DOE/ER/53270--T3

DE-AC03-88ER 53270

Modeling and Simulation Support for ICRF Heating of Fusion Plasmas

SAIC Proposal 1-624-71-910-02

March 15, 1990

Annual Report 1990

Science Applications International Corporation
An Employee-Owned Company

1710 Goodridge Drive, P.O. Box 1303, McLean, Virginia 22102 (703) 821-4300

Other SAIC Offices: Albuquerque, Boston, Colorado Springs, Dayton, Huntsville, Las Vegas, Los Angeles, Oak Ridge, Orlando, Palo Alto, San Diego, Seattle, and Tucson

2. RECENT RESULTS AND EXPERIENCE IN ICRF ANTENNA MODELING

2.1 University of Wisconsin Collaboration

Recent experimental, theoretical and computational results have shown the need and usefulness of a combined approach to the design, analysis and evaluation of ICH antenna configurations. The work at the University of Wisconsin (UW) in particular has shown that much needed information on the vacuum operation of ICH antennas can be obtained by a modest experimental and computational effort. For example, measurements taken with a model experiment, backed up by benchmarked computational studies, have pointed out a possible source of unfavorable coupling to Ion Bernstein Waves due to incorrect geometry of the antenna sidewalls and endcaps. The codes can now be used to find new configurations which eliminate these unwanted effects in minimum time and cost before the more expensive experiments are carried out. The results of the UW antenna simulation have proven that 3-D modeling and evaluation of such complex structures are not only feasible but can be carried out successfully and yield information which is either not possible to obtain experimentally or may provide previously unknown insights and understanding of the devices. The point here is that both experiment and computation should be carried out in an iterative fashion.

These model experiments at UW and SAIC simulations have shown dramatically the potential for positive impact upon the ICRF program. For example, the ICRF antenna currently planned for the UW tokamak was experimentally investigated for its vacuum performance characteristics on a laboratory test stand. The ARGUS simulator successfully modeled the test antenna plus test stand geometry, Figures 1 and 2, including Faraday shields employing solid or slotted supports, Figure 3, and included the realistic

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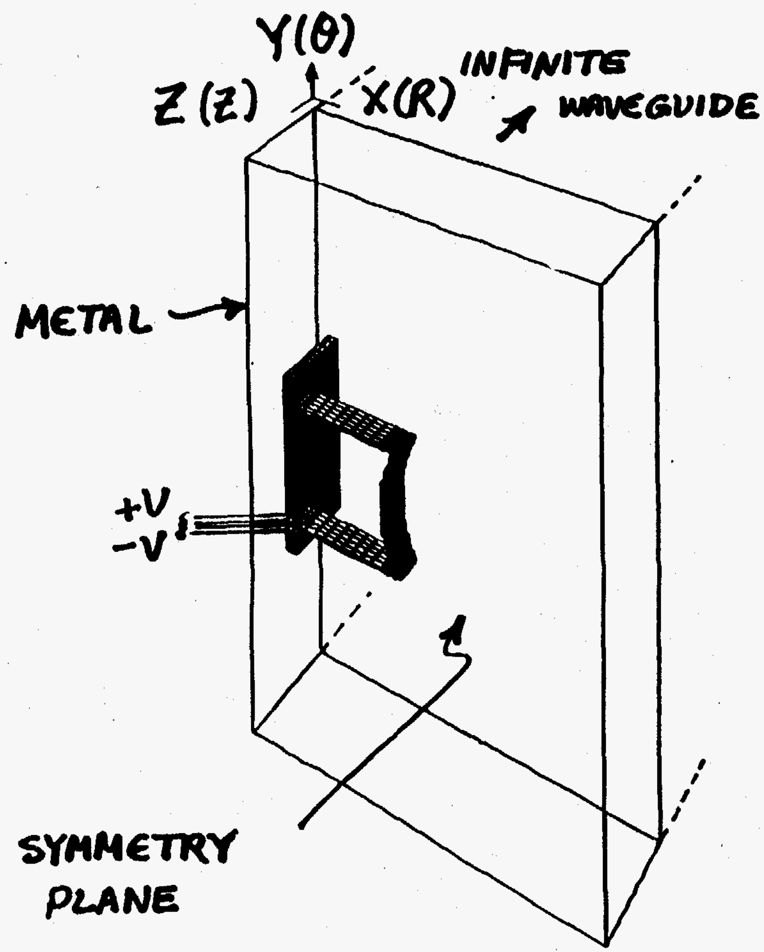
SIMULATION MODEL FOR ICRF ANTENNA



- ANTENNA STRUCTURE IS ENCLOSED IN AN INFINITE WAVEGUIDE WHICH IS NUMERICALLY TRUNCATED AT A FINITE LENGTH AT WHICH BOUNDARY THE OUTGOING RADIATION IS EXPRESSED AS THE COMPLETE SET OF WAVEGUIDE MODES. A SYMMETRY CONDITION AT THE OTHER BOUNDARY REDUCES THE SIMULATION BY HALF.

