A NEW INVESTIGATION OF MICROBURSTS AT METER-DECAMETER WAVELENGTHS

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Abstract. We report on a new investigation of microbursts at meter–decameter wavelengths observed using the Broad Band Array at Gauribidanur Radio Observatory. This is an independent set of observations of microbursts: previous observations had been obtained only by the Clark Lake multifrequency radioheliograph. We confirm several properties of microbursts reported earlier. In addition, we have studied some new properties of microbursts such as time profile characteristics, flux density and energy spectra for comparison with the corresponding properties of normal type III bursts. The present study supports the idea that the microbursts and the normal type III bursts are generated by electron beams of similar characteristics. We interpret the low brightness temperature of microbursts as follows: plasma waves generated by the electron beams through beam-plasma instability are quickly isotropized as they scatter on the density fluctuations in the corona. The resulting low levels of plasma waves are converted into transverse radiation of low brightness temperature. One important consequence of the isotropization is that the second harmonic plasma emission dominates the fundamental and hence the microbursts are expected to be predominantly a harmonic plasma emission.

1. Introduction

X-ray microflares and microbursts at meter–decameter wavelengths are believed to represent small-scale energy release (Lin *et al.*, 1981; Kundu *et al.*, 1986). In order to understand the source of this small energy release, we need to clarify the characteristics of the microbursts. A natural question is whether or not these are similar to the normal type III bursts. Microbursts at meter-decameter wavelengths appear as brief enhancements above the quiet-Sun emission with a brightness temperature in the range of a few times 10^5 to 10^7 K. Kundu *et al.* (1986), White, Kundu, and Szabo (1986), and Gopalswamy, Kundu, and Szabo (1987) assumed that microbursts are weak type III bursts in their analyses. Following these investigations involving a small number of events, Thejappa, Gopalswamy, and Kundu (1990) took up a statistical study of the characteristics of microbursts and compared them with those of normal type III bursts. It was found that most of the microburst characteristics are similar to those of normal type III bursts; the average drift rate was found to be somewhat lower, although within the observed range of type III drift rates. These studies suggest that the microbursts are lower brightness extensions of normal type III bursts.

The Clark Lake microbursts were observed with ~ 1 s time integration. Since the observations were sequenced through 3 or 4 frequencies, the data points at any given frequency are separated by 4–5 s. Therefore, it was not possible to determine the peak brightness temperature accurately. It is necessary to verify the brightness temperature

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range of the microbursts independently with simultaneously obtained observations at many frequencies. All the meter–decameter microbursts reported so far are only from the Clark Lake multifrequency radioheliograph (Kundu *et al.*, 1983). Recently, Bastian (1991) reported single-frequency observation of microbursts at 20 cm wavelength. It is important to study the bursts observed using another telescope with different characteristics to firmly establish their properties. In this paper we present new observations of microbursts obtained simultaneously at four frequencies in the range of 38 to 65 MHz with 100 ms time resolution. The temporal, spectral, and flux density characteristics of microbursts are compared with those of normal type III bursts.

Previous studies on microbursts assumed that the emission is at the fundamental of the plasma frequency (Kundu *et al.*, 1986; White, Kundu, and Szabo, 1986). Gopalswamy, Kundu, and Szabo (1987) compared the density in the microburst source region with that derived from optical observations for several limb events and found that it was difficult to choose between fundamental and harmonic. They suggested that harmonic emission may be favored since fundamental is less likely to be observed over the limb due to directivity reasons. In this paper, we address this question from a theoretical point of view: we reconsider the interpretation of microbursts based on the theoretical investigations of Goldman and DuBois (1982) and Muschietti, Goldman, and Newman (1985) on the energy density of plasma waves in the presence of density fluctuations. These authors were able to account for the low level of Langmuir waves observed in the interplanetary medium as a consequence of the presence of density fluctuations. While these low level plasma waves cannot explain the interplanetary type III bursts, we find that they can readily explain the microbursts.

2. Observations

The present observations were made using the Broad Band Array at Gauribidanur, India (Subramanian *et al.*, 1986). The antenna system operates in the frequency range of 30 to 70 MHz. Delay shifters are used to steer the NS beam of the array to ± 45 degrees in zenith angle in steps of 0.5 degree. The collecting area of the array is 2000 m^2. The receiver system consists of a four channel correlation receiver operating at 38, 45.7, 55.5, and 64.25 MHz. The bandwidth and time constant used are 1 MHz and 100 ms, respectively. The sensitivity is better than 2.5×10^{-2} s.f.u. at 65 MHz and 4.0×10^{-2} s.f.u. at 38 MHz, so it is more than adequate to detect extremely weak radio bursts from the Sun.

The data used in the present analysis were obtained during the period March–October 1988. Only bursts which occurred within ± 5 min of the transit of the Sun were used in the analysis to minimize the effects of east–west beam gain correction at all frequencies. Antenna gain may change with declination, and due to the difference between the setting of the beam and actual position of the source in the sky; proper corrections were applied to counter these effects. The radio sources Tau A, Virgo A, Hydra A, and Hercules A were used as calibrators since their positions were very close to the Sun during the above period. The flux density of the calibrators at 38, 45.7, 55.5, and

64.25 MHz were calculated using their 38 MHz flux densities and a spectral index given by Kellermann, Pauliny-Toth, and Williams (1969) between 38 and 178 MHz. The spectral type of the bursts could be easily recognized as similar to the type III bursts from the observed drift rates. We examined the *Solar Geophysical Data* (SGD) and found that these are not storm type III bursts. Only on one day (October 10, 1988) there was a noise storm but it occurred outside the time range of our observations. No Hα flare was present during any of our events.

