Role of Higher Order Effects on Kinetic Alfv´en Solitary Waves

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Over the past few decades, the study of Kinetic Alfv´en waves (KAWs) have gained much attention because of their importance in energy and charge transport processes in magnetopause, space and astrophysical plasmas[1].The KAWs play an important role when wave-particle interactions are more dominant than particle-particle collisions. The wave-particle interactions significantly affect the plasma dynamics. Alfvén waves are the low frequency waves below the ion cyclotron frequency and the plasma β is typically much smaller than the electron to ion mass ratio. KAWs arise in plasma when the perpendicular wavelength becomes comparable to ion gyroradius where, ions circle around the magnetic lines of force and electrons will attach to the magnetic field lines. Electrons and ions respond differently to the magnetic field perturbations due to different Larmor radius. This fact leads to the charge separation and impacts wave dispersion and thus result in the formation of kinetic Alfv´en waves. Further, when the electron thermal speed is larger than Alfvén speed then the finite electron pressure along the magnetic field generates a parallel electric field. Study of kinetic Alfv´en waves in plasma environments such as in Saturn's magnetosphere is important for understanding the concept of acceleration of charged particles and also in similar plasma environments, where coexistence of electron populations with different characteristics is dominant[2]. The existence of electron populations at different temperatures has been observed in various space and astrophysical plasma (such as Saturn magnetosphere etc.). Saturn magnetosphere can be divided into three regions: (I) inner magnetosphere, for distance <6 R_s (where R_s =60330 km is the radius of saturn) (ii) middle magnetosphere, for 6-15 R_s (iii) outer magnetosphere, for distance >15 R_s. The inner magnetosphere is widely used to describe wave-particle interactions and is characterized by the ion pickup regions. The source of plasmas in the Saturn's magnetosphere can be its satellites, such as Enceladus, Titan as well as its rings. Plasma ions can be absorbed by these satellites, e.g. depending on orbital eccentricity, these satellites can sweep the plasmas while leaving behind a plasma deficit zone. As H^+ ions are dominant in all regions of Saturn magnetosphere and have high concentration to excite ionic waves, we have taken H^+ ions in our plasma system[3]. Non-Maxwellian electrons with two distinct temperatures have been found in Saturn's magnetosphere. One important component in observations in Saturn's magnetosphere is the non-Maxwellian (non-thermal) distribution of electrons ubiquitously observed. Plasmas consist of superthermal particles have been observed in space such as in planetary magnetospheres[4]. To model superthermal particle distributions, Vasyliunas (1968) postulated a distribution function parameterized by a spectral index κ to characterize excess superthermality. The various plasma properties are strongly affected by superthermal distribution. Linear dispersion relation of KAWs show strong dependence on the superthermality parameter. In present investigation, higher order non-linear and dispersive effects of kinetic Alfv´en solitary waves (KASWs) have been obtained. The Korteweg de-Vries (KdV) equation which describes the dynamics of the nonlinear structures is derived by using amplitude reductive perturbation technique in a magnetized plasma consists of positive ions, two distinct electron populations (cold and hot electrons) modelled by kappa distribution. The effects of various plasma parameters such as hot-to-cold electrons density and temperature ratio, superthermality index (κ), and plasma beta on the characteristics of KASWs are analysed. It is remarked that the effect of higher order approximation on amplitude and width of the soliton in the considered plasma system, has modified the properties KASWs. The result of present investigation may be useful to understand the formation of nonlinear excitations in space plasma environments where two temperature electrons are present.

References :-

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