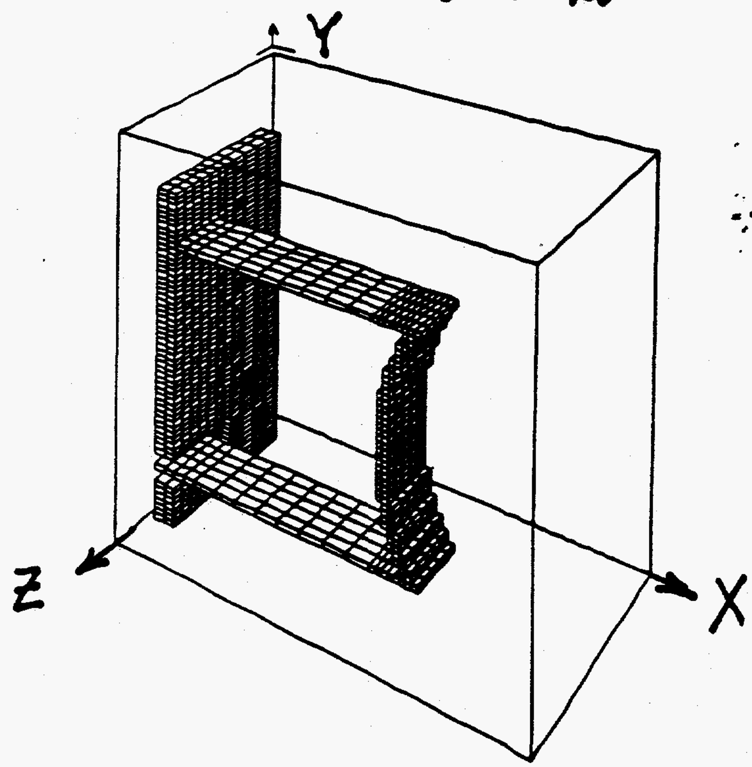
- STRAP IS DRIVEN BY POTENTIAL AT LEAD (4.5 MHz)

- 4 BLOCK PROBLEM; EACH BLOCK OF SIZE 6 x 53 x 93 GRID PTS.

Figure 1

BARE STRAP ON TEST STAND

- COMPARISON WITH "ANTENA" CODE
  - "ANTENA" USES MOCKED UP STRAP CURRENT PROFILE (35%- 30%- 35%)



- COMPARISON WITH EXPERIMENT
  - SELF CONSISTENT STRAP CURRENT

Figure 2

STRAP WITH FARADAY SHIELD

(SLOTTED SIDE SHIELDS)