3. Characteristics of Microbursts

Figure 1 shows a typical drift scan of the Sun at four observing frequencies. Quiescent emission with superposed bursts can be seen at all frequencies. The broad time profile is due to quiet Sun which is also observed occasionally without bursts (Subramanian and Sastry, 1988). As can be seen in the Figure 1, the bursts have a flux density a few times greater than the undisturbed Sun. Since the sensitivity is better than

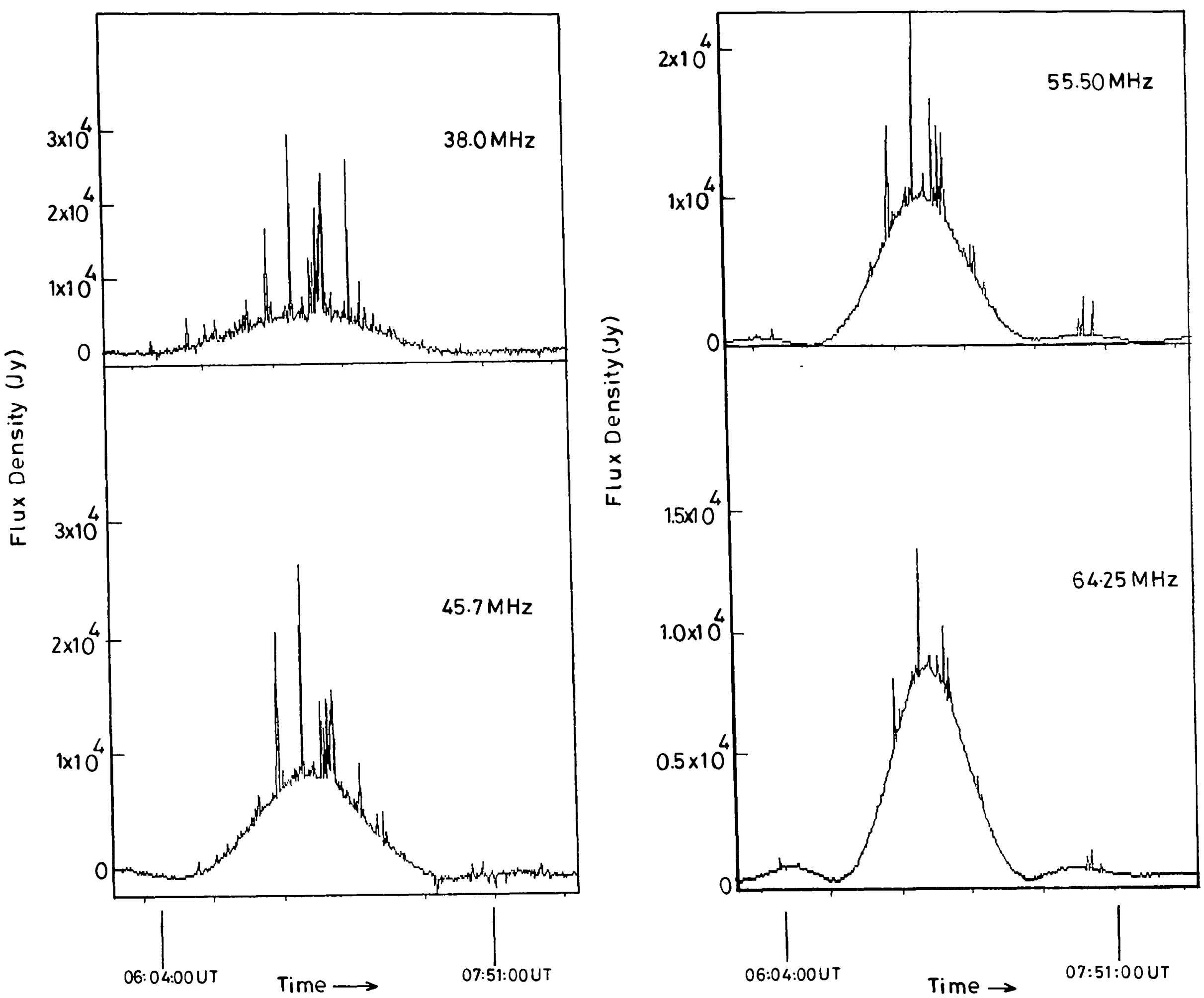

Fig. 1. Drift scan of the Sun showing both continuum and burst emission at four frequencies obtained on August 19, 1988. The flux density scale (vertical) is not the same at all frequencies.

2.5×10^{-2} s.f.u. at 65 MHz it is possible to detect even weak radio bursts from the Sun. Figure 2 shows the time profile of a typical microburst observed with a time constant of 100 ms. Note that the burst starts first at the highest frequency and progressively later

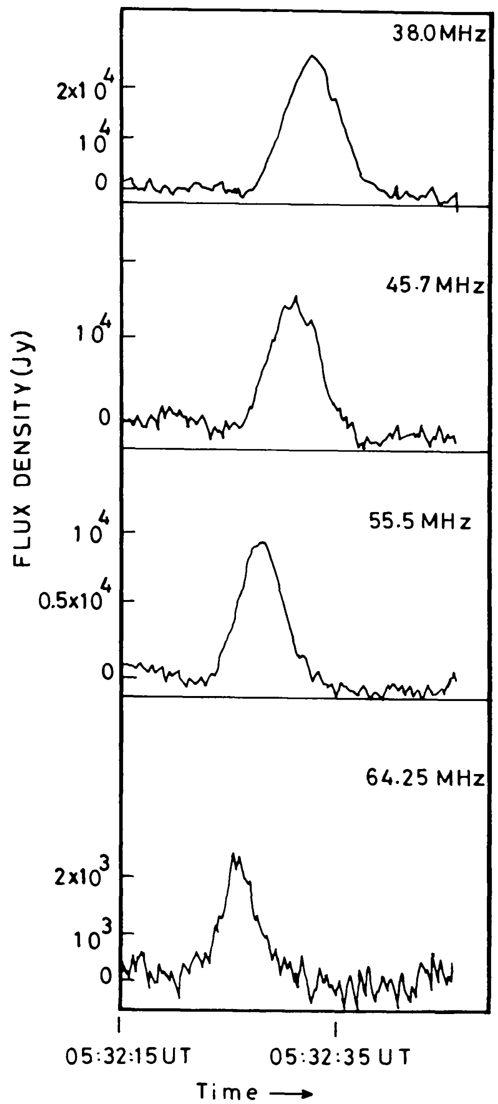

Fig. 2. Time profile of a typical microburst observed on July 14, 1988 at four frequencies: 38.0, 45.7, 55.5, and 64.25 MHz. The systematic delay in the peak time of the burst at lower frequencies gives the drift rate of the burst. Note also the increase in duration towards the lower frequencies.

at lower frequencies. Using these time profiles we derive some of the observational characteristics of the microbursts.

