ON THE CORRELATION BETWEEN EXCITER DURATION AND DECAY CONSTANT OF SOLAR DECAMETER TYPE III RADIO BURSTS

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Abstract. It is observed that while there exists a strong correlation between the decay constant and the exciter duration for isolated type III radio bursts, it is absent for those type III radio bursts which are preceded by type IIIb radio bursts. A possible theoretical explanation for the presence of correlation in one case and lack of it in the other is proposed.

1. Introduction

It was first pointed out by Aubier and Boischot (1972) that it is possible to derive the duration of the exciter D_e and the decay constant τ from the time profile of type III radio bursts under certain assumptions. They also showed that these two parameters are positively correlated. These results are confirmed by Barrow and Achong (1975) and also Poquerusse (1977). We have measured the exciter durations and decay constants for isolated type III radio bursts and also for those type III bursts which are preceded by type IIIb bursts (hereafter referred as associated type III bursts) and the results are reported here. We find that D_e and τ are strongly correlated for isolated type III bursts, whereas such a correlation does not seem to exist for associated type III bursts. An attempt is made to explain the observed results on the basis of the characteristics of the beam-plasma system responsible for the generation of the type III radio bursts.

2. Observations

These observations were made during the period January 1971 to March 1972 using an antenna system of about 25 dB gain and a multichannel receiver. Most of the data in the present analysis was collected during the period July–August 1971. The center frequency was 25 MHz, the bandwidth and the time constant were 13 kHz and 10 m respectively. The channel separations were usually 100 kHz but can be varied from 20 kHz onwards. Details of this equipment were given in Sastry (1972, 1973). Typical examples of type III bursts and the preceeding type IIIb bursts are given in Krishan *et al.* (1980).

3. Results

Following the procedure of Aubier and Boischot (1972), the exciter durations and the decay constants were measured for 52 isolated type III bursts and for 32

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associated type III bursts. The error in the measurement of the exciter duration for each type III burst is ±0.5 s and that in decay constant is ±0.3 s. The measured values of D_e and τ vary from burst to burst and the mean value of D_e and τ in the case of isolated type III bursts are 4.8 s and 2 s respectively. A scatter diagram of D_e and τ is shown in Figure 1a. One can see that the two parameters are positively correlated and the linear correlation coefficient is 0.7. In the case of associated type III bursts, the mean values of D_e and τ are 6.5 s and 1.9 s respectively. Figure 1b shows a scatter diagram of D_e and τ for this case and it is clear that the correlation is very weak. The linear correlation coefficient is 0.2.

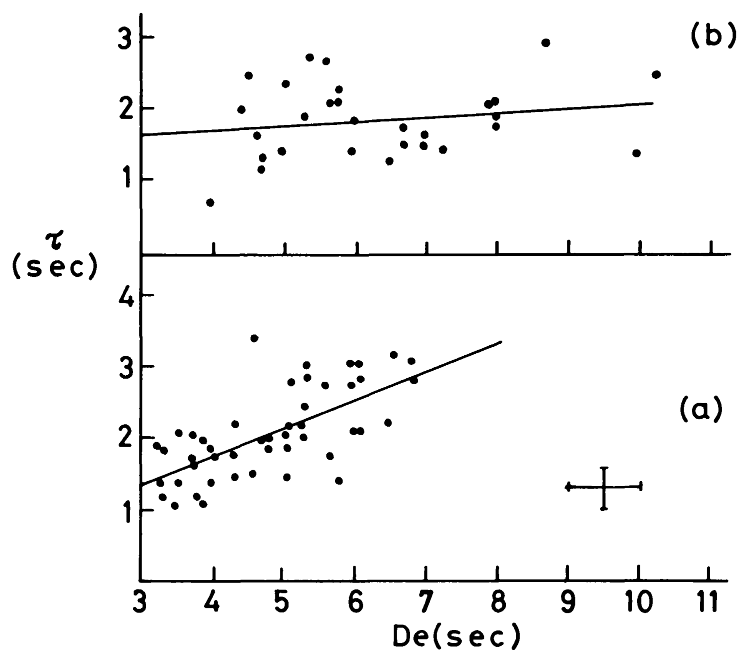

Fig. 1. Scatter diagram of D_e and τ for isolated type III solar radio bursts. (b) Scatter diagram of D_e and τ for associated type III solar radio bursts.

