THEORY OF ANTENNAS IN PLASMAS UNDER RESONANCE CONDITIONS: PROBLEMS AND APPLICATIONS

E. A. Mareev[(1)], Yu. V. Chugunov[(2)]

[(1)]Institute of Applied Physics, Russian Academy of Sciences,
46 Ulyanov st., Nizhny Novgorod, 603950 Russia
E-mail: mareev@appl.sci-nnov.ru

[(2)]As (1) above, but E-mail: chugun@appl.sci-nnov.ru

ABSTRACT

Modern problems of antenna theory are reviewed with particular focus on the following aspects: 1. Electromagnetic field and impedance of electric and magnetic antennas in plasmas under resonance conditions. 2. Self-consistent solutions for electric current and charge distribution. 3. Nonlinear problems. 4. Low frequency probes including sheath and particle absorption problems. 5. Receiving antenna and resonance. 6. Quasi-thermal noise spectroscopy in magnetized plasmas. 7. Diagnostics of dusty plasmas.

INTRODUCTION

Antennas and probes are widely used for in-situ measurements of electric field and plasma parameters in space. A number of missions such as Ulysses, Wind, Voyager, Cluster, Viking, Activny etc. have allowed space scientists to accumulate a large quantity of data using electric and magnetic antennas, operated in the passive or in the active regime. But the accurate interpretation of the measurements is difficult, due to the complicated behavior of antennas in space.

ANTENNAS IN PLASMAS UNDER RESONANCE CONDITIONS

Space conditions mean that the antennas are immersed in plasmas, and are generally not far from a spacecraft having a complicated shape. A number of complex physical phenomena are involved, making data interpretation very difficult: collection or emission of charged particles by the antenna surface; sheath formation; several types of nonlinearity, arising at low levels of electric field strength; density and temperature gradients around a probe; nonequilibrium velocity distribution of the ambient plasma; spacecraft motion. These nonequilibrium phenomena together with plasma resonances, temporal and spatial dispersion substantially change the amplitude-frequency characteristics of the antenna impedance and of the measured electromagnetic signals. An accurate account of all these processes is far from completion up to now. Recent efforts to take into account the contribution of these phenomena to the main characteristics of electric antennas (electromagnetic field structure, impedance, effective scales, induced noise voltage spectra), and to applicate the theoretical results for the interpretation of spacecraft data are briefly reviewed in the present paper. In other words, we review the problems of antenna theory, with particular focus on the following aspects:
1. Investigation of the electromagnetic field and impedance of electric and magnetic antennas in isotropic and magnetized plasmas under resonance conditions. Search for exact analytical solutions of respective boundary problems.
2. Investigation of self-consistent solutions for electric current distribution on the antenna (spacecraft) surface.
3. Nonlinear problems. There are two kinds of nonlinear problems allowing more or less comprehensive analytical treatment: a case of small amplitude perturbations, and a case of strongly non-local effects in partially ionized media.
4. Studies of low frequency probes taking into account the sheath and the absorption of charged particles. The current-voltage and charge-voltage curves characterize antenna-plasma coupling and allow one to calculate the probe impedance and harmonic magnitudes under different physical conditions.
5. Receiving antenna. Calculation of an effective length of a receiving dipole antenna in the resonance frequency bands.
6. Development of the method of quasi-thermal noise spectroscopy with electric antennas in magnetized plasmas, including the calculation of model spectra of the noise voltage induced in the lower hybrid and upper hybrid frequency bands.
7. Study of the response of an electric antenna to the presence of charged dust particles in plasmas with applications to in-situ measurements in space and geophysical plasmas. [1]

[1] This work was supported by INTAS grant N 00-0465 and the Russian Foundation for Basic Research (project N 00-02-17758).