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THE UNIVERSITY OF MICHIGAN

COLLEGE OF ENGINEERING

DEPARTMENT OF ELECTRICAL ENGINEERING

Radiation Laboratory

INVESTIGATION OF PHYSICAL MODEL FOR
SATELLITE DETECTION

Semi-Annual Report
August 15, 1961 - February 15, 1962

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Signal Corps Technical Requirement Nr. SCL-5488A, 6 August 1958
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Prepared by

R. J. Leite

OBJECT

Formulate by theoretical analysis, the nature of the disturbances, the existence of passive RF radiation, and the nature of the radiating mechanism resulting from a satellite passing through the ionosphere.

1. PURPOSE

The purpose of the work being performed under the present modification of the basic contract is to indicate whether or not the emission of passive microwave radiation at measurable intensities above the normal atmospheric noise background results from the passage of a satellite through the ionosphere by theoretically analyzing the nature of the disturbances, the existence of passive radiofrequency radiation, and the nature of the radiating mechanism.

2. ABSTRACT

Almost all theoretical work on this program has been terminated. Two theoretical studies, namely, microwave emission from the wake of a satellite and wake configuration of a non-spherical satellite have been successfully completed. Technical reports have been prepared and will be published soon. A third theoretical study, emission from a diffuse shockwave at the onset of re-entry, will be terminated and an interim summary report prepared.

The initial comparison between observed and computed look-angle tracking data was considered to be acceptable. Further comparisons will be required when the USASRDL experimental system is made completely operational.

3. TECHNICAL WORK

3.1 Theoretical Work

3.1.1 General

Almost all theoretical work reported in the previous Semi-Annual Report (2764-34-P) was either completed or terminated. Because of the precarious financial condition of the contract, due to certain renegotiation decisions, USASRDL requested that the level of effort be drastically reduced to bring the program in line with the budgetary limits. In order to comply with this request, all theoretical work not directly related to the midcourse problem was terminated immediately and the remaining work was phased out in such a manner that the work could be brought to some logical conclusion and the placement of the technical personnel in other programs could be affected with minimum hardship to them.

On 9 October 1961, representatives of the Radiation Laboratory met at USASRDL to discuss the progress of the theoretical work and the nature of future plane and prospects. On 10 October 1961, a detailed review of the work on ARPA Order No. 120-61 was presented at ARPA. It was indicated by ARPA personnel that it would be desirable to have The University of Michigan contract continue through the period when experimental data was being obtained by USASRDL. In reply to a request from USASRDL, a cost estimate for a contract extension of six months, on a stretch-out basis, was submitted on 28 November 1961.

3.1.2 Microwave Emission from the Wake of a Satellite

Professor R. K. Ritt has completed the theoretical analysis of the physical mechanism by which high frequency microwave emission can be generated within the flow field which comprises the wake of a satellite. A technical report describing this work is being put into final form at the present time. It will have the following title: "Evolution of an Inhomogeneous Rarefied Plasma and Associated High Frequency Electromagnetic Radiation," Report No. 2764-10-T.

3.1.3 Wake of a Non-Spherical Satellite

Dr. W. Sawchuk has terminated the problem of determining the ionization contours in the wake of a prolate spheroid satellite at three angles of attack. Figures indicating the ion and electron isopycnic contours, the equi-net-charge contours, and the general nature of the equipotential contours are presented in the technical report which summarizes this work. The title of this report is "Wake of a Charged Prolate Spheroid at Angle of Attack in a Rarefied Plasma," Report No. 2764-9-T.

3.1.4 Emission at the Onset of Re-entry

At the request of USASRDL, mentioned previously, the work on this subject is being terminated and an interim summary report will be prepared. This report, by Dr. C. Mason, will describe briefly the following topics: the approach used in formulating the problem, the non-linear differential equations which

define the shockwave, the plasma jump conditions used in solving the associated boundary-value problem, and the probable direction along which subsequent efforts would proceed if the study were to be continued. The title of the forthcoming report will be "Electromagnetic Radiation from a Shockwave in a Low Density Partially Ionized Medium," Report No. 2764-11-T.

3.1.5 Satellite Look-Angle Computer Program

During October, 1961, USASRDL obtained azimuth and elevation data as functions of time-of-day for three passes of Tiros II and one pass of Tiros III by using the 108 Mc tracking feed on the 60-ft antenna. Upon comparison with computer data, it was found that for Tiros II the computed azimuth angles were approximately 13 degrees greater than the observed azimuth angles while there was relatively good agreement between computed and observed elevation angles. The computed time of occurrence of a particular orbital position preceded the observed time by approximately 1.3 minutes. For Tiros III, the comparison was essentially the same as above except that observed times preceded computed times by approximately one minute. A graphical presentation of these comparisons and an associated discussion of an interpretation of these results was forwarded to Mr. Arthur Eckstein at USASRDL. It is believed that additional comparisons will be required when the system becomes operational.

3.2 Experimental Work

3.2.1 General

No experimental work was performed during this reporting period.

4. CONCLUSIONS

4.1 Theoretical Work

The preliminary phase in each of two theoretical studies has been brought to a successful conclusion, and the results have exceeded the technical goals established at the beginning of the program. A report on one effort has been prepared, and the second is almost complete. The technical reports of this work are indicated in Sections 3.1.2 and 3.1.3. A third theoretical program is being terminated at an intermediate point due to present budget limitations. The report indicating the work completed prior to the termination is being prepared as indicated in Section 3.1.4.

Analysis of comparisons between observed and computed azimuth and elevation angles indicated that some fixed bias may be present in the antenna system. This apparently constant azimuthal displacement could be attributed to something akin to a boresight error in the tracking feed orientation or a displacement of the antenna position recording system. The discrepancy did not appear to be related to the direction of track, i.e., clockwise or counterclockwise rotation of the

antenna. More data are required to obtain more conclusive results.

5. PROGRAM FOR NEXT INTERVAL

Due to the uncertain level of effort permissible on the contract during the remainder of the contract, it is impossible to ascertain what topics, if any, will be studied. Therefore, in lieu of an anticipated program, an enumeration of logical extensions of presently completed or terminated work will be given.

1. Microwave Emission from the Wake of a Satellite
    a. Perform piggyback or satellite experiments to determine the frequency spectrum and energy level of the emission.
    b. Using inputs from (a) calculate the energy spectrum of the emission. (This calculation could be performed now; however, experimental inputs would help to establish bandwidth limits and thereby reduce the number of calculations required).
2. Wake of a Non-Spherical Satellite
    a. Perform calculations at several other angles of attack to attain better understanding of wake flow field transitions.
    b. Reduce flow field grid size to obtain more accurate solutions in immediate vicinity of the satellite.
    c. Find grid size limit which will permit the plasma sheath on frontal surface of satellite to be defined and then examine the

thickness of this sheath as a function of accommodation coefficient.

d. Examine change in flow field as function of variation of eccentricity of prolate spheroid.

3. Emission at the Onset of Re-entry

a. Complete numerical solution of non-linear differential equations to obtain description of steady-state shockwave structure.

b. Extend above case by including time variation, obtain unsteady shockwave configuration, and examine electromagnetic emission characteristics of a diffuse, unsteady shockwave.

The satellite look-angle program will be used to furnish appropriate tracking data to USASRDL upon request. Accompanying any tracking data will be recommendations of frequencies to receive additional emphasis. Upon receipt of radiometric data resulting from tracking operations, the Radiation Laboratory will examine the data, perform appropriate analysis, and recommend future targets and procedures based upon results of this analysis.