Reduced equations for electromagnetic turbulence in tokamaks

F.L. Hinton, M.N. Rosenbluth and R.E. Waltz

General Atomics, P.O. Box 85608, San Diego, California 92186-5608, U.S.A.

Abstract

In simulations of electromagnetic turbulence in tokamaks, it is essential to include current carried by electrons parallel to the magnetic field. The electron transit time scale restricts the allowable time step, which makes these simulations computationally challenging because physical processes occuring on much longer time scales must also be followed. We have derived a set of reduced equations corresponding to the limit of zero electron mass, in which the electron transit time scale is removed, thus eliminating this restriction. Kinetic equations are derived for passing and trapped electrons separately, using an expansion procedure consistent with the gyrokinetic equation for the ions. The passing electron equation is used to obtain an Ohm's law which can be used to time-advance the vector potential. This Ohm's law is shown to be consistent with magnetic flux conservation. Ampère's law is used to eliminate the electron parallel flow velocity in the continuity equation. The trapped electron response is determined by a bounce-averaged kinetic equation. The gyrokinetic equation is to be used to determine the ion distribution function. Quasineutrality, using the ion density perturbation, is an integral equation for the scalar potential, which is easily solved numerically. The equations take the form of time-advance equations, in which time derivatives appear only on the left hand sides, which facilitates numerical solution using explicit methods. For a simple linearized slab model, the condition for numerical stability of an explicit finite difference scheme is shown to be the Courant condition using the Alfvén speed, which allows significantly longer time steps for relevant values of β_e, the ratio of electron pressure to magnetic pressure.

PACS Nos. 52.65.Tt, 52.55.Fa, 52.30.Gz