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Whistler wave generation by non-gyrotropic, relativistic, electron beams

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Super-thermal electron beams travelling away from the Sun on the open magnetic field lines are widely accepted to be the source of the Type–III bursts. The earliest idea of the generation of the Type–III bursts was based on the plasma emission mechanism. A fast moving electron beam excites Langmuir waves at the local plasma frequency, ω_p. The Langmuir waves are partially transformed via scattering at ω_p and $2\omega_p$, with ion sound and oppositely propagating Langmuir waves, respectively, into electromagnetic waves. As the electron beam propagates away from the Sun, through less dense coronal and interplanetary environment, the frequency of the emitted electromagnetic radiation decreases, because plasma frequency is a function of the square root of the plasma density. Type-III bursts have been subject of theoretical, observational and numerical studies. The first detailed theory of the Type-III emission invoked coherent plasma waves, generated by a stream of fast particles, which are due to Rayleigh and combination scattering at ω_p and $2\omega_p$ subsequently transformed into radio waves. Stochastic growth of the density irregularities was invoked in order to produce stochastically generated clumpy Langmuir waves, where the ambient density perturbations cause the beam to fluctuate around marginal stability. Other theories on the mechanism which generates the Type-III emission include: linear mode conversion of Langmuir waves, Langmuir waves producing electromagnetic radiation as antennas and non-gyroptropic electron beam emission [1] of commensurable properties to the Type-III bursts.

In Refs. [2,3] it was found that the non-gyrotropic beam excites electromagnetic radiation by the current transverse to the magnetic field, which results in $(\omega, k)-$space drift while propagating along the 1-dimensional spatial domain throughout the decreasing plasma density profile. The role of the electron beam pitch angle and the background density gradient profile was investigated in [4]. In this study [5], for the first time, the backwards propagating wave component evident in the perpendicular components of the electromagnetic field in such a system is presented. Features of the wave component propagating backwards from the front of the non-gyrotropic, relativistic, beam of electrons injected in the Maxwellian, magnetised background plasma with decreasing density profile are studied by using the Particle-In-Cell code EPOCH. Magnetic field in the 1.5-dimensional system is varied in order to prove that the backwards propagating wave is harmonic of the electron cyclotron frequency. The analysis has lead to the identification of the backwards travelling waves as whistlers. Moreover, the whistlers are shown to be generated by the normal and anomalous Doppler resonance. Large fraction of the energy of the perpendicular electromagnetic field components is found to be carried away by the whistler waves.

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