3.1. Frequency drift

The drift rate is estimated by comparing the times of peak flux density at different frequencies. The drift rate is measured only for bursts which appeared at all frequencies. All the bursts showed forward drift (from higher to lower frequencies). From the distribution of the drift rate shown in Figure 3, we see that most of the bursts

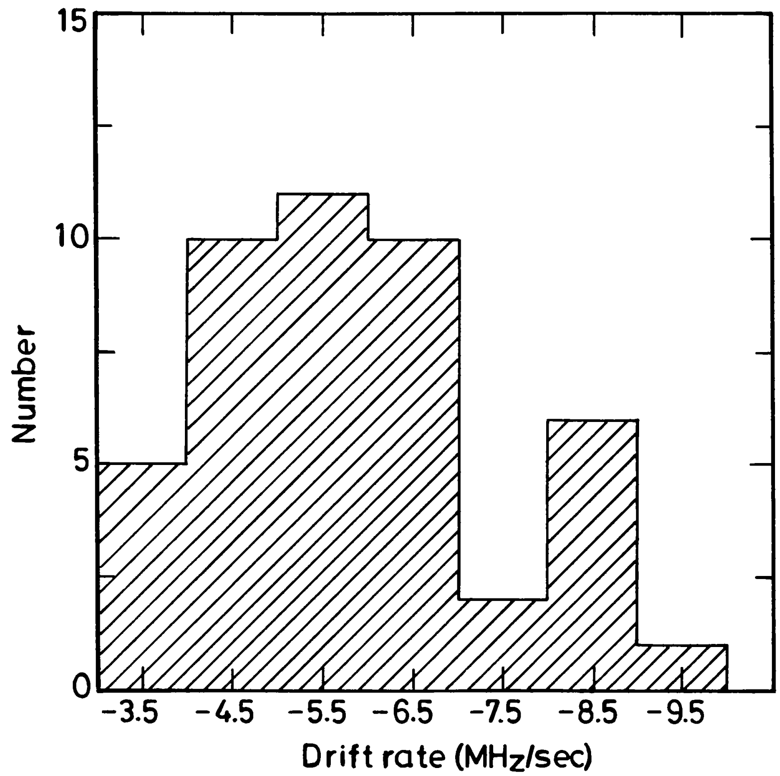

Fig. 3. Distribution of frequency drift rates. The negative sign of the drift rates indicates that the bursts drift from higher to lower frequencies.

have the drift rate in the range of -4.5 to -6.5 MHz s^{-1}, with an average value of ~ -5.8 MHz s^{-1}. This is smaller by a factor of ~ 2 compared to the drift rate of normal type III bursts, given by Alvarez and Haddock's (1973) empirical relation: $df/dt = -0.01f^{1.84}$ where df/dt is in MHz s^{-1} and f is in MHz. Of course, the actual values of df/dt for normal type III bursts have a large dispersion (Suzuki and Dulk, 1985) and our value is within the observed scatter. Similar values were obtained for Clark Lake microbursts (Thejappa, Gopalswamy, and Kundu, 1990). Hence we may conclude that the drift rates of microbursts are similar to those of normal type III bursts.

3.2. Half-power duration

The half-power duration (HPD) of microbursts was measured from the time profile at four frequencies, with an error bar of ± 0.25 s. One can see from Figure 4 that the HPD decreases with increase in frequency. The average value of HPD at 38, 45.7, 55.5, and 64.25 MHz are shown in Table I. For comparison we have also given the duration obtained from the empirical relation for normal type III bursts. The HPD (seconds) of normal type III bursts scales with frequency f (MHz) as $220/f$ (Suzuki and Dulk, 1985). We can see that the HPD of microbursts agrees with that of type III bursts at 55.5 and 64.25 MHz. At lower frequencies the HPD of microbursts is somewhat smaller than that given by the empirical relation. We do not know if this is significant because the actual observed values used to obtain the empirical relation had considerable scatter

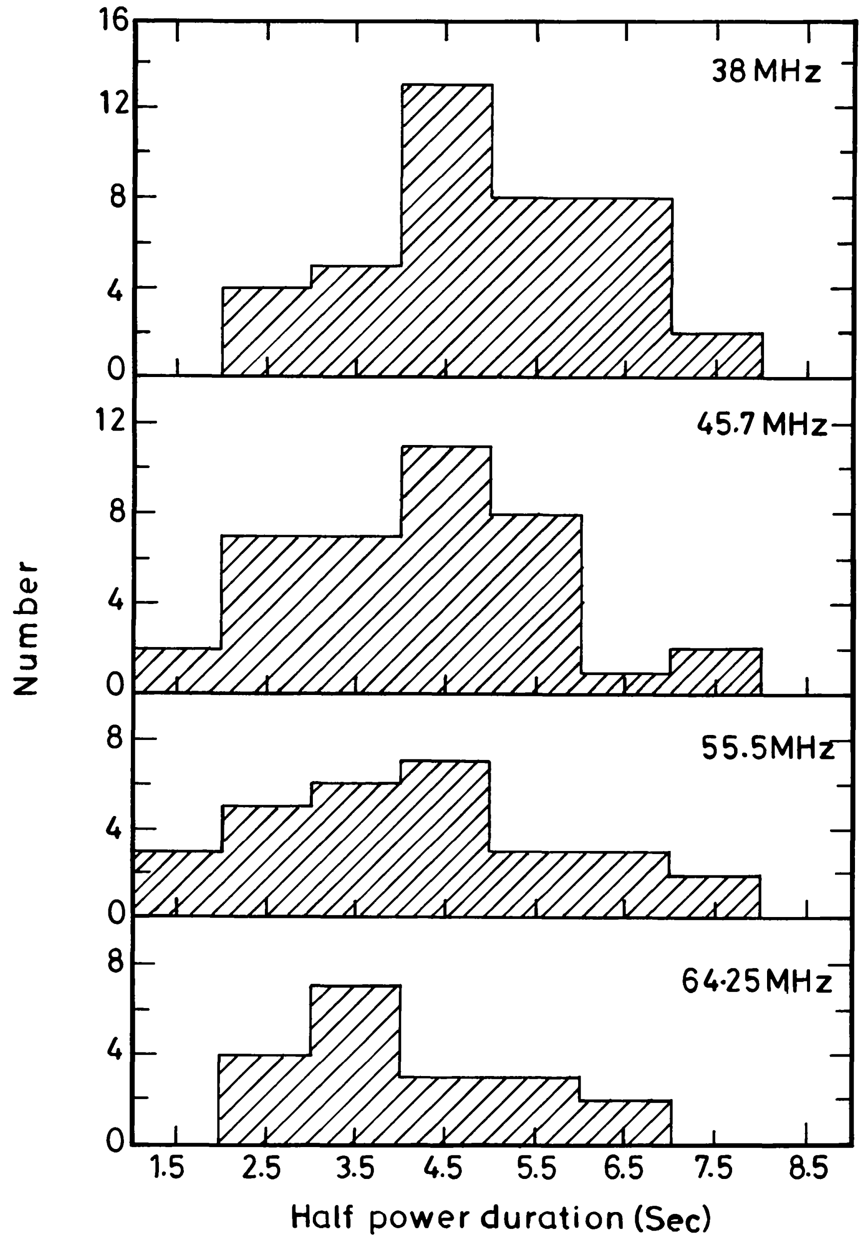

Fig. 4. Distribution of half-power duration of microbursts at four frequencies. Increase in duration at lower frequencies is evident.

