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LLNL-TR-747324

Improved Design/Reduction of Manufacturing Costs of Space-Traveling Wave Tube Amplifiers Final Report CRADA No. TC-0461-93

C. C. Shang, M. Drasco

March 6, 2018

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Improved Design/Reduction of Manufacturing Costs Space-Traveling Wave Tube Amplifiers

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Final Report
CRADA No. TC-0461-93

Date: September 25, 1997

Revision: 0

A. Parties

The project is a relationship between the Lawrence Livermore National Laboratory (LLNL) and Hughes Aircraft Company.

University of California
Lawrence Livermore National Laboratory
7000 East Avenue, L-795
Livermore, CA 94550

Hughes Aircraft Company
Hughes Electron Dynamics Division
P.O. Box 2999
Torrance, CA 90509

B. Project Scope

The purpose of the CRADA was to develop new microwave codes for analyzing both slow-wave structures and beam-wave interactions of traveling wave tube amplifiers (TWTAs), the microwave power source for satellite and radar communication systems. The scope of work also included testing and improving power modules through measurements and simulation.

C. Technical

A moment-method code called EIGER, under development in parallel with this project, is now available with the capability of modeling dielectrics, but no results with support rods are available at this time. An earlier version of EIGER, called PATCH, which could only model conducting surfaces, was used in this project. Also, the thin-wire modeling code NEC was used as a check on the PATCH results to model tape helices with wires of radius equivalent to the tape width.

Numerical modeling based on the moment-method solution of integral equations was shown to be an efficient and accurate method of analyzing helical slow-wave structures. Both the strip model using the PATCH code and the equivalent wire model in NEC provided accurate results for the propagation constant and current on the helix. Interaction impedance and field modes were also computed and were in agreement with the known behavior of a helix.

Helices with metal dispersion-shaping strips and an enclosing barrel were modeled as were helices with solid as well as tape conductors.

D. Partner Contribution

Hughes provided LLNL with data and models and helped LLNL to benchmark the design codes. However, the funding for this project was terminated before the work could be completed.

E. Documents/Reference List

Numerical Modeling of a Helical Slow-Wave Structure for a TWT Amplifier, G. J. Burke, M. Caplan, G. Kamin, C. Shang, Lawrence Livermore National Laboratory, August 15, 1996.

Quarterly Reports:

03/01/94 - 06/30/94

07/01/94 - 09/30/94

10/01/94 - 12/31/94

01/01/95 - 03/30/95

04/01/95 - 06/30/95

07/01/95 - 06/30/96

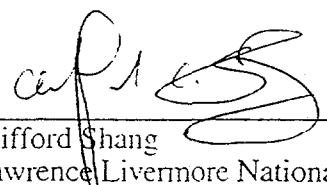
F. Acknowledgment

Participant's signature of the final report indicates the following:

- 1) The Participant has reviewed the final report and concurs with the statements made therein.
- 2) The Participant agrees that any modifications or changes from the initial proposal were discussed and agreed to during the term of the project.
- 3) The Participant certifies that all reports either completed or in process are listed and all subject inventions and the associated intellectual property protection measures attributable to the project have been disclosed or are included on a list attached to this report.
- 4) The Participant certifies that if real property was exchanged during the agreement, all has either been returned to the initial custodian or transferred permanently.
- 5) The Participant certifies that proprietary information has been returned or destroyed by LLNL.

 23 JUNE 98

William Wilhelm Date
Hughes Aircraft Company


Clifford Shang Date
Lawrence Livermore National Laboratory

- Attachment I - Final Abstract
Attachment II - Project Accomplishments Summary
Attachment III - Final Quarterly Report

Improved Design/Reduction of Manufacturing Costs of Space-Traveling Wave Tube Amplifiers

Attachment I

Abstract

CRADA No. TC-0461-93

Date: September 25, 1997

Lawrence Livermore National Laboratory and Hughes Aircraft Company have formed a partnership to combine their expertise in satellite communication technology. Hughes Aircraft is the only company in the U.S. producing space-qualified tubes. These tubes are microwave power sources for all satellite and radar communication systems. By applying Lawrence Livermore's state-of-the-art electromagnetic and circuit modeling capabilities, Hughes hopes to produce less expensive, more efficient, and lighter space-based helix tube amplifiers in a shorter time, giving the company a competitive edge in both domestic and overseas markets.

Improved Design/Reduction of Manufacturing Costs of Space-Traveling Wave Tube Amplifiers

Project Accomplishments Summary (Attachment II) CRADA No. TC-0461-93

Date: September 25, 1997

Revision:

A. Parties

The project is a relationship between the Lawrence Livermore National Laboratory (LLNL) and Hughes Aircraft Company.

