Asymptotic analysis of the Whistler waves propagation in space plasma thrusters

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Recent advances in plasma-based propulsion systems have led to the development of electromagnetic Radio-Frequency (RF) plasma generation and acceleration systems, called Helicon Plasma Thruster (HPT) and derived from high density industrial helicon plasma sources. The propulsive figures of merit (e.g. specific impulse and thrust efficiency) are strictly related to the power deposition inside the plasma source, requiring the optimization of the power coupled between the RF driven antenna and the plasma. Different models have been developed to study, design and optimize such a plasma propulsion system. These models are based on the full wave solution of the Maxwell-Vlasov equation system, and rely on the simplifying assumption of uniform axial magnetic field as well as one dimensional density profile. An asymptotic method for the solution of the Maxwell-Vlasov equation system is adopted and relies on the WKB expansion of the electromagnetic field. This allows the study of the propagation and power deposition in plasma characterized by two-dimensional density profile and confined by a general magnetic configuration. The reduced set of the WKB equations for the wave phase and for the square amplitude of the electric field have been solved. This approach has been employed - for the first time - in the analysis of plasma sources for space applications. A direct comparison between common helicon sources with axial, constant and uniform confinement magnetic field, and plasma sources with actual confinement magnetic field lines revealed a propagative picture with mode conversions, cut-offs and resonances inside the source that affect the power deposition. The results are relevant for space thruster applications, but they can be fruitfully employed in industry plasma sources for the identification of the best source configuration (in terms of confinement magnetic field lines in addition to actual plasma density profiles), thus providing the maximum power transfer from the RF antenna to the plasma.