Nonlinear modeling of lower hybrid wave propagation in collisional tokamak plasmas

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Non-inductively driven plasma current is a key to access improved stability and plasma confinement necessary for efficient fusion reactors based on the tokamak concept [1]. Lower hybrid (LH) wave power has been suggested as a method to drive plasma current [2]-[6]. The efficiency of current drive was observed to decrease sharply above a critical plasma density, which is unfortunately lower than the operating density envisaged for a fusion reactor [7]. Recent experiments [8]-[10] suggest that LH current drive might be efficient even at reactor relevant plasma densities. In these experiments, suitable methods were used to reduce parasitic effects that are believed as responsible for the lack of LH current drive in high-density plasmas, mainly parametric instabilities (PI) [11], [12] wave scattering off density fluctuations (WS) [13], [14] and collisional damping (CD) [11], [15]. PI are nonlinear interactions determining the power depletion of launched LH "pump wave" to feed LH sidebands waves in the frequency and wavenumber spectra. The sideband and pump waves are coupled through low frequency (LF) modes, mainly ion sound quasi-modes (ISQM) and ion-cyclotron quasi-modes (ICQM), as confirmed by experimental investigations [16], [17]. The modeling of LH parasitic effect is thus important for the interpretation of current LHCD experiments and the design of LHCD systems for future devices. A new set of integro-differential nonlinear wave equations has been recently derived in the framework of a kinetic theory coupled to the Maxwell equations, to evaluate PI driven by LH waves in collisional tokamak plasmas [18]. They allow treating the full LH spectrum in parallel and poloidal wave numbers, diffraction effects and cascade mode coupling, which are ignored in the standard theory of PI for inhomogeneous plasma [11], [12]. Here we extend this theory considering the scattering off density fluctuations. The model is based on the self-consistent system of the Maxwell equations for the electromagnetic field (**E**, **B**) coupled to the following kinetic equation for the single particle distributions f_α of each plasma species, with mass m_α and electric charge q_α

$$\frac{\partial f_\alpha}{\partial t} + \mathbf{v}\cdot\frac{\partial f_\alpha}{\partial \mathbf{r}} + \frac{q_\alpha}{m_\alpha}\left[\mathbf{E} + \frac{\mathbf{v}}{c}\times\mathbf{B}\right]\cdot\frac{\partial f_\alpha}{\partial \mathbf{v}} = -\nu_\alpha\left[f_\alpha - f_{\alpha o}\frac{n_\alpha}{n_{\alpha o}}\right]$$