University of California
Lawrence Livermore National Laboratory
7000 East Avenue, L-795
Livermore, CA 94550

Hughes Aircraft Company
Hughes Electron Dynamics Division
P.O. Box 2999
Torrance, CA 90509

B. Background

Lawrence Livermore National Laboratory and Hughes Aircraft Company formed a partnership to combine their expertise in satellite communication technology. Hughes Aircraft is the only company in the U.S. producing space-qualified tubes. These tubes are microwave power sources for all satellite and radar communication systems. By applying Lawrence Livermore's state-of-the-art electromagnetic and circuit modeling capabilities, Hughes hoped to produce less expensive, more efficient, and lighter space-based helix tube amplifiers in a shorter time, giving the company a competitive edge in both domestic and overseas markets.

C. Description

The purpose of the CRADA was to develop new microwave codes for analyzing both slow-wave structures and beam-wave interactions of traveling wave tube amplifiers (TWTA), the microwave power source for satellite and radar communication systems. The scope of work also included testing and improving power modules through measurements and simulation.

The aim of this project was to model the electromagnetic response of a complete helical slow-wave structure for a traveling wave tube (TWT), including the solid helical conductor, dielectric support rods, and the enclosing barrel. Also of interest was loss in the support rods, which may be applied nonuniformly along the rods to control gain and dispersion. Although several electromagnetic modeling techniques are applicable to this problem, only moment-method modeling was considered. For the helix model, the moment method offered the advantages of efficient solution in the frequency domain and modeling with flat elements conforming to the curved

boundaries, rather than the stepped-boundary approximation usually found in finite difference models.

Numerical modeling based on the moment-method solution of integral equations was shown to be an efficient and accurate method of analyzing helical slow-wave structures.

D. Expected Economic Impact

New microwave codes for analyzing both slow-wave structures and beam-wave interactions of TWTAs that result in improved power modules for satellite and radar communication systems will improve the electronic efficiency of the systems, reduce the cost and time to production, and reduce the weight of space tubes to achieve a competitive edge in domestic and foreign markets.

E. Benefits to DOE

Analytical tools for TWTAs will help maintain the nation's core competency in electromagnetics and pulsed power technologies. In addition, this work will help develop new applications in the commercial area for defense-related microwave technologies.

F. Industry Area

Electromagnetics and microwave technologies industries.

G. Project Status

Microwave codes were successfully used to model details of the interaction circuit. However, this effort was terminated by the University before anticipated completion due to funding constraints.

H. LLNL Point of Contact for Project Information

Clifford C. Shang
P.O. Box 808, L-153
Livermore, CA 94551
PH: (510) 422-6174
FX: (510) 423-5080

I. Company Size and Point(s) of Contact

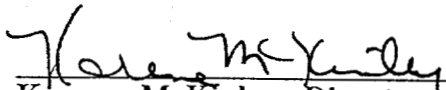
Mitch Drasco, PH: (310) 517-6170

J. Project Examples

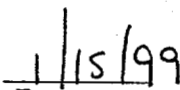
A final report entitled, *Numerical Modeling of a Helical Slow-Wave Structure for a TWT Amplifier* was produced.

K. Release of Information

I certify that all information contained in this report is accurate and releasable to the best of my knowledge.



Karena McKinley, Director
Industrial Partnerships
and Commercialization



Date

RELEASE OF INFORMATION

I have reviewed the attached Project Accomplishment Summary prepared by Lawrence Livermore National Laboratory and agree that the information about our CRADA may be released for external distribution.



William Wilhelm
Hughes Aircraft Company

23 JUNE 98
Date

Lawrence Livermore National Laboratory

Improved Design/Reduction of Manufacturing Costs of

Title: Space Traveling Wave Tube Amplifiers

Participant: Hughes Aircraft Company

DOE TTI No.: WSA

CRADA No.: TC-0461-93

TACT: AMPE

Account Numbers 5067-75, 5079-35, 4760-52

Date Accounts Closed:

Approved Funding Profile (\$K)

Reporting Period:

07/01/95 - 06/30/96

Date CRADA Executed:

02/03/94

DOE Approval Date:

12/14/93

Scheduled Ending Date:

02/03/96

Project Completion Date:

