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Gordon McKay Laboratory
Harvard University
Cambridge, Massachusetts

Semi-Annual Status Report on

Grant NGR-22-007-056

Theoretical and Experimental Investigations of Antennas and Waves in Plasma

For the period

March 1, 1966 through August 31, 1966

September 1, 1966

Prepared for

Grants and Research Contracts Division
Office of Space Science and Applications
National Aeronautics and Space Administration
Washington, D.C. 20546

Experimental and Theoretical Investigations on Plasma Coated Antennas - B. Rama Rao

Preliminary experimental investigations have been made to measure the impedance and current distribution of finite length dipole antennas surrounded by a plasma sheath. The plasma sheath around the antenna has been produced by means of a hot-cathode, d.c. discharge contained inside a long, double-walled glass tube. Diagnostic measurements to study the plasma properties have been made using both Langmuir probe and Tonks-Dattner resonance techniques. The maximum range of electron densities obtainable from this type of plasma is from 10^9 to 10^{11} electrons per cm^3, corresponding to plasma frequencies in the range 284 to 2840 megacycles. The electron temperature is found to vary from 30,000 to 50,000° Kelvin. The collision frequencies are also in the gigacycle range and hence fairly high. The antenna measurements have been made at frequencies from 600-1000 megacycles, so that the antenna characteristics both above and below the plasma frequencies can be measured. Extensive investigations will be made in the vicinity of the plasma frequency to determine the effect of the compressibility of the plasma on the antenna, and also the relative contributions from the electromagnetic and plasma modes to the radiation resistance of the antenna. The current distribution and impedance will be measured for a wide range of plasma parameters.

Various types of plasma tubes, incorporating both the needle and slot type brush cathodes and being constructed in this laboratory. Plasma diagnostic measurements will be made to examine the relative merits of the different cathodes, in regard to their ability to produce a well-behaved and stable plasma. These plasma tubes will eventually be used for studying acoustic interactions in plasmas.

Theoretical investigations on the following problems are now underway: (1) radiation and impedance characteristics of a short dipole imbedded inside a radially inhomogeneous plasma column (2) radiation from a short dipole inside a compressible plasma sphere.

Investigations on Acoustic Interactions in Plasmas - W. A. Saxton

Transducers for detecting sound waves in plasmas have now been fully calibrated. These units have been used as microphones to measure a plasma's natural acoustic waves. The amplitude of the waves is being correlated against the amplitude spectra of naturally occurring electrical oscillations in an effort to determine the source and nature of electrical noise in laboratory plasmas. The results of such studies should ultimately be useful in analyzing low-frequency acoustic effects in any plasma.

Laboratory apparatus is being designed for studies of possible acoustic wave amplification in cryogenically cooled plasmas. In this experiment sound waves will be forced into an electrically quiet stable brush-cathode type discharge whose neutral gas temperature has been lowered to that of liquid helium. Under proper conditions of gas pressure electron density, electron temperature and acoustic frequency recent theory indicates amplification and oscillation effects. In view of certain results in acoustically disturbed plasmas at room temperature, there is strong evidence indicating that plasmas do amplify sound waves. A study of basic parameters involved suggests that these effects become greatly enhanced in cryogenic surroundings

Transmission-Line Immersed in a Plasma - T. Padhi

An experiment to measure the properties of a transmission line immersed in a plasma is in preparation. A bare two-wire line is being used and provision is being made to vary the d.c. bias on the line so that a study can be made of the variation of line parameters with the thickness of the positive ion sheath around the line.

Theoretical Study of Antennas in Plasmas - A.D. Wunsch

Work has been completed on the problem of finding the radiation resistance of an antenna immersed in a cold magneto-plasma. The antenna is assumed oriented perpendicular to the static magnetic field, and a form has been assumed for the distribution of current along the antenna. Numerical results have been obtained for several different lengths of antenna and for two values of static magnetic field. Results have also been obtained for an antenna of infinitesimal dimensions (Hertzian dipole).

The method of solution is one proposed by S. R. Seshadri and has the advantage of displaying, as a natural step in the analysis, those frequency ranges over which the antenna resistance is infinite. It is found that the Hertzian dipole exhibits an infinite radiation resistance over the same frequency ranges as those producing infinite radiation resistance for a Hertzian dipole oriented parallel to the magnetic field. By taking the antenna to be a strip of finite length and width, all singularities in the radiation resistance disappear, except the one at the upper hybrid resonance frequency of the plasma. This infinity is a consequence of the limitations of magneto-ionic theory.

The radiation resistance of the Hertzian dipole and the strip behave with frequency qualitatively in much the same way as if they were oriented parallel to the static magnetic field. However, it is found that there is one frequency, a mode cut-off frequency, where there is a significant difference in behavior. Here, for perpendicular orientation there is a sharp increase of radiation resistance with frequency that does not occur for parallel orientation.

In other work, a computer program is being written to give the Fourier coefficients describing the current distribution on a dipole antenna immersed in a warm isotropic plasma. Consideration is being given to the problem of removing the singularity in current at the driving point of the antenna. This singularity appears as a consequence of assuming a delta-function generator to be the means of excitation. With the singularity removed, driving-point susceptance as well as conductance values may be determined for the antenna.

The staff now working on this grant consists of Professor B. Rama Rao, Dr. William A. Saxton and three part-time students Miss M. Bharathi, Mr. T. Padhi and Mr. A. D. Wunsch.

[redacted]

Submittedby

Ronold W. P. King

Ronold W. P. King, Director
NASA Grant NGR-22-007-056