TABLE I

Measured time profile characteristics of microbursts

Frequency (MHz)	Flux density (s.f.u.)			Half-power duration (s)	Half-power duration of type III bursts (s)
	Maximum	Minimum	Average		
38.00	8.85	1.08	3.13	4.93	5.79
45.70	7.91	0.72	2.88	4.18	4.82
55.50	5.90	0.33	2.02	3.95	3.96
64.25	2.68	0.12	1.01	3.69	3.43

(Suzuki and Dulk, 1985). It is also possible that the time resolution of the data used to derive the empirical relation was poorer than ours at these frequencies.

3.3. Time profile of microbursts

Following the procedure of Aubier and Boischot (1972), we measured the exciter duration D_e and decay time τ for 43 microbursts. The errors in the measurement of D_e and τ were $\pm$ 0.5 s and $\pm$ 0.2 s, respectively. The quantities of D_e and τ vary from burst to burst. The average value of D_e is about 7.95 s at 38 MHz decreasing to about 1.4 s at 45.7 MHz. The number of good time profiles at 55.5 and 64.25 MHz were small so statistical analysis was not done. The average value of D_e and τ of microbursts are plotted against frequency in Figure 5 along with the corresponding plots for normal type III bursts (as given by Aubier and Boischot, 1972; and Barrow and Achong, 1975).

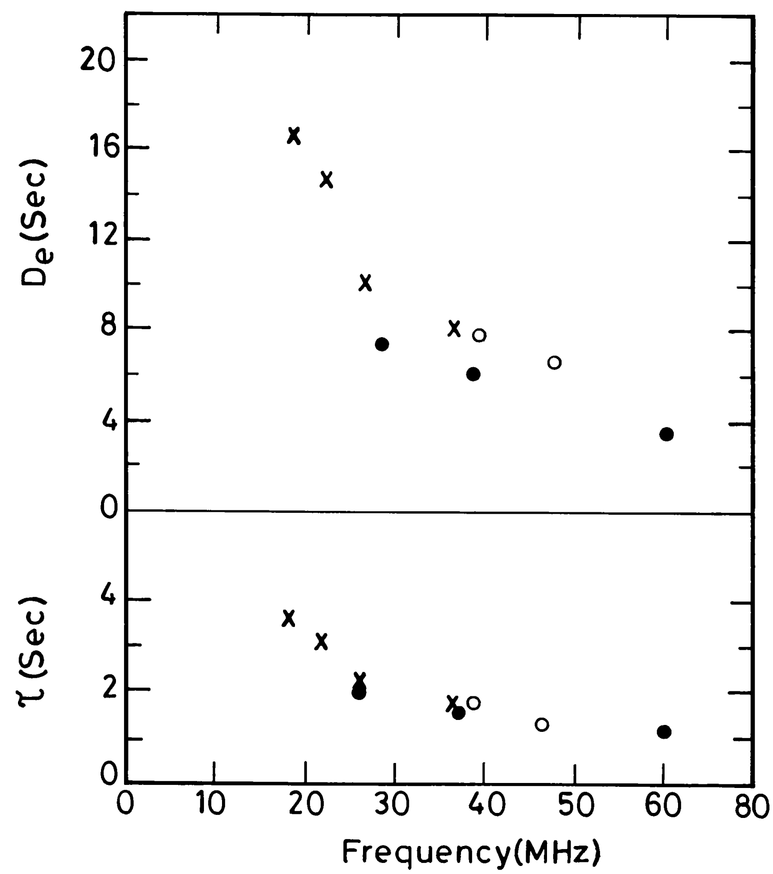

Fig. 5. Plot of average values of exciter duration D_e and decay time τ are against frequency for the microbursts (open circles). Previous values obtained by Aubier and Boischot (1972) and Barrow and Achong (1975), denoted respectively by filled circles and crosses, are also plotted for comparison.

The values of D_e and τ of microbursts lie close to those of type III bursts and seem to follow the trend shown by normal type III bursts. Figure 6 is a scatter plot of D_e and τ where we have combined the measurements at all the frequencies. We have also shown the least-squares fit to these data points. The correlation coefficient between D_e and τ is 0.56 for which 95% confidence limits are 0.32 and 0.72. In the case of normal type III

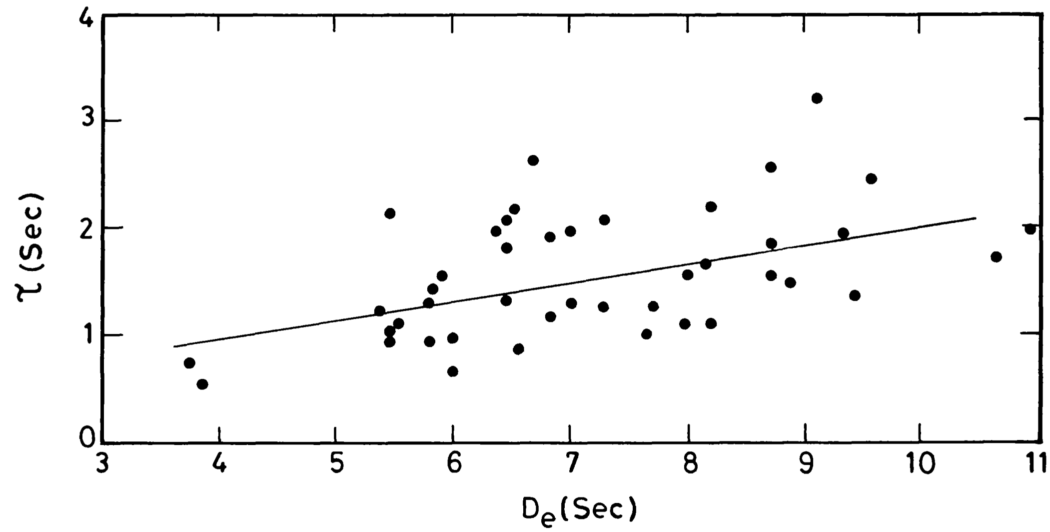

Fig. 6. Scatter plot of the decay time versus the exciter duration showing the correlation between the two quantities. Data from all the frequencies are combined in this plot. The solid line is the least-square fit to the data points.

bursts, Barrow and Achong (1975) have found that D_e and τ are correlated with a linear correlation coefficient of 0.63; Subramanian, Krishan, and Sastry (1981) reported a linear correlation coefficient of 0.7. We find that the correlation coefficient between D_e and τ is slightly smaller for microbursts. These characteristics are determined by the collision frequency in the coronal plasma and the extent of the exciting beam. Hence we may conclude that the electron beam responsible for microbursts are similar to those exciting normal type III bursts.