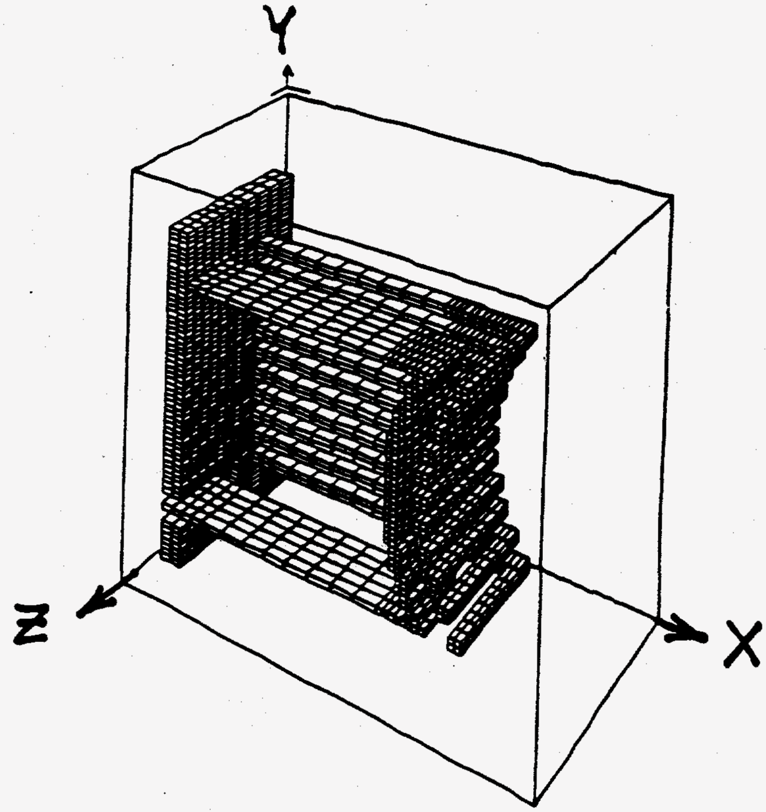


Figure 3

current feed connections which are fed by oscillating voltage inputs at the feed points. Thus, instead of prescribing given current wave forms, the electric fields in the co-axial leads responsible for driving the antenna currents are prescribed. The simulation thus yields an unbiased prediction of the overall current distribution in the antenna structure. For example, the simulation results showed a curious reversal in the axial magnetic field component which was not anticipated; see Figure 4. The simulations predicted the field to reverse, as shown in the figure; and subsequent experimental measurements proved this to be so; the reason for the reversal stems from the self-consistent currents flowing in the test stand back plate. 2-D codes such as the "ANTENA" code of McVey (Ref. 16) are incapable of simulating such a phenomenon and, moreover, in order to reproduce the results of even the near-field antenna pattern the current distribution in the conductors must be given in a manner that assumes a-priori knowledge of the distribution. For example, the "ANTENA" code can be forced to reproduce some of the ARGUS and experimental results if the 2-D model is assumed to have 35%, 30%, 35% of the current flowing in the left one-third, middle one-third, and right one-third of the current strap, respectively

For the simulated antenna structure, the dimensions, structural details including conductors and insulators and electrical connections to the e al power supply were translated by the ARGUS logical geometry gı g routines. Relatively few geometry iterations, based on recent AR experience with the UW antenna, were required to determine the com ional antenna grid.

Results of the UW-SAIC joint ICRF antenna analysis effort have been presented at several international meetings and numerous meetings in the

- We measure $\dot{B}_Z$ along the surface of the strap to indicate the current profile in the strap.
- Similiar computations by Argus are in close agreement.
- Note that the location of the null in $\dot{B}_Z$ is also accurately predicted.

