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Final Scientific Report for

Contract No. ⬛ F49620-79-C-0141

Resonance in Weakly Nonlinear Systems

Submitted by J. Kevorkian

Department of Aeronautics and Astronautics

University of Washington

Seattle, Washington 98195

During the contract period June 1, 1970 - May 31, 1980, the principal investigator in collaboration with two graduate students conducted research in the four areas outlined in the contract. The progress of this research is summarized below.

1) <u>Adiabatic Invariants for Nearly Periodic Hamiltonian Systems Passing through Resonance</u>

This research concerns the existence of global adiabatic invariants which survive resonance passage. We have adapted techniques from Hamiltonian perturbation theory with modern singular perturbation analysis to derive such invariants. Some of these results are reported in [1] and deal with a system of two degrees of freedom for which an explicit expression for the adiabatic invariant is derived.

In [1], we first review the classical technique for calculating adiabatic invariants and exhibit the occurence of zero divisors in the results as a certain critical term evolves slowly through a resonance condition. We then isolate the coordinate associated with the singularity and remove the remaining coordinate from the Hamiltonian to any desired order by successive canonical transformations. The momentum conjugate to the removed coordinate

is the global adiabatic invariant, and the reduced Hamiltonian is then solved by constructive and matching three multiple variable expansions which describe the solution before during and after resonance passage.

2) Passage through Resonance

The principal investigator was an invited speaker at an advanced seminar on singular perturbations and asymptotics held at the Mathematics Research Center, University of Wisconsin - Madison during May 28-30, 1980.

The lecture gave a survey of the topic of passage through resonance including some of the recent results reported in [1] as well as earlier work concerning sustained resonance for reentry problems. The proceedings of this seminar will include this survey article, [2].

3) Resonant Wave Interactions

Using the Klein-Gordon equation as a mathematical model for weakly non-linear dispersive systems we have completed a study of resonant wave interactions. We express the solution as a multiple variable expansion involving both spatial and temporal slow variables and derive results which remain uniformly valid for resonant combinations of the wave numbers.

This work is in its preliminary stages and will be continued during the next grant period. We plan to study problems of resonance passage in nonlinear acoustics analogous to those discussed in Sec. 1

4) Entry Dynamics

A necessary first step in studying entry dynamics analytically is an accurate mathematical model of high altitude trajectories. The simplest non-trivial example occurs for the case of a spherical (non-lifting) satellite entering with no control an exponentially varying atmosphere.

Reference [3], carried out under the present contract, reports on this problem. Multiple variable expansions are used to describe the osculating orbital elements and these are in excellent agreement with numerical results. In view of the good accuracy of this model and procedure we plan to study more complicated problems within the same framework.

References

1. J. Kevorkian, "Adiabatic Invariance and Passage through Resonance for Nearly Periodic Hamiltonian Systems". Submitted to Studies in Applied Mathematics.

2. J. Kevorkian, "Passage through Resonance", To appear in the Proceedings of the Advanced Seminar on Singular Perturbations and Asymptotics", Mathematics Research Center, University of Wisconsin - Madison.

3. A. J. M. Chakravarty, "Orbital Decay Due to Drag in an Exponentially Varying Atmosphere", To Appear in A.I.A.A. Journal of Guidance and Control.