3.4. Peak flux density

At meter and decameter wavelengths, the Culgoora and Clark Lake radio telescopes have been used to measure the brightness temperature and size of solar radio bursts. We obtained accurate values for the peak flux density of 50 microbursts at 38, 45.7, 55.5, and 64.25 MHz by calibrating their peak amplitude with that of radio sources which lie close to the Sun. Figure 7 shows the distribution of peak flux density at different frequencies. The peak flux varied by a factor of 10 at any frequency. The error in the measurements are 10% at 38 MHz and 15% at 64.25 MHz. Table I shows the maximum, minimum and average values of the measured flux densities at different frequencies. For example, the average flux density of microbursts (2.88 s.f.u.) at 45 MHz is about three orders of magnitude smaller than that for normal type III bursts (3.2×10^3 s.f.u. at 43 MHz – see, e.g., Suzuki and Dulk, 1985). Since we do not have spatial information we estimate the peak brightness temperatures indirectly using the source sizes obtained by Clark Lake radioheliograph. Thus, assuming that the size of microbursts is ~ 7 arc min at 65 MHz and ~ 18 arc min at 38 MHz, we obtain brightness temperatures in the range of 10^6 to 10^7 K, agreeing with Clark Lake values. Thus we confirm that the microbursts constitute an extension of normal type III bursts to the lower end of the brightness temperature spectrum.

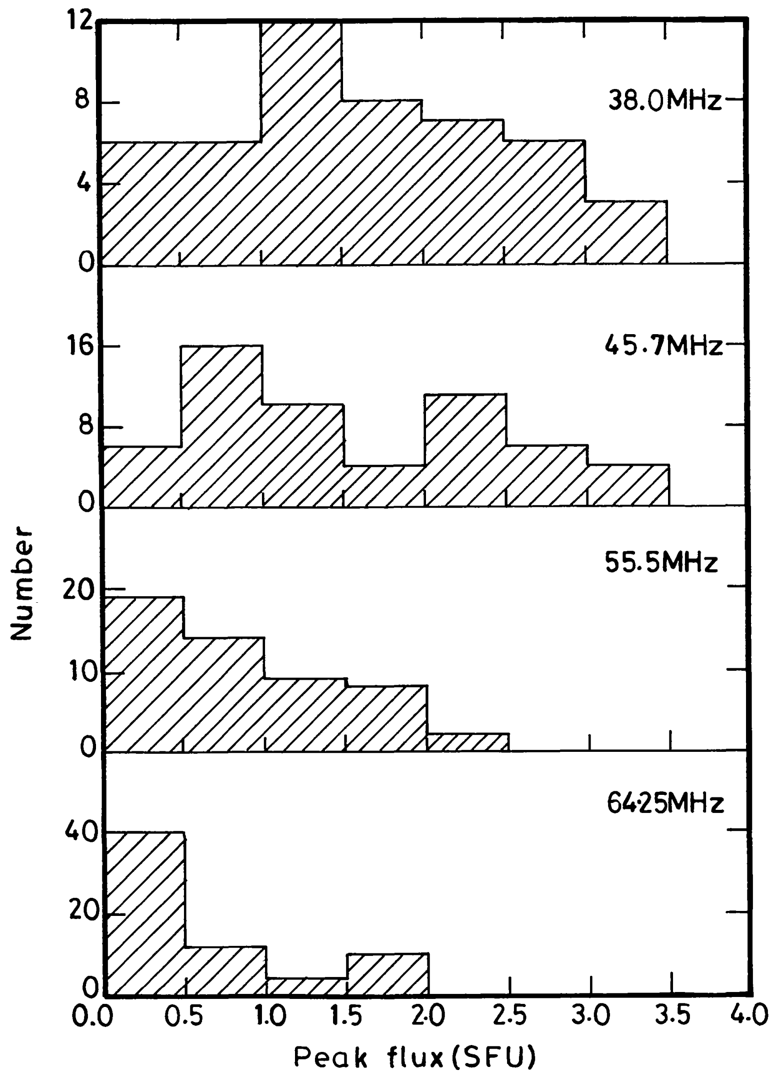

Fig. 7. Histograms of peak flux densities of microbursts at the four observing frequencies.

3.5. Peak flux density spectra

From the observed flux densities at four frequencies, we found two major types of spectra: (i) straight spectra and (ii) curved spectra. In the case of straight spectra, the spectrum over the whole frequency range can be described by a simple power law so that the log–log plot of the peak flux S_f versus the frequency f is a straight line. Figure 8 shows a typical straight spectrum. The spectral index n varied from -2 to -6 with an average value of -4.65 ± 1.6. The spectral index for type III bursts calculated from the average flux density at 169, 80, and 43 MHz reported by Suzuki and Dulk (1985) gives a value of -4.6. In the case of curved spectra, spectral peaks occur near 45.7 or 55.5 MHz. Figure 9 shows a typical example. Weber (1978) has found spectral peaks in the case of interplanetary type III bursts. Out of 50 microbursts studied, 24 showed straight spectra, 13 showed peaks at 45.7 MHz, 10 showed spectral peaks at 55.5 MHz, and 3 showed zig-zag variations in their spectra.