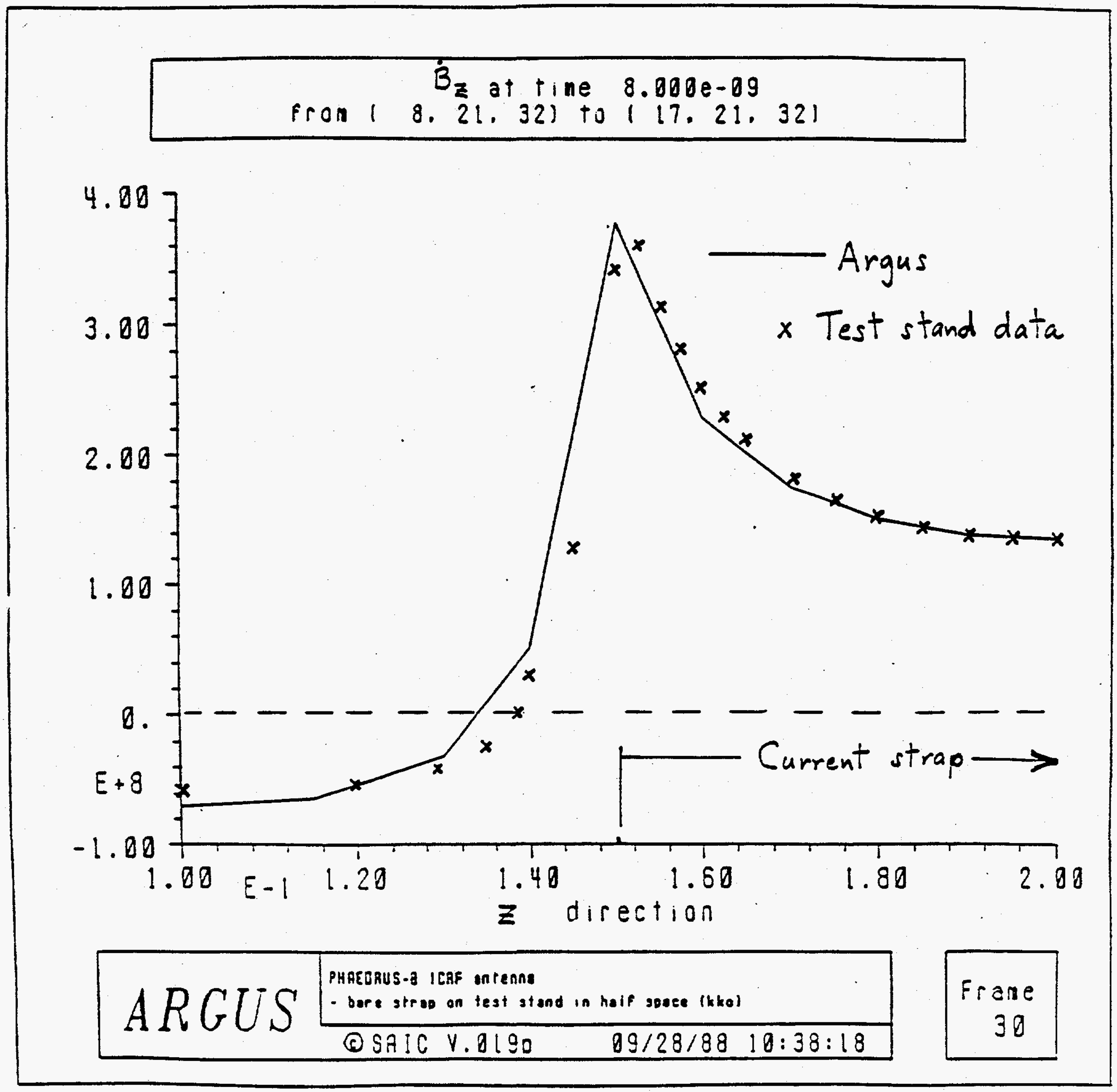


Figure 4

United States. For example, Appendix A contains the presentations for the international Edge Physics Meeting in Germany, October 1989 (A-1) and the European Plasma Physics Society Meeting in Venice, May 1989 (A-2). The principle result that is contained in these two presentations is the demonstrated capability to model and simulate the global behavior of complex 3-D antenna structures and to a great extent, many of the detailed features that are a direct result of incremental changes in antenna geometry such as Faraday shield dimension and spacing. As an example of the detailed nature of the simulations, Appendix B contains a summary of the most recent results obtained from the UW antenna simulation effort. The principle result to be found in the material in Appendix B is the spatial variation of the electric and magnetic rf fields in locations where it is experimentally difficult, if not impossible, to measure.

2.2 PPPL Collaboration

The PPPL bay M antenna has been modeled using the ARGUS code. The results of this effort are shown in Appendix C. The complexity of the PPPL antenna is clearly shown in the figures representing the computational grid-structure. Comparison with the antenna blueprints also confirm that the gross features (cavity, septum, strap, feeds) and selected details (Faraday shield bars including spacing and dimensions) are captured in the computer model. The simulation results for two separate strap phasings (0-0 and 0-π) show that different antenna behavior is obtained. This behavior is associated with current accumulation leading to unwanted fringing and enhanced electric fields in regions where these fields should be weak. In addition, the simulations allow, for the first time, a prediction of the antenna power spectrum.

2.3 ORNL Collaboration

SAIC has recently begun a collaboration with the ICRF antenna design and analysis group at ORNL. At present there are two separate projects underway. The first is associated with the simulation of and determination of the effect of adding slots in the antenna septum and side walls. The slots are expected to eliminate flux linkage between adjacent current straps and to eliminate the negative "K" part of the radiated power spectrum. The negative K's act to buck out fast wave current drive.

The second project concerns the modeling and simulation of the ORNL folded waveguide (FWG) concept. This antenna is designed for high Q operation and hence should couple higher power to the plasma than is currently possible with the conventional strap antennas. The FWG modeling effort is being carried out jointly with ORNL staff.

3. PROPOSED RESEARCH

SAIC proposes to continue the ICRF antenna modeling and simulation effort begun earlier under DOE funding (DOE Contract DE-AC03-88ER53270) and to expand the scope of the work to include the following main areas of concentration:

i) Determination of geometry parameters govening the vacuum performance of single and multi strap antennas,

ii) Determination of geometry parameters governing the vacuum performance of advanced ICRF antennas such as the FWG concept,

iii) Determination of effects of edge and core plasmas on the performance of ICRF antennas.

3.1 Single and Multistrap Fast Wave and IBW Antennas

The projects underway at UW, PPPL, and ORNL will continue and will concentrate on the following issues. The effect of putting slots into the septum or sidewalls of fast wave antennas will be investigated in collaboration with UW and ORNL. Simulations of candidate slot geometry will be carried out using the UW and PPPL antenna geometry simulated with the ARGUS code and compared with experiments at UW and ORNL. The results of these studies will provide the data base required to perform trade-off studies leading to the optimization of fast wave antennas for current drive applications such as those considered for the D-III device at GA.

The CIT antenna geometry will also be simulated using the ORNL base design. The results will provide a prediction of the antenna power spectrum. In the event that the power spectrum requires modification due to unforeseen edge plasma effects, the simulation results will provide the data base required for modification studies.

3.2 Advanced Antenna Concepts

The Use of ARGUS simualtions during the conceptualization and development phase of new or advanced ICRF antenna technologies will provide insight and understanding of the devices in advance of detailed costly laboratory model experiments. Such insight has already been demonstrated and documented during the joint effort with UW; considerable antenna optimization has been performed first computationally and later verified through a few experiments. The initial effort in this proposed work will be concerned with the ORNL FWG antenna. This antenna is described in Appendix D. In the Appendix it is easily seen that the proposed FWG configuration lends itself ideally to simulation and we expect to provide considerable detail in the simulation giving an extensive parametric data base which can be used to optimize FWG devices with confidence. A combined simulation and experimental verification study will be carried out jointly with ORNL.

