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Electromagnetic precursor excitations from a moving charged object

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A charged object moving in a plasma can excite a trailing wake of electrostatic or electromagnetic waves much like a boat moving on the surface of a lake creates wake structures behind it. However, a fast moving boat traveling more rapidly than the phase velocity of the surface water wave can also emit waves ahead of it in the form of precursor solitons or shock structures. Such a phenomenon of fore-wake excitations has been widely studied in hydrodynamics and precursor structures have also been experimentally observed in a number of laboratory studies of model ships being towed in a channel [1-3]. In principle, a similar phenomenon can also occur in a plasma medium when the charged object moves at a supersonic velocity (e.g. with respect to the ion acoustic speed, Alfven speed etc) and one can expect to see nonlinear structures moving ahead of the object. The conditions for such excitations exist naturally in many space plasma situations, e.g. the interaction of the supersonic solar wind component with the earth or moon, the fast streaming of space craft or charged debris objects interacting with the plasma in the ionosphere etc. Recently a proof-of-principle laboratory experiment observed the excitation of upstreaming dust acoustic solitons when a dusty plasma is made to flow supersonically over a stationary electrostatic potential hill [4]. The experimental results have been well validated by model calculations based on a forced Korteweg-de Vries (fKdV) equation [4] as well as fluid [5] and molecular dynamic simulations [6]. A suggestion for exploiting such precursors for Space Situational Awareness (SSA) purposes had been mooted in [7] and served as a major motivation for the investigations in [4-6] The basic idea is that the multiple emissions of solitons (ion acoustic ones in this case) can create a cloud of plasma irregularity that may be easily detectable from the earth and act as a tracking aid for the debris. However these electrostatic structures can be quite short lived due to strong Landau damping in the Low Earth Orbit (LEO) region and **electromagnetic nonlinear structures** might provide a better alternative by creating longer life time and larger spatial extent irregularity clouds. Such driven electromagnetic excitations have not so far been studied in this context and our present work is devoted to such an investigation. Treating the moving charged debris objects as a current source we develop an appropriate theoretical framework to study the excitation of electromagnetic waves like magneto-sonic waves, shear Alfven waves etc. A nonlinear formulation based on the reduction perturbation technique provides an equation analogous to the fKdV for the study of electromagnetic emissions. We use analytic and numerical solutions of this equation to discuss the features of magneto-sonic solitons and magneto-sonic shocks in the LEO region and delineate the parametric regimes and conditions for their excitation. We also discuss the possibility of identifying such structures in existing ionospheric satellite data as well as the feasibility of detecting them in a laboratory setup.

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