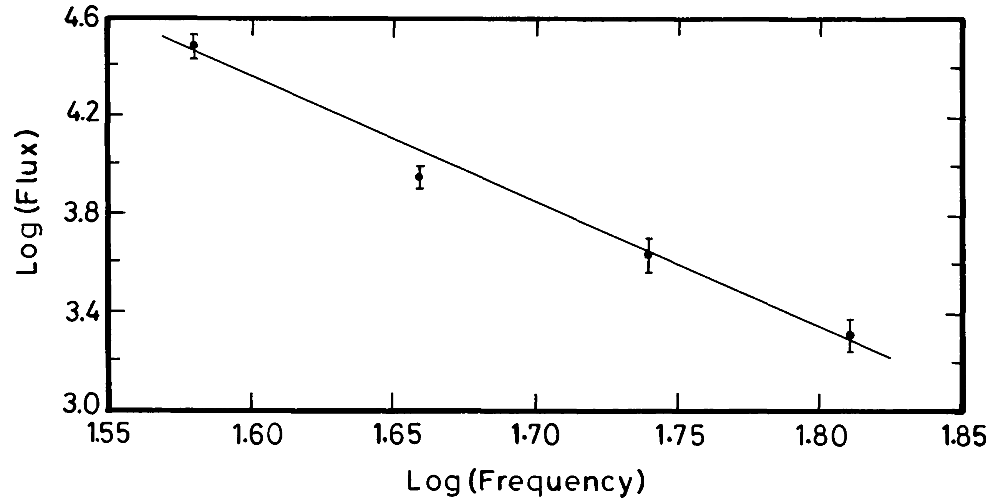

Fig. 8. Straight flux density spectrum of microbursts. The flux density is in units of 10^{-4} s.f.u.; the frequency is in units of MHz. The solid line is the least-squares fit to the data points.

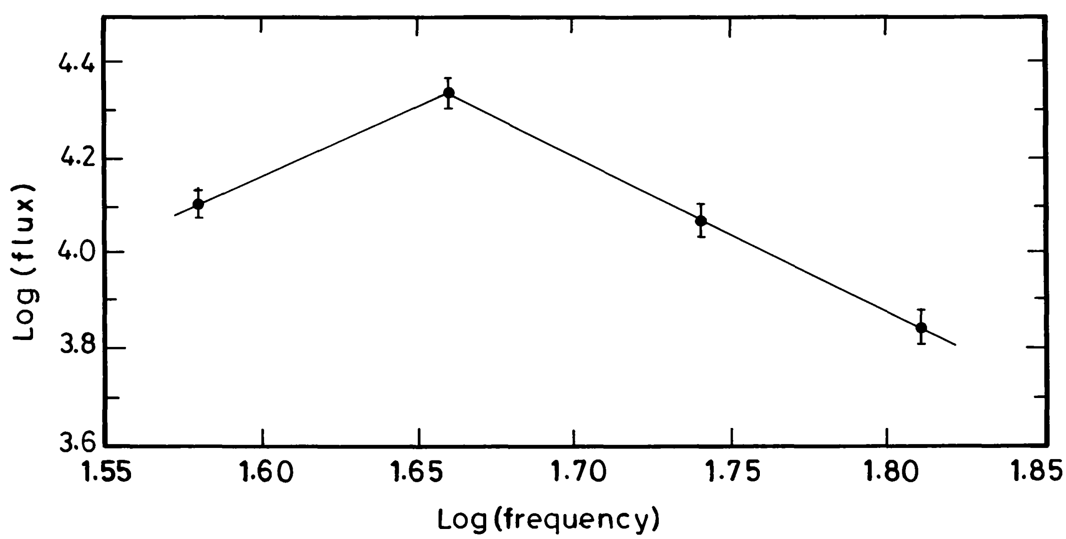

Fig. 9. Curved flux density spectrum of microbursts. The flux density is in units of 10^{-4} s.f.u.; the frequency is in units of MHz.

3.6. Energy spectra

To study the variation of the amplitude of bursts with frequency in a way which is independent of time, we evaluated the total energy per unit frequency interval that flows normally through unit area at the Earth during the burst. It is given by $E_f = S_f \Delta t$ where S_f is the intensity at frequency f and Δt is duration of the burst. Wild (1950) was the first to determine the energy spectra of type III burst in the frequency range of 70 to 120 MHz. Elgaroy and Lyngstad (1972) measured the energy of type III bursts at 225 MHz and compared their results with (i) those obtained for interplanetary type III bursts at 3.5 MHz (Haddock and Graedal, 1970) and (ii) those for coronal type III bursts in the range 70 to 120 MHz (Wild, 1950). They found that the energy can be expressed by a relation of the form $E_f \sim f^{-n}$ where $2.8 < n < 3.6$. However, there are no measurements of the energy spectra of type III bursts below 70 MHz. Thus, our observations may fill the gap below 70 MHz. The energy of microbursts at 38, 45.7, 55.5, and 64.25 MHz were obtained by integrating the time profiles at the corresponding frequencies. Figure 10 shows the energy spectra obtained by plotting the average energy

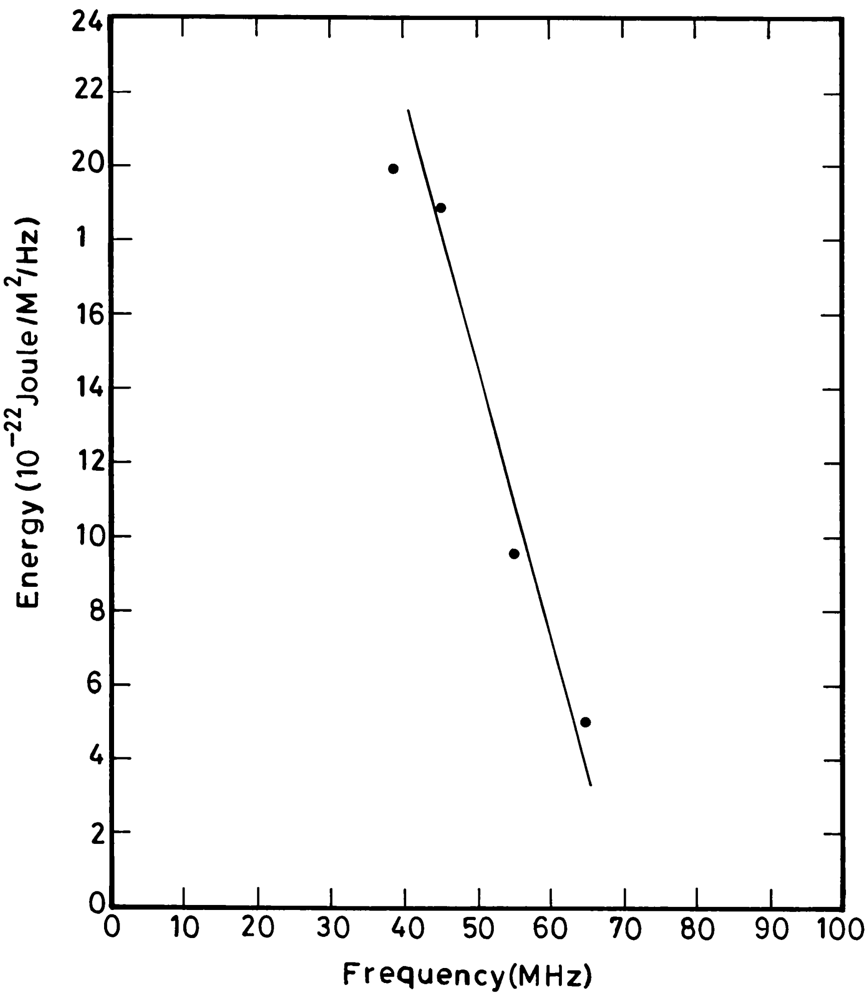

Fig. 10. Energy spectrum of the microbursts. The solid line is the least-squares fit to the data points.