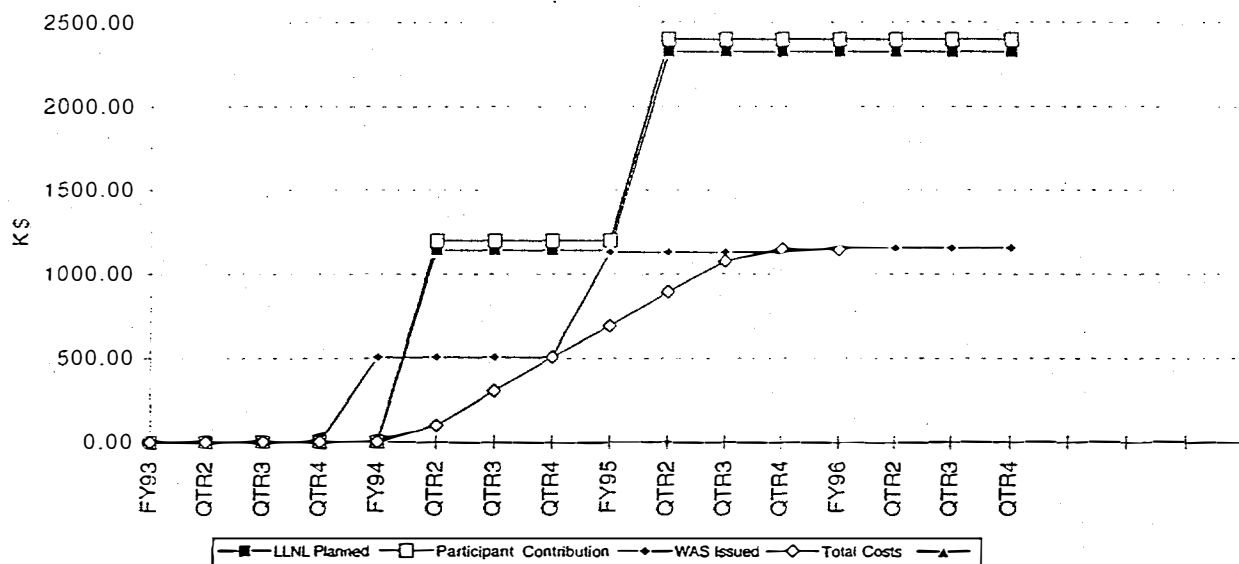
09/27/96

B & R Code (S):

DP0102011

DP0301

	FY93	FY94	FY95	FY96	FYOUT	Total
LLNL Planned	0	1140	1186	0	0	2326
Participant In-Kind	0	1200	1200	0	0	2400
Participant Funds-In	0	0	0	0	0	0
DP0102011 Funds	0	505	183	10	0	699
DP0301 Funds	0	0	440	20	0	460
Total Costs	0	505	643	-1	0	1147



GB0103041 Cost	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	FYTD
FY93	0	0	0	0	0	0	0	0	0	0	0	0	0
FY94	0	0	0	0	0	100	52	60	91	69	76	56	505
FY95	99	46	39	27	7	-22	0	-14	0	0	0	0	183
FY96	0	0	0	0	0	0	0	0	0	0	0	0	0
FYOUT	0	0	0	0	0	0	0	0	0	0	0	0	0

689

DP0301 Costs	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	FYTD
FY93	0	0	0	0	0	0	0	0	0	0	0	0	0
FY94	0	0	0	0	0	0	0	0	0	0	0	0	0
FY95	0	0	0	40	65	86	78	61	56	55	10	8	460
FY96	-1	0	0	0	0	0	0	0	0	0	0	0	-1
FYOUT	0	0	0	0	0	0	0	0	0	0	0	0	0

458

STAFF w/phone:

Lab PI: Cliff Shang (510) 422-6174

Participant: Mitch Drasco (310) 517-6170

Resource Manager: Pam Howard (510) 423-6099

DOEOAK: Jerry Scheinberg (510) 637-1653

DOEHQ: DP-20

Lawrence Livermore National Laboratory

Reporting Period: 07/01/95 - 06/30/96

Page 2

DOE TTI No.: WSA

CRADA No.: TC-0461-93

Milestones and Deliverables:

List the complete set of milestones for all phases of the CRADA. Continue on a separate page if necessary.
Report any changes from the original CRADA or previous quarterly report on the CRADA Change Form.

Completion Date:

Scheduled

Actual

1. Final report written	08/96	08/96
2. Close out activities completed	09/96	09/96
3	06/95	06/95
4		
5		
6		
7		
8		

Verification of participants' in-kind contribution was made in accordance with LLNL policy. Explain basis of verification:

Please initial:

YES X

NO

Technical discussions and satisfactory technical progress of industrial partner

Visited partner this quarter

List any subject inventions by either party (include IL# for LLNL inventions), additional background intellectual property, patents applied for, software copyrights, publications, awards, licenses granted or reportable economic impacts

Verification that all equipment and proprietary information has been returned to the initial owner or permanently transferred

Please initial:

YES X

NO

Accomplishments

Describe Technical/Non-Technical lessons learned and other observations.

Summarize causes/justification of deviations from original scope of work.

Continue on a separate page if necessary.

Reviewed by CRADA project Program Manager:

Date:

Reviewed by Karena McKinley, APL Partnering, IP&C:

Date:

Direct questions regarding this Report to IP&C Resource Manager, Susan Springer, at (510) 422-5507

Karena McKinley 1/15/99