3.3. Edge and Core Plasma Effects

The extension of the simulation efforts described in 3.1 and 3.2 to include the influence of edge and core plasma will be completed during the proposed research program. This effort consists of several distinct areas of study separated by spatial scale and level of computational complexity. For example, the edge plasma effects include the formation of sheath regions around the Faraday shield components, edge plasma heating and fast ion impact on antenna structure local to the plasma edge. Core plasma effects such as total power absorption and reflected power to and from the antenna will provide the crucial information needed to determine the antenna coupling and loading. Coupling and loading information is essential to optimize matching a given antenna design to a particular plasma column.

(The difference in performance between the TFTR bay L and M antennas illustrates this point rather strongly. At present there is no universally accepted understanding of this difference.)

SAIC has begun, under the previous contract, to couple the fluid dynamic model of the plasma (developed by E. Horowitz of SAIC) to the ARGUS code. Currently, the fluid code is being adapted to the "toroidal" plasma equilibrium used by Batchelor, et al., (Ref. 21). Also, an algorithm developed by S. Auerbach of SAIC, is being implemented to maintain the condition $E_{||} = 0$ in the bulk of plasma. The algorithm allows the full rf field pattern to be propagated outside the main plasma and matches these outside fields to the boundary of the plasma-vacuum interface. We will continue the development of the ARGUS fluid plasma code. The completed code system will provide a global simulation of the full antenna field pattern coupling to the bulk plasma and will result in a global measure of the antenna plasma loading.

The edge plasma effects an antenna performance will be concentrated initially in the development of a model and simulation of two-dimensional sheath phenomena.

Energy deposition on the plasma scrape-off layer during intense ICRH heating has deleterious consequencies for the overall efficiency. It causes increased impurity flux in the plasma core by the release of carbon atoms from the limiter and chamber walls and metal atoms from the Faraday screen. The influx of impurities is caused by collisions of energetic ions with the material surrounding the plasma. It is therefore important to understand the mechanisms that accelerate ions near the antenna to sufficient energies to cause sputtering. These energies, typically of the order of 0.5 keV, are much higher than the typical ambient plasma temperatures ~ 10 eV. In a strongly magnetized plasma strong ion acceleration requires either repeated resonant wave-particle interaction and/or high field gradients within a scale length of one Larmor radius. Resonant acceleration requires excitation of ion cyclotron frequencies below the rf frequency. This may occur via linear mode conversion in the presence of a density gradient, nonlinear parametric excitation and scattering off edge plasma modes. The above methods, in particular parametric pump decay, have been studied often in the past. Creation of high field gradients inside the plasma sheaths that form around the interface with the Faraday screen rods also seems capable of ion energization to sputtering energies. A one-dimensional theory has been developed restricting the electron motion in the y (poloidal) direction (Ref. 30). Because of the angle between the magnetic field lines and the toroidal direction, and the presence of an intense field.

$$\vec{E} = \hat{y} E_y e^{-i\omega t} , \qquad (1)$$

each species α executes an oscillation of amplitude Δ_y:

$$\Delta y_\alpha = \frac{eE_y}{m_\alpha \omega^2} \sin\theta \qquad (2)$$

where m_α is the species mass and θ is the angle between the magnetic field line and the toroidal direction. Much larger excursion for electrons leads to electron depletion near the metal-plasma boundary and formation of an averaged dc component (rf rectification). The rf field is "expelled from most of the space between two grids of the screen and the induced voltage is thus distributed over a much shorter length, namely the width of the plasma sheath Δ. This results in much higher local fields, capable of accelerating ions to keV levels over distances of the order of one Larmor radius.

The one-dimensional picture, although it has produced some qualitative agreement with experimental results, is far from complete. A cross section of a Faraday screen rod in the r-θ (x-y) plane is a two-dimensional object. The plasma sheath formation can not be addressed in one dimension only but as one entity around the rod. In addition it can be shown that a new driving mechanism, ExB drift, generates a plasma sheath across the x-direction as well. To see this, consider the ExB displacement due to the rf E_y component

$$\Delta x_\alpha = \frac{e/m_\alpha E_y}{\Omega_\alpha^2 - \omega^2} \qquad (3)$$

where Ω_α is the specie cyclotron frequency.

