Whistler Wave Excitation in Axially Magnetized Cylindrical Plasma Structures in the Presence of Collisional Losses

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We consider the excitation of electromagnetic waves by a circular loop antenna in the presence of an axially magnetized cylindrical plasma column surrounded by either an unbounded background magnetoplasma of lower density or free space with allowance for the absorption of electromagnetic energy due to electron collisions in the plasma. It follows from our previous studies [1] of the guided propagation of whistler-range waves in plasma channels that the presence of even moderately small collisional losses in the plasma can result in division of the guided waves into weakly and strongly damped modes with significantly different transverse field structures. In particular, the field structures of strongly damped modes are dominated by small-scale quasielectrostatic whistler-mode waves, whereas the field structures of weakly damped modes are determined by the large-scale helicon waves. Because of this fact, the efficiencies of excitation of modes of the above two sets should be different. It is the purpose of the present paper to analyze to what extent the amplitude coefficients of individual modes in a plasma column are affected by the collisional losses and which modes can be dominant depending on the electron collision frequency.

Using the modal approach developed for representing the source-excited electromagnetic fields [2], a rigorous solution for the total field comprising both the discrete and continuous parts of the spatial spectrum of the excited waves has been found. In the case where the field is excited by a loop antenna, we calculate the amplitude coefficients of modes, evaluate the total field, and discuss how its structure depends on the electron collision frequency and the plasma distribution across the plasma column. Based on the obtained field representation, an expression for the impedance of a loop antenna has been derived and the contributions of guided and unguided modes of the plasma column to the antenna impedance have been determined for the whistler frequency range. Conditions have been revealed under which the real part of the antenna impedance is dominated by the contribution of guided waves.

It is ascertained that division of guided whistler modes into strongly and damped ones, which is possible under certain conditions in a bounded or cylindrically stratified unbounded collisional magnetoplasma, leads to significant redistribution of the power emitted from the loop antenna among the excited waves. As a result, the amplitude coefficients of weakly damped modes turn out to be much greater than those of strongly damped modes. Nevertheless, the latter ones are found to give the predominant contribution to the total power emitted from the antenna, because their number considerably exceeds the number of modes with smaller damping. Allowance for the obtained results seems important for proper understanding of the features of the antenna coupling to modes guided by cylindrically stratified magnetized plasma structures under conditions typical of active ionospheric or model laboratory experiments on whistler wave ducting.

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References

1. A. V. Kudrin and V. A. Es'kin, "Whistler Wave Propagation in a Bounded Collisional Magnetoplasma," *Phys. Scr.*, **74**, October 2006, pp. 425–438.
2. I. G. Kondrat'ev, A. V. Kudrin, and T. M. Zaboronkova, *Electrodynamics of Density Ducts in Magnetized Plasmas*, Amsterdam, Gordon and Breach, 1999.