at each frequency against frequency, along with the least-square fits. The value of n in the expression $E_f \sim f^{-n}$ is 2.62 ± 0.12, which is slightly lower than the value of n for type III bursts obtained in the frequency range of 3.5 to 225 MHz.

4. Interpretation

Theorists of solar radio bursts are concerned with explaining high brightness temperatures, as high as 10^{15} K. Since the type III bursts are due to the plasma emission process, high brightness temperature can be obtained only from very high levels of

Langmuir turbulence. On the contrary, we are interested in very low brightness temperatures ($\leq 10^7$ K) for the microbursts and hence we must look for conditions under which low levels of Langmuir waves are generated. Low levels of Langmuir waves were often observed in the solar wind (Lin *et al.*, 1981) where these waves were found to saturate at a level far lower than the one expected from a bump-on-tail electron distribution. Following the works of Nishikawa and Ryutov (1976) and Goldman and DuBois (1982), Muschietti, Goldman, and Newman (1985) showed that the properties of density inhomogeneities found in the solar wind determine the level of Langmuir waves. If the inhomogeneities are isotropic, then the beam plasma instability is quenched due to the diffusion of Langmuir waves in wave number space thus taking them out of resonance with the beam. When the inhomogeneities are elongated along the magnetic fields, they cannot transport the Langmuir waves into stable regions of the wave number space and hence high levels of Langmuir waves are possible. Thus, we can postulate that microbursts occur when the corona contains predominantly isotropic density inhomogeneities.

4.1. Fundamental or harmonic?

Fundamental-harmonic structure is often seen in the case of normal type III bursts. Although fundamental emission tends to be brighter than the harmonic for normal type III bursts, there are cases where the opposite is true. Simulations of nonlinear plasma processes often show that the second harmonic is brighter than the fundamental (see, e.g., White, Kundu, and Szabo, 1986). No fundamental harmonic structure has been reported in microbursts as there is no dynamic spectrograph with sufficiently high sensitivity available; the Clark Lake radioheliograph operated only at three or four frequencies and hence was not suitable for studying fundamental-harmonic structure. Gopalswamy, Kundu, and Szabo (1987) determined the coronal electron density from the locations of microbursts assuming the emission to be at fundamental and harmonic and compared with the densities derived from white light coronagraph (Solar maximum Mission Coronagraph/Polarimeter) observations. The results were inconclusive, although taken together with the fact that those were limb events where normally fundamental emission is seldom observed due to directivity reasons, one may conclude that they are harmonic emission. In spite of the lack of observational evidence, microbursts were assumed to be a fundamental of plasma process based on theoretical considerations: since the second harmonic emission is a nonlinear process, it is expected to be less efficient at lower levels of Langmuir waves implied by the low brightness temperatures of microbursts. Here we show that the microbursts may be due to second harmonic plasma emission which is a direct consequence of the conditions in the solar corona that cause low level of Langmuir waves. The primary objection to the second harmonic emission stems from the need for a secondary population of plasma waves propagating in a direction opposite to the beam generated (primary) plasma waves, which is required so that head-on collisions between the two populations take place. In the case of an isotropic distribution of plasma waves, there is no need for a secondary population of plasma waves and the head-on collisions take place efficiently. In the following we compare the brightness temperatures attainable from fundamental and harmonic plasma processes.

4.2. Estimates of Brightness Temperatures

If isotropic density fluctuations are present in the corona with sufficiently high levels, they can isotropize the Langmuir waves at a rate given by the diffusion coefficient D (Goldman and DuBois, 1982):

$$D = \left(\frac{\pi}{12}\right) \frac{\omega_{pe}}{k^2 \lambda_D^2} \frac{q}{k} \left\langle \frac{\delta n^2}{n^2} \right\rangle , \quad (1)$$

where ω_{pe} is the plasma frequency, k is the wave number of Langmuir waves, λ_D is the Debye length, q is the typical wave number associated with the fluctuation, δn is the fluctuating part, and n is the average part of the coronal electron density. The diffusion time, D^{-1}, must be small enough that the Langmuir waves are quickly isotropized. Considering a beam with a speed of $\sim 6 \times 10^9$ cm s^{-1}, the beam generated waves have a wave number of ~ 0.05 cm^{-1}. The size of the density fluctuations have been found to be $\sim$ a few km at $\sim 6\, R_\odot$ from the Sun (Yakovlev *et al.*, 1980). Extrapolating these values to the decametric corona, we can take $q^{-1} \sim 0.5$ km. At $\sim 2\, R_\odot$, Yakovlev *et al.* (1980) also obtained a fluctuation density of $\delta n \sim 4 \times 10^5$ cm^{-3} which corresponds to $\delta n/n \sim 1.3 \times 10^{-2}$. Thus, we get $D^{-1} \simeq 5.3 \times 10^{-4}$ s. This is about one to two orders of magnitude larger than the e-folding time of beam modes. The diffusion time will be still smaller, if the density fluctuations are stronger. Typically $\delta n/n \sim 2 \times 10^{-2}$ are used to account for the low brightness temperature of quiet Sun at decameter wavelengths (Aubier, Leblanc, and Boischot, 1971) which is consistent with the values we used above. Following Goldman and DuBois (1982) and Muschietti, Goldman, and Newman (1985), Gopalswamy (1993) determined the energy density of Langmuir waves in the solar corona, for a range of realistic beam parameters. It was found that the spectral density of plasma waves was enhanced by two to three orders of magnitude over the thermal fluctuations. The enhancement extends from a minimum wave number $k_{\min} \sim 0$ to a maximum wave number $k_{\max} \sim 0.15$ in units of the Debye wave number, λ_D^{-1}. Typically, the total energy density W integrated over the wave number space was found to be

$$W = \frac{E^2}{4\pi k_B n T} = \frac{4 \times 10^2}{6\pi^2 n \lambda_D^3} \left(k_{\max}^3 - k_{\min}^3\right) , \quad (2)$$

where E is the electric field of Langmuir waves, k_B is the Boltzmann's constant, n and T are the electron density and temperature of the corona. The energy density is normalized to the thermal energy density, $nk_B T$. At 50 MHz plasma level, $n = 3.1 \times 10^7$ cm^{-3} and for $T = 1 \times 10^6$ K, the Debye length $\lambda_D = 1.2$ cm. Thus we get an energy density of $W = 4.3 \times 10^{-10}$ which is a few times greater than the thermal level of plasma waves (1.4×10^{-10}).