According to (3) the ion displacement is now much larger than that of the electron as $\Delta x_i/\Delta x_e \cong m_i/m_e >> 1$. A sheath in the x-direction resulting from ion depletion will form with of opposite polarity than the electron-depleted sheath across x. The interaction of these two charge layers is an intriguing question that must be addressed in two dimensions. Furthermore it seems that an alternating charge density in the x-y direction will cause a tangential electric field around the rod cross-section. If this is true a new ExB inwards influx may considerably increase the rate of impurity production. We intend to resolve the question of sheath formation in a realistic 2-d geometry both analytically and numerically. The 2-D geometry will be obtained from a 2-D slice of the 3-D ARGUS antenna simulations retaining the computed time dependent 2-D rf fields. Addition of electron and ion dynamics via the 2-D version of ARGUS, MASK, will allow a self-consistent simulation of the sheath formation, electric field buildup and ion acceleration. This work should shed light on the controversy surrounding the validity of the so-called standard models of impurity generation (Ref. 23).

4. DELIVERABLES AND SCHEDULE

The timely completion of the proposed research will allow our results to impact the ongoing research and development of ICRF antenna configurations. To this end, SAIC has organized the research into four tasks. These tasks are described below along with a proposed schedule for task completion and delivery of results.

Task 1 Determination of single and multiple strap fast wave and IBW antenna performance with geometry modification.

Under this task we will simulate a sequence of geometry modifications and catalogue the antenna performance (field structure, K spectrum) as a function of the geometry feature. The first modification will concern the use of slots in the TFTR like antenna sidewalls and septum to determine the effect of flux linkage on the radiated power spectrum. Other proposed modifications (to be determined as the need arises according to particular design studies) include the use of resistors for disruption control, alternate Faraday geometry, to name just a few.

The first results from the slot studies will be completed after 3 months into the contract. The remaining results, depending on the exact number of modifications, will be completed in 9 months after contract start.

Task 2 Determination of performance of FWG antenna and optimized FWG geometry.

This task will provide the required data base to optimize (maximize the power coupled to the plasma by maximizing the vacuum Q) the FWG antenna geometry. It is estimated that first results will be obtained in 3 months with final results completed in 6 months after start of contract.

Task 3 Completion of ARGUS-plasma code for global coupling determination.

Completion of this task, begun under the initial contract, will enable the ICRF designers to predict the loading characteristics of antennas in the presence of the bulk plasma core where the transmitted rf power is absorbed. We expect to finish mating the ARGUS and fluid codes during the first 6 months and to have completed the code checkout and benchmarking at the end of the first 12 months. During the second 12 months, the antenna configurations that have been analyzed for vacuum performance will be simulated using the "loading" simulator. Details of the exact geometry to be analyzed will be decided upon by mutual agreement between SAIC and the UW, PPPL, and ORNL user community.

Task 4 Edge Physics Studies

The edge physics studies will provide insight into those issues which affect the ability of ICRF antennas to withstand the intense edge region environment (heating, erosion, and sputtering) and the ultimate effect on antenna performance. The first study associated with the 2-D nature of sheath formation has been described in detail in the proposal and it is expected that initial theoretical and computational results will be ready after 6 months. These studies will continue and will be paced according to the development of further understanding of the edge region through experimental findings and interaction with the edge physics community.

5. MANAGEMENT AND PERSONNEL

Dr. William Grossmann will serve as the principle investigator for the proposed research. Dr. Grossmann was the principle investigator for the initial SAIC antenna modeling project described in Section 2 of this proposal. Assisting him will be Drs. Adam Drobot, Spilios Riyopoulos, Eric Horowitz, and Alan Mankofsky. Each of these scientists has nationally recognized experience and capabilities in computer simulation and fusion plasma physics. In addition, the project will use the services of Drs. Kwok Ko and Michael Kress who have contributed to the development of the ARGUS code.

Collaboration with the UW, PPPL, and ORNL groups will be maintained through the key technical contacts: Drs. Noah Hershkowitz, Pat Colestock, and Dan Hoffman respectively. In addition, SAIC will make available the vax based version, VARGUS, to each of these groups and will train UW, PPPL, and ORNL staff to use this code. This local capability will allow multiple and concurrent simulation studies to be carried out.

