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Air Force Cambridge Research Laboratories
Air Force Research Division, ARDC
United States Air Force
Laurence G. Hanscom Field
Bedford, Massachusetts
ATTN: CRRDP

SUBJECT: Semi-Annual Technical Summary Report

Order Number: ARPA 147-60

Project Code Number: 7600

Name of Contractor: Air Force Command and Control Development Division

Date of Contract: 22 July 1960

Amount of Contract: $94,000

Contracting Agency: Detachment 2, AFRD

Contract Number: AF 19(604)-7428

Project Scientist and Engineer: Professor Keeve M. Siegel

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Short Title of Work: Plasma Physics

This is the first semi-annual report on Contract Number AF 19(604)-7428 and covers the period from 1 August to 31 December 1960. This contract deals with the subject of non-linear modeling in plasmas. Specifically the problem of interest is the attempt to gain an understanding of the interaction of very high intensity electromagnetic fields with plasmas surrounding satellites or re-entry type shapes and to consider the possibility of performing the very difficult task of modeling from the costly, dangerous and difficult experiments that would be envolved to low-powered laboratory experiments which will yield realistic information on the main problem of interest. We know that linear modeling theory, which forms the basis for almost all of the current laboratory work in many fields, is not applicable for this problem. Thus the modeling technique needed to consider the main problem of interest here (via a low-powered laboratory experiment) must be a non-linear one.

Work on this contract, as set up by the Radiation Laboratory, can be described as being carried out along three lines of endeavor. The first involves work on the basic problem of the interaction of Maxwell's Equations with the Boltzmann Transport Equation with the complex permittivity and permeability dependent upon the applied field. This is the fundamental problem under this contract with the first goal being to decide at which point in the analysis the attempts at non-linear modeling should be made. Work on this task is in process with no success to report to date.

The second line of endeavor under this contract, has in essence two parts: firstly, we are considering a variety of plasma problems which will add insight into our basic problem, and secondly, we are considering a relatively simple plasma problem for which non-linear modeling can be exhibited. Two examples of a preliminary nature of this were enclosed with the second quarterly letter report in the form of internal University of Michigan memoranda. The first was one by S. Samaddar (4134-501-M) entitled "Study of Slow-Wave Propagation Along A Plasma Column in Presence of Finite dc Magnetic Field Inside a Metallic Circular Cylindrical Wave-guide, Excited by a Symmetrical Magnetic Ring Source" and the second memo was by K.M. Chen (4134-502-M) entitled "Plasma Sheath Formed by a Stationary Plasma on an Infinite Plate".

The memo by Chen is the first step in the consideration of a specific plasma problem; the second step (now in process) involves a moving plasma on an infinite plane. Here the velocity distribution functions of the plasma are found from the Boltzmann equation, the potential distribution in the plasma sheath is determined from the Poisson's equation and the potential of the boundary is determined from an equilibrium condition. By solving for the velocity distribution function and the potential distribution simultaneously, the plasma sheath on a plane boundary is completely determined. The purpose of this study is to investigate the nature of the plasma in the vicinity of a boundary. Theoretical results presented here may be useful in experimental plasma physics and in a study concerning an antenna on a space vehicle which is wrapped by a plasma sheath.

Our main effort along this line involves the interaction of a high intensity electromagnetic wave with a low density plasma. This is the first part of an investigation concerning the interaction of a high intensity EM wave with a plasma. By "low density", we mean that the effect of collisions can be neglected; the high density plasma case in which the collision effect is important will be the next step along this line of study.

The purpose of this study is to exploit the basic properties of a plasma when it interacts with a high intensity EM wave. There are many publications concerning this subject but they deal mainly with the small signal case. The conventional results, valid for the small signal case, are no longer accurate for the large signal case. It is well known that the basic constants which describe the medium vary as functions of the field intensity. The approach pursued in this initial study is to find the velocity distribution function of a plasma by solving the basic equations exactly. After the velocity distribution functions of a plasma are obtained many of the properties of the plasma can be found readily. The conventional approach adapted in many papers is to assume the velocity distribution function as a summation of an isotropic part and a non-isotropic part varying with the frequency of the incident wave.

In the case of a high intensity incident wave this assumption is not valid and the velocity distribution function should be found directly from a Boltzmann equation without any approximation made before solving the equation.

The third line of endeavor established under this contract involves the consideration of the applicability of our experimental facility (being designed and built under another contract) for non-linear modeling experiments in plasmas. Work on this third line of endeavor has not received any major attention, and will not, until the theoretical work nears an "experimental check" stage.

During the coming third quarter the considerations and study along the first two lines of endeavor will phase into the initial attempts of actually non-linearly modeling the phenomenon. Personnel with experience gained on our other non-linear modeling contract have been transferred to this contract; this background analysis will be helpful in this contract.

R.E. Kleinman returned to the Laboratory from Europe on 5 December and is being placed in charge of the theoretical effort on this contract, effective on 1 January 1961.

Respectfully submitted

J. W. Crispin Jr.

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JWC:cr