The brightness temperature of electromagnetic radiation from isotropic plasma waves is given by (Zaitsev and Stepanov, 1983; Gopalswamy, 1990, 1993)

$$T_{b_1} = \frac{\pi}{72} \frac{\omega_p}{\nu_{\text{eff}}} \frac{v_\phi^2}{V_e^2} TW \quad (3)$$

for emission at the fundamental, and

$$T_{b_2} = \frac{2(2\pi)^5}{15} \frac{c^4 n T}{\omega_p^2 \nu_{\text{eff}} v_\phi} \frac{W^2}{X^2} \quad (4)$$

for the second harmonic emission. In Equations (3) and (4) ν_{eff} is the effective electron-ion collision frequency in the corona; v_ϕ is the phase velocity of Langmuir waves and $X = (\Delta k)^3 c^3/\omega_p^3$ is related to the effective range (Δk) of wave numbers over which the plasma waves interact. This is the region of wave number space $k_{\text{min}} < k < k_{\text{max}}$ discussed above. Equations (3) and (4) are valid for values of W low enough that induced processes do not dominate (Gopalswamy, 1993). Let us consider second harmonic emission at 50 MHz. We need to consider parameters relevant to the 25 MHz plasma level. Taking the maximum k to be $\sim 0.15\lambda_{\text{D}}^{-1}$, we get $X = 8.4 \times 10^2$. At plasma frequency $\omega_p = 2\pi \times 25$ MHz, $n = 7.8 \times 10^6$ cm^{-3}, $\lambda_{\text{D}} = 2.5$ cm, and $\nu_{\text{eff}} = 1.2$ s^{-1} for $T = 10^6$ K. Hence, we get $W \sim 2 \times 10^{-10}$ from Equation (2). Substituting these values in (4), we get $T_b \simeq 2.8 \times 10^6$ K. On the other hand, the brightness temperature of fundamental emission at 50 MHz is given by Equation (3) as 2.0×10^5 K, an order of magnitude smaller. The fundamental emission at 25 MHz which comes from the same region as the 50 MHz harmonic has also a brightness temperature of $\sim 2 \times 10^5$ K. In fact the ratio of fundamental to harmonic brightness temperature, given by

$$\frac{T_{b1}}{T_{b2}} = 4.3 \times 10^5 \frac{c^2}{V_e^2} \frac{(\Delta k)^3}{\omega_p^2 W} . \quad (5)$$

This equation compares the fundamental and harmonic emission at a given frequency. The fundamental emission originates from the level where the observing frequency equals the local plasma frequency. The harmonic emission comes from a location where the observing frequency equals half the local frequency. This ratio is less than unity for the range of energy densities relevant to microbursts: from the thermal level ($\sim 1.4 \times 10^{-10}$) to the maximum energy density attainable for realistic beam parameters, under the influence of density fluctuations ($\sim 1.0 \times 10^{-9}$). For higher energy densities, the induced processes will become important; however, those energy densities are not realizable under the influence of isotropic density fluctuations. Thus the second harmonic emission always dominates the fundamental in the range of energy densities required for microbursts. Similar comparison has been made previously in the contexts of storm radiation (Gopalswamy, 1990) and moving type IV radiation from coronal arches (Gopalswamy and Kundu, 1989).

In principle, it is possible to test our prediction from polarization measurements of the microbursts. The fundamental emission is expected to be of high degree of polarization as compared to the second harmonic emission. This has been established both theoretically and observationally. Unfortunately, there is no polarization information from both the telescopes (Clark Lake radioheliograph and Gauribidanur Broad band Array) that observed the microbursts.

5. Discussion and Conclusions

In this paper, we have independently confirmed several properties of microbursts at meter-decameter wavelengths, first observed by the Clark Lake multifrequency radioheliograph (Kundu *et al.*, 1986). We have confirmed most of the previous results: some with better and some others with poorer observing capabilities. For instance, we measured the drift rates and half power durations slightly better because of higher time resolution. On the other hand, we did not have the spatial resolution of Clark Lake, and hence we had to assume source sizes to obtain the brightness temperatures. However, our flux density measurements are accurate which show that the microbursts indeed have lower peak flux densities as compared to those of normal type III bursts; for most of the frequencies, the microburst flux is smaller by three orders of magnitude. We have found a new characteristic that the index of energy spectra for microbursts is slightly lower than that reported for normal type III bursts. Although the values of the peak flux density are lower, the shape of the flux density spectra are similar to those of normal type III bursts. Thus we conclude that the microbursts have a behavior similar to that of normal type III bursts in the corona as well as in the interplanetary medium in most respects except for the lower brightness temperature. We have thus verified with an independent set of observations from the Gauribidanur Broad band Array that the microbursts at meter–decameter wavelengths constitute an extension of the brightness temperature spectrum of normal type III bursts.

In previous attempts to interpret the microbursts, fundamental plasma emission was assumed. Our calculations suggest that the microbursts may be due to second harmonic plasma emission, if the low level of plasma waves needed to generate the microbursts are isotropic. Density fluctuations known to be present in the corona are adequate to isotropize the plasma waves generated by an electron beam similar to the normal type III electron beam. The implication to the nature of the accelerated electrons is that the microbursts are due to the same sort of electron beams as type IIIs, but occur in a different sort of medium. Thus, the presence of microbursts may be taken to suggest the presence of isotropic density inhomogeneities in the solar corona. The normal type III bursts result in situations where the density fluctuations are anisotropic so that they do not limit the growth of beam instability through diffusion. The prediction that the microbursts are second harmonic plasma emission can be verified if polarization information is available. Thus future observations with polarization information are highly desirable.

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