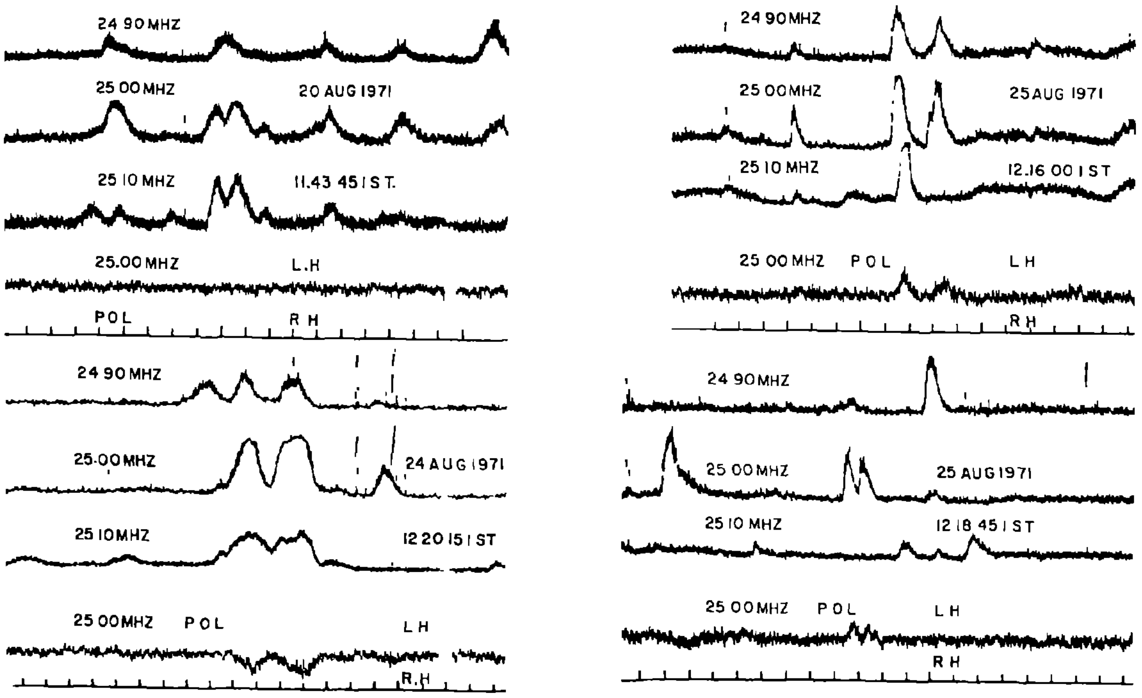

FIG. 4. Examples of double bursts. *Left top:* unpolarized. *Left bottom:* RH circularly polarized. *Right top:* LH circularly polarized. *Right bottom:* narrow-band double burst polarized in the RH sense. The time markers are at intervals of one second.

of electron density and temperature can be either positive or negative. The assumed temperature of the corona at the 25-MHz plasma level is much less than the usually accepted value of 10^6 K. On the basis of the theory of coherent plasma oscillations Elgaroy (1966) also derived low temperatures of the order of 0.5×10^6 K for the 100- and 200-MHz plasma levels. To overcome this difficulty he suggested that the storm bursts are generated in filaments with lower temperatures than the surroundings.

Elgaroy (1969) showed that if the double bursts are caused by magneto-ionic splitting then the two components should be polarized in opposite senses. Fomichev and Chertok (1970) showed that if one receives the direct and reflected rays from the corona then the polarization properties of the two components would be different. If the double bursts are similar to the correlated bursts reported by Kai (1969) then the two components are expected to be polarized in opposite senses. But since the two components are found to be polarized to the same degree and in the same sense, it would appear that none of the above mechanisms can explain the occurrence of the double bursts. It might be worth while to point out here that the percentages of double bursts and single bursts that are polarized are the same during our observing period. Another similarity between double and single bursts is that both exhibit frequency splitting. This might mean that the mechanism of emission is the same in both types of bursts and that the double bursts are not due to propagation effects.

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.

REFERENCES

De Groot, T., 1966, *Rech. Astron. Obs. Utrecht*, **18**, 1.
Eckhoff, H. K., 1966, Inst. of Theoret. Astrophys., Univ. of Oslo, Norway, Rep. No. 18.
Elgaroy, O., 1960, *Astrophys. Norveg.*, **6**, 55.
Elgaroy, O., 1966, *Astrophys. Norveg.*, **10**, 127.
Elgaroy, O., 1969, *Astrophys. Letters*, **3**, 39.
Ellis, G. R. A., 1969, *Austral. J. Phys.*, **22**, 177.
Fomichev, V. V., and Chertok, I. M., 1970, *Sov. Astron.-AJ*, **14**, 261.
Kai, K., 1969, *Proc. Astron. Soc. Austral.*, **1**, 186.
Malville, J. M., 1962, *Astrophys. J.*, **136**, 266.
Sastry, Ch. V., 1971, *Astrophys. Letters*, **8**, 115.
Takakura, T., 1963, *Publ. Astron. Soc. of Japan*, **15**, 462.

Received in final form 20 March 1972