4. Discussion

A fast electron beam propagating through the corona is believed to be responsible for the excitation of type III solar radio bursts. The type IIIb radio bursts are probably produced when the strength of the electric field of the electrostatic beam plasma instability exceeds the threshold for the excitation of the side band instability, Smith and de la Noe (1976) and Krishan *et al.* (1981). The duration of the exciter is the time taken by the electron beam to cross any given plasma level in the corona. Aubier and Boischot (1972) have already pointed out that the observed correlation between D_e and τ is difficult to explain on the basis of collisional damping of plasma waves. Many authors (Zaitsev *et al.*, 1972; Takakura *et al.*, 1973) believe that the main damping mechanism is probably non-collisional. The damping of type III bursts could be due to the absorption of energy by the particles with velocity smaller than the phase velocity of the wave during the induced wave particle scattering. In this case using an approximate analytical solution of the quasi-linear diffusion equation (Takakura and Shibahashi, 1976; Magelssen and Smith, 1977), one can write an expression for the decay time τ Krishan (1981) as

$$\frac{1}{\tau} = \nu = \frac{1}{2E^2}\frac{\mathrm{d}}{\mathrm{d}t}E^2 = \frac{\mathrm{d}}{\mathrm{d}t}[\tfrac{1}{2}mn_2u_2^2]$$
$$= 6\pi^{3/2}\frac{u_2^2}{u_1^2}\frac{n_2}{n_1}\frac{u_1}{V_{01}}\left(\frac{n_1}{n_0}\right)^2\omega_{pe}\exp\left[-\frac{(V_{\mathrm{ph}}-u_2)^2}{V_{0\mathrm{b}}^2}\right], \tag{1a}$$

where $V_{01} \simeq V_{0\mathrm{b}}$ are the thermal velocities, n_0 is coronal electron density, $E^2/8\pi$ is the energy density of the electrostatic field associated with the beam-plasma instability, (n_1, u_1) and (n_2, u_2) are the densities and velocities of the faster and the slower components of the electron beam respectively, ω_{pe} is the plasma frequency, and $V_{\mathrm{ph}} \sim u_1$ is the phase velocity of the wave. The exciter duration can be written as

$$D_e = \left(\frac{3N_2}{4\pi n_2}\right)^{1/3}\frac{1}{u_2}\left[1+\frac{u_2}{u_1}\left(\frac{N_1n_2}{N_2n_1}\right)^{1/3}\right], \tag{1b}$$

where $N_1 + N_2 = N$ is the total number of energetic electrons ejected into the corona. If the electron beam or the exciter is more or less a uniform cloud of electrons in the case of isolated type III bursts such that $n_1 = n_2$, $N_1 = N_2 = N/2$ and $u_2 \lesssim u_1$. Then

$$\tau = \frac{1}{6\pi^{3/2}}\frac{u_1^2}{u_2^2}\frac{V_{01}}{u_1}\left(\frac{n_0}{n_1}\right)^2\frac{1}{\omega_{pe}}\exp\left[\left(\frac{u_1-u_2}{V_{01}}\right)^2\right] \tag{2}$$

and

$$D_e = \left(\frac{3N/2}{4\pi n_1}\right)^{1/3}\left[\frac{1}{u_1}+\frac{1}{u_2}\right], \tag{3}$$

where N is the total number of energetic electrons. Therefore, τ and D_e are strongly correlated since they both depend on the exciter parameters, (n_1, u_1, and u_2).

In the case of associated type III bursts the exciter could be non-uniform. The front of the beam is more dense and faster than its rear. The front end is mainly responsible for the excitation of the beam plasma instability and thus for E^2. The decay constant depends on E^2 and has a strong functional dependence on the characteristics of the front portion of the beam. The size of the beam is principally due to the rear end since the rear end being less dense has bigger size assuming the same total number of electrons N being ejected in the corona. Therefore, the exciter duration is approximately the time taken by the rear end of the beam to cross a particular plasma level and this duration is a function of n_2 and u_2. So, in the case of associated type III bursts,

$$\tau = \frac{1}{6\pi^{3/2}}\frac{u_1^2}{u_2^2}\frac{V_{01}}{u_1}\frac{n_0^2}{n_1n_2}\frac{1}{\omega_{pe}}\exp\left[\frac{(u_1-u_2)^2}{V_{01}^2}\right] \tag{4}$$

and

$$D_e = \left(\frac{3N_2}{4\pi n_2}\right)^{1/3} \frac{1}{u_2}\left[1 + \frac{u_2}{u_1}\left(\frac{N_1 n_2}{N_2 n_1}\right)^{1/3}\right]. \tag{5}$$

