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GENERATION OF INTERMEDIATE DRIFT BURSTS BY MAGNETOHYDRODYNAMIC WAVES IN THE SOLAR CORONA

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Abstract. The plasma mechanism of radio emission generation in an inhomogeneous medium is investigated. In the model under study, the electron beam with loss-cone distribution generates upper-hybrid waves that, in turn, are transformed into radio emission. It is shown that the influence of the plasma density inhomogeneity limits the plasma waves' intensity considerably due to variation in their wave vector. The results are used to interpret the intermediate drift (IMD) bursts. A model is proposed in which these bursts are reflections of propagating small-scale (with amplitudes of about 1% and sizes of hundreds of kilometers) magnetohydrodynamic (MHD) disturbances of magnetic tubes. It is shown that this model allows us to explain the spectral parameters of the bursts in question. At present, the lack of precise and independent data about the magnetic field does not allow us to decide definitively between the existing models (whistler or MHD waves) of the IMD bursts; nevertheless, if the proposed model is correct, it can be used to determine the characteristics of the coronal MHD waves.

1. Introduction

The last decade has seen the emergence of more and more evidence favouring the existence of magnetohydrodynamic (MHD) waves and oscillations in the solar corona (Roberts, 2000). Whereas large-scale oscillations of coronal magnetic loops are directly observable (Aschwanden *et al*., 2002; Schrijver, Aschwanden, and Title, 2002; Verwichte, Nakariakov, and Cooper, 2005), small-scale disturbances reveal themselves in an indirect way. The influence of the medium's small-scale inhomogeneities should be most explicit in nonthermal radio emission, as coherent mechanisms of its generation are very sensitive to source parameter variations.

Vlasov, Kuznetsov, and Altyntsev (2002) showed earlier that large- and small-scale inhomogeneities of magnetic field and plasma significantly affect the maser mechanism of radio emission generation. Variation of the wave vector of the electromagnetic waves was proven to be the main factor, resulting in the waves escaping from resonance with accelerated electrons. It was shown that the clusters of sub-second spikes may reflect the structure and dynamics of plasma turbulence with scales of the order of tens of kilometers.

However, the maser mechanism functions only in relatively strong magnetic fields (the required ratio of Langmuir and electron cyclotron frequency is $\omega_{\rm p}/\omega_B \lesssim 1$). In the solar corona, as a rule, $\omega_{\rm p}/\omega_B \gg 1$ and the maser mechanism

is ineffective. Various versions of the two-stage plasma mechanism seem to be a more probable source of the nonthermal radio emission.

Therefore, the purpose of this paper is to investigate the influence of inhomogeneities of the medium on the plasma mechanism of radio emission generation. The results of the investigation are used to interpret the so-called intermediate drift bursts (IMD bursts, fiber bursts). Modulation of the background type IV burst radiation by a travelling MHD wave is considered to be one of the most probable generation mechanisms for these bursts (Treumann, Güdel, and Benz, 1990). It will be shown here that the observed properties of the IMD bursts can be explained by taking into account the influence of inhomogeneities on the plasma waves generation.

In Section 2, generation of upper-hybrid waves in an inhomogeneous medium is investigated. In Section 3, observations of IMD bursts are described and the existing approaches to their interpretation are discussed. In Section 4, a new model of IMD bursts generation by MHD waves is presented and the simulation results are compared with the observations.

2. Plasma Wave Generation in an Inhomogeneous Medium

2.1. The influence of plasma inhomogeneity on upper-hybrid wave amplification

Let us consider the plasma mechanism of emission generation. An electron beam with loss-cone distribution is supposed to generate upper-hybrid waves, which are later transformed into radio emission due to nonlinear interactions. Such a process has been proposed, in particular, for the interpretation of solar type IV radio bursts (Kuijpers, 1974; Stepanov, 1974).

The dispersion equation for upper-hybrid waves has the form

$$\varepsilon_{\parallel} = 1 - \frac{\omega_{\mathrm{p}}^2}{\omega^2}\left(1 + \frac{\omega_B^2}{\omega^2} + 3\frac{k^2 v_{\mathrm{T}}^2}{\omega^2}\right) = 0, \tag{1}$$

where $\varepsilon_{\parallel}$ is the longitudinal dielectric permeability, ω, ω_{p}, and ω_B are the oscillation frequency, the plasma (Langmuir) frequency, and the electron cyclotron frequency, respectively, $\mathbf{k}$ is the wave vector and $v_{\mathrm{T}} = \sqrt{k_B T / m_{\mathrm{e}}}$ is the mean thermal velocity of plasma electrons (with temperature T). The upper-hybrid wave frequency equals

$$\omega^2 \simeq \omega_{\mathrm{p}}^2 + \omega_B^2 + 3k^2 v_{\mathrm{T}}^2. \tag{2}$$

The wave and particle resonance condition has the form

$$\psi_s = \omega - k_z v_z - s\omega_B / \Gamma = 0, \tag{3}$$

where ψ_s is the time derivative of the phase difference of the waves and electron gyrorotation, s is the harmonic number, k_z and v_z are the longitudinal (parallel to the magnetic field) components of the wave vector $\mathbf{k}$ and the electron velocity $\boldsymbol{v}$,