FREQUENCY DRIFT RATE MEASUREMENTS OF CORONAL TEMPERATURES

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ABSTRACT

The frequency drift rates of radio emission are traditionally used to determine the velocity of the exciting agency for a chosen coronal density model. The speed of the exciting agency, say an electron beam, is assumed to remain constant during its propagation through the radio emission region. Here, we allow the electron beam to decelerate either due to its collisions with the ambient coronal particles or due to any of the diffusion and plasma transport mechanisms. The deceleration is related to the time derivative of the frequency drift rate. Thus, assuming the plasma mechanism for the radio emission combined with the slowing down of the electron beam enables us to self consistently determine the plasma density profile and the temperature of the radio emitting region. Conversely, the frequency dependence of the drift rate can be determined for a given temperature of the emission region. A comparison with the observed drift rate can then tell us about the validity of the beam slow-down model.

INTRODUCTION

The bursty radio emission originating in the solar corona often shows a drift in its frequency of emission. The frequency drift arises due to the motion of the radio source (energetic electron beam) through a plasma of varying density such as the solar corona and the fact that emission frequency is a function of the coronal density. From the measured drift rate, the speed of the electron beam, assumed to remain a constant, is determined for a known density model. However, the beam may suffer collisional and or diffusional losses (Takakura & Shibahashi, 1976) during its propagation. The resulting deceleration can modify the frequency drift rate. Thus, it is shown here that a self consistent model of the radio emitting region, particularly its temperature, can be derived by including the physics of the deceleration of the beam.

TEMPERATURE AND THE BEAM DECELERATION

In the fluid model, the evolution of an electron beam of velocity u, undergoing collisions with a stationary plasma (the corona) can be described by $du/dt = -\nu u$, (Tanenbaum 1967), where the collision frequency ν is, in general, a function of the beam and the coronal parameters. For the plasma emission model, the radio frequency f (MHz) is related to the coronal density n as $f = f_o(n/n_o)^{1/2}$. This provides a relation between ν and f . The frequency drift rate df/dt of the radio emission is given by $df/dt = fu/2H_n$, where $H_n^{-1} = (1/n)\ (dn/ds)$, whith H_n^{-1} the characteristic spatial scale of the density variation and dn/ds denoting

*On sabbatical leave from the Indian Institute of Astrophysics, Bangalore, India the density gradient along the propagation path of the radio source. From the above equations we find:

$$\nu = f^{-1}(df/dt) - (d^2f/dt^2)(df/dt)^{-1} . \tag{1}$$

Thus, the drift rate gets related to the coronal and beam parameters through the collision frequency. For the sake of an illustration, we choose an isotropic velocity distribution for the radio source since such a distribution has been shown to produce strong plasma emission (Melrose 1985). Thus, we model the Coulomb collision frequency as $\nu = \nu_o(f/f_o)^2$ with $\nu_o = 5 \times 10^{-4} f_o^2/T_{c6}^{1.5}\ g(x)\ \mathrm{s}^{-1}$, where x is the ratio of the beam energy and coronal thermal energy and g is a dimensionless function. Here we make the well-accepted assumption that the coronal temperature remains nearly constant in the emission region of a specified frequency band such as the decimeter, the meter and the decameter bands. All the zero subscripted quantities refer to the region of the starting emission frequency f_o. With this model, from the solution of Eq. 3 we find under the assumption $x \simeq 1$ for which $g \simeq 1$,

$$\begin{aligned} &df/dt = -\nu_o f^3/2f_o^2 \ ; \quad u/u_o = (f/f_o)^2 = n/n_o = exp(-s+s_o)/|H_{no}| \ ; \\ &f/f_o = exp(\nu_o t)[1-0.5(1-exp(2\nu_o t))]^{-0.5} \quad \text{and} \quad T_{c6} = [2.5\times10^{-4} f^3 (df/dt)^{-1}]^{2/3} \ . \end{aligned} \tag{2}$$

Thus, the knowledge of the drift rate enables us to determine the temperature of the radio emitting region for a given radio source.

DISCUSSION AND CONCLUSIONS

In order to determine the coronal temperature from the frequency drift rate, we need to know ν for which we need to know the distribution function of the radio source. The radio source could be a monoenergetic electron beam, a drifting Maxwellian with a large or small thermal spread or an isotropic thermal distribution. The latter produces strong plasma emission for $x > 1$. However, for a relatively weak radio source, $x \geq 1$, and $g \simeq 1$. Using the typical observed values of the drift rates, we find $T_{c6} \simeq 1$ for $|df/dt| = 250$ MHz s^{-1} at $f = 100$ MHz and $T_{c6} \simeq 40$ for $|df/dt| = 1000$ MHz s^{-1}. Further, it is seen that df/dt should vary as f^3. This, of course, is a consequence of our choice of the collision and plasma emission models valid only for an isotropic distribution of a weak radio source. It remains to be seen how the other distributions change it. In addition, the collision process may be other than the Coulomb. Anomalous collisions such as due to plasma instabilities may be operating. In this case the collision frequency ν will have a different density and temperature dependence and consequently lead to a different estimation of the temperature. The beam may propagate in a mode other than the free streaming mode. It may be undergoing one of the anisotropic diffusion processes with different parallel and perpendicular diffusion coefficients and slowing down as (Huba 1994):

$$d/dt(u - \langle u \rangle)_\perp^2 = \nu_\perp u^2 \quad \text{or} \quad d/dt(u - \langle u \rangle)_\parallel^2 = \nu_\parallel u^2 \ , \tag{3}$$

where the perpendicular and parallel ν depend on the temperature as $T^{-1/2}$ instead of $T^{-3/2}$. This will produce completely different estimates of the temperature along with different density and drift rate profiles. This investigation along with other issues such as beam distribution function and variation of the beam and coronal temperatures is in progress.

REFERENCES

Huba, J.D., *NRL Plasma Formulary*, 31 (1994).

Melrose, D.B., in *Solar Radiophysics*, Eds. D.J. McLean and N.R. Labrum (1985).

Takakura, T. and Shibahashi, H., *Solar Phys.*, **46**, 323 (1976).

Tanenbaum, B. S., *Plasma Physics*, p. 109, 251, McGraw-Hill Book Company, New York (1967).