Since $n_2 < n_1$ and $N_1 < N_2$ we find that τ and D_e are uncorrelated with respect to the parameter n_1. The correlation between τ and D_e with respect to n_2 is much weaker for associated type III bursts than the correlation with respect to n_1 for isolated type III bursts. Thus the exciter duration and the decay constant are weakly correlated with respect to the electron density of the exciter for associated type III bursts. It may appear at first sight from Equations (4) and (5) that τ and D_e are also uncorrelated with respect to u_1 but this is not the case; since the ratio u_2/u_1 cannot depart very much from unity in order to get reasonable estimates of τ and D_e. For isolated type III bursts at $\omega_{pe} = 25$ MHz for $u_2/u_1 \sim 0.9$, $u_1/V_{01} \sim 10$, $n_1/n_0 \sim 10^{-5}$, $N \sim 10^{33}$, $V_{01} = V_{0b}$, we find $\tau \simeq 1.8$ s and $D_e \simeq 5$ *s*.

For associated type III bursts, the decay constant is found to be approximately the same as for isolated type III bursts, but since $n_2 < n_1$, the exciter duration will be more than that for isolated type III bursts. These calculations indicate a favourable trend towards the observed results.

The nonuniformity in the velocity of the electron beam responsible for the excitation of type III solar radio bursts has already been invoked to explain the stabilization of the electron beam (Zaitsev *et al.*, 1972). In addition, the density profile could also be nonuniform as pointed out by Švestka (1976).

It is possible to study the density characteristics of the beams responsible for associated type III bursts at various periods by measuring the correlation between D_e and τ. This obviously involves measuring significant number of time profiles for each period and is not possible with the present limited data. We hope to be able to do this when sufficient data becomes available.

5. Conclusion

The observed correlation between the exciter duration and the decay constant for isolated type III solar radio bursts and lack of it for type III bursts preceded by type IIIb bursts is believed to result due to the different nature of the exciter in the two cases. The isolated type III bursts have an exciter which is more or less of uniform density and speed. The decay constant and the exciter duration both are functions of only one set of parameters (n_1, u_1, u_2) and hence there is correlation between the two. The associated type III bursts have an exciter which is of highly nonuniform nature. The decay constant being mainly the function of the front end and the exciter duration being chiefly due to the larger rear end, the two are weakly correlated for associated type III radio bursts.

References

Aubier, M. and Boischot, A.: 1972, *Astron. Astrophys.* **19**, 343.
Barrow, C. H. and Achong, A.: 1975, *Solar Phys.* **45**, 459.
Krishan, V.: 1981, *Proceedings of International Conference on Plasma Physics*, Japan (to appear).
Krishan, V., Subramanian, K. R., and Sastry, Ch. V.: 1980, *Solar Phys.* **66**, 347.
Magelssen, G. R. and Smith, D. F.: 1977, *Solar Phys.* **55**, 211.
Poquerusse, M.: 1977, *Astron. Astrophys.* **56**, 251.
Sastry, Ch. V.: 1972, *Astrophys. Letters* **11**, 47.
Sastry, Ch. V.: 1973, *Solar Phys.* **28**, 197.
Smith, R. A. and de la Noe, J.: 1976, *Astrophys. J.* **207**, 605.
Švestka, Z.: 1976, *Solar Flares*, D. Reidel Publ. Co., Dordrecht, Holland, p. 273.
Takakura, T. and Shibahashi, H.: 1976, *Solar Phys.* **46**, 323.
Takakura, T., Naito, Y., and Ohki, K.: 1973, in R. Ramaty and R. G. Stone (eds.), *High Energy Phenomena on the Sun*, (Symp. GSFC X-693-73-193), p. 573.
Zaitsev, V. V., Mityakov, N. A., and Rapoport, V. O.: 1972, *Solar Phys.* **24**, 444.