References

1. K. Theilhaber, "Theory of the JET ICRH Antenna," Nucl. Fusion 24, 11 (1984).
2. D. Anderson, et al., "Analytical Models for Predicting the Ion Velocity Distributions in JET in the Presence of ICRH Heating," Institute for Electromagnetic Field Theory and Plasma Physics Report, CTH-IEÏÊ/PP-1986-16.
3. D. Edery, et al., "Numerical Modelization of rf Waves in the Ion Cyclotron Range of Frequency for Tokamak Plasmas," CEA/CEN Report Cadarache.
4. M. Brambilla, "A Model for the Numerical Simulations of Ion Cyclotron Heating of Tokamak Plasmas," IPP5/15, May 1986.
5. M. Brambilla, "Theory of Bernstein Waves Coupling with Loop Antennas," IPP5/15, April 1987.
6. V.P. Bhatnagar, et al., "Extension and Illustration of ICRH Codes Installed at JET," Laboratoire de Physique des Plasmas Report No. 84, March 1987.
7. D.W. Faulconer, et al., "Plasma-Induced TM Mode Transparency of Electrostatic Shields Used in RF Heating," Proc. 12th European Conf. on Controlled Fusion and Plasma Physics, Budapest, 2-6 Sept. 1985.
8. D.W. Faulconer, et al., "The Role of Temperature and Rotational Transform in ICRH Mode Conversion," Proc. 14th European Conf. on Controlled Fusion and Plasma Physics, Madrid, 22-26 June 1987.
9. D.J. Hoffman, et al., "ICRF Coupling on DIII-D and the Implications on ICRF Technology Development," ibid.
10. Y. Uesugi, et al., "200 MHz Fast Wave Current Drive on JFT-2M Tokamak," ibid.
11. K. Steinmetz, et al., "Confinement and Profile Effects During ICRF Heating on ASDEX," ibid.
12. O. Sauter, et al., "HFS and LFS Excited Modes in the ICRF," ibid.
13. D. Swain, et al., "Technology Development of Antennas for Ion Cyclotron Heating Experiments in Fusion Devices," ibid.

14. K. Ko, W. Grossmann, et al., papers IR5 and IR7, Bull. APS 33, 1872 (1988); and R. Majeski, T. Tanaka, et al., paper IR7, Bull. APS 33, 1873 (1988).
15. P. Colestock and J. Hosea, personal communication.
16. B. McVey, MIT Report PFC/RR-84-12 (1984).
17. D.J. Hoffman, et al., "Fast-Wave Current Drive Design Issues," DoE Workshop on High Power ICH Antenna Designs for High Density Tokamaks, Boulder, CO, Jan. 31 - Feb. 2, 1990.
18. F. Durodie, et al., "ICRH Stationary High Power Performances on TEXTOR with Carbonization and Boronization," ibid.
19. J. Hosea, "ICRF Antenna Operations and Studies on TFTR," ibid.
20. M. Mayberry, et al., "Recent IBW Results on DIII-D and Their Implications for ICH in High Density Tokamaks," ibid.
21. D.B. Batchelor, et al., "Antenna Loading, Propagation, and Absorption in Alcator C-Mod," ibid.
22. N. Hershkowitz, "ICH Antenna Design Issues," ibid.
23. J. Jacquinot, et al. "Effect of Beryllium Evaporation on the Performance of ICRH on JET," ibid.
24. P. Bonoli, et al. "Full Wave Code Modelling of ICRF In High Density Tokamaks," ibid.
25. J-M. Noterdaeme, "Progress in the Understanding and Avoidance of Impurity Production with ICRH in ASDEX," ibid.
26. M. Porkolab, "Mechanisms for Edge Absorption," ibid.
27. I.S. Lehrman, "Coupling to High Density C-Mod Plasmas," ibid.
28. T. Fujii, "High Power Density ICRF Experiments on JT-60," ibid.
29. T.D. Shepard, "ALCATOR-C," ibid.
30. J.A. Tagle, et al., "Electric Field and Radial Transport During ICRF Heating in the Edge Plasma of Jet," IAEA Technical Committee Meeting on ICRH/Edge Physics, Garching, Oct. 2 - 5, 1989.
31. M. Bures, et al., "ICRH/Plasma Edge Interaction in JET with Beryllium Gettering," ibid.
32. G. Van Oost, et al., "ICRF/Edge Physics Research on TEXTOR," ibid.
33. R. Van Nieuwenhove, et al., "Effect of RF Heating on DC Electric Fields in the SOL of TEXTOR," ibid.
34. R. Van Nieuwenhove, et al., "Capacitive Probe Measurements During RF Heating on TEXTOR," ibid.

35. R. Koch, et al., "Study of Coupling and Edge Effects During ICRF Heating Experiments Using an Electrostatic Antenna on TEXTOR," ibid.

36. M.J. Ballico, et al., "Probe Measurements of ICRF Surface Waves in the Tortus Tokamak," ibid.

37. V.V. Chechkin, et al., "Edge Plasma Potential and Associated Ion Fluxes to the Surface During ICRF Plasma Production and Heating in the URAGAN-3 Torsatron," ibid.

38. F. Ryter, et al., "Influence of Boronization and Carbonization on ICRF-Heated Plasmas In ASDEX," ibid.

39. S. Clement, et al., "Effect of ICRH on the JET Edge Plasma with Carbon and Beryllium Coated Limiters," ibid.

40. J. Jacquinot, et al., "Effect of Beryllium Evaporation on the Performance of ICRH on JET," ibid.

6. COSTING

STANDARD FORM 1411

An Employee-Owned Company

CONTRACT PRICING PROPOSAL COVER SHEET

1. Solicitation/Contract/Modification No. N/A

Form Approved
OMB No. 3090-01

2. Name and address of offeror (include zip code)

Science Applications International Corporation
10260 Campus Point Drive
San Diego, CA 92121
c/o SAIC, Technology Research Group
1710 Goodridge Drive, P.O. 1303
McLean, Virginia 22102
Attn: Linda S. Spokane, M/S 2-3-1
Code 52302

3A. Name and title of Offeror's Point of Contact
Linda S. Spokane
Contracts Representative

3B. Telephone No.
(703)734-4031

4. Type of Contract Action (check)
_X_A. New Contract
___B. Change Order
___C. Price Revision/ Redetermination
___D. Letter Contract
___E. Unpriced Order
___F. Other (specify)

5. Type of Contract (check)
___FFP __X__CPFF ___CPIF ___CPAF
___FPI ___Other (specify)

6. Proposed Cost (A + B = C)

A. Cost	B. Fee	C. Total
$525,623	$52,325	$577,948

7. Place(s) and Period(s) of Performance: McLean, Virgina
15 April 1990 - 14 April 1992

8. List and reference the identification, quantity and total price proposed for each contract line item. A line item cost breakdown supporting this recap is required unless otherwise specified by the Contracting Officer. (Continue on reverse, and then on plain paper, if necessary. Use same headings.)

A. LINE ITEM NO.	B. IDENTIFICATION	C. QUANTITY	D. TOTAL PRICE	E. REF
	MODELING AND SIMULATION SUPPORT FOR ICRF HEATING of FUSION PLASMAS SAIC Proposal No. 1-624-71-910-02	1 Job	$577,948	A - E

9. Provide Name, Address, and Telephone Number for the following (if available)

A. Contract Administrative Office
Mr. William J. Johnson/ DCASR LA-GSACA-72
7675 Dagget Street, Suite 200
San Diego, CA 92111-2241
(619) 495-7484

B. Audit Office
Ms. Celia Cohan/DCAA
10260 Campus Point Drive
San Diego, CA 92121
(619) 535-7411

10. Will you require the use of any government property in the performance of this work? (If "Yes", identify)
___Yes _X___No

11A. Do you require government contract financing to perform this proposed contract? (If "Yes", complete Item 11B)
_X__Yes ___No

11B. Type of financing (che
___Advance Payments
___Progress Payments
___Guaranteed Loans
_X_CPFF Billings

12. Have you been awarded any contracts or subcontracts for the same or similar items within the past 3 years? (If "Yes", identify item(s), customer(s), and contract number(s))
___Yes _X___No

13. Is this proposal consistent with your established estimating and accounting practices and procedures and FAR Part 31 Cost Principles? (If "No", explain)
_X_Yes ___No

14. Cost Accounting Standards Board (CASB) Data (Public Law 91-379 as amended and FAR Part 30)

A. Will this contract action be subject to CASB Regulations? (If "No", explain in proposal)
_X_Yes ___No

B. Have you submitted a CASB Disclosure Statement (CASB DS-l or 2)? (If "Yes", specify in proposal the office to which submitted and if determined to be adequate)
_X_Yes ___No DCAS/San Diego - Adequate

C. Have you been notified that you are or may be in non-compliance with your disclosure statement or cost accounting standards? (If "Yes", explain in proposal)
_X_Yes ___No See Reference B.9

D. Is any aspect of this proposal inconsistent with your disclosed practices or applicable cost accounting standards? (If "Yes", explain in proposal)
___Yes _X_No

This proposal is submitted in response to the RFP, contract, modification, etc. in Item 1 and reflects our best estimates and/or actual costs as of this date

15. Name and Title
Linda S. Spokane
Contracts Representative

16. Name of Firm
SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

17. Signature
Linda S. Spokane

18. Date of Submission
15 March 1990

NSN 7540-01-141-9845 1411-101 STANDARD FORM 1411 (1C-83) Prescribed by GSA FAR (48CFR)53.215-2(c)

REFERENCE A

COST ELEMENT BREAKDOWN

SAIC

An Employee-Owned Company

REFERENCE A
1-624-71-910-02

MODELING AND SIMULATION SUPPORT FOR ICRF HEATING of FUSION PLASMAs
COST-ELEMENT BREAKDOWN
15 April 1990- 14 April 1992

	YEAR ONE	15 Apr 90-	14 Apr 91	YEAR TWO	15 Apr 91-	14 Apr 92	TOTAL PROGRAM		Reference
DIRECT LABOR	Rate	Hours	Amount	Rate	Hours	Amount	Hours	Amount	
440S	49.57	1,120	55,518	50.58	1,120	56,650	2,240	112,168	
321S	20.55	1,040	21,372	20.97	1,040	21,809	2,080	43,181	
61Y	11.10	40	444	11.33	40	453	80	897	
		--------	--------		--------	--------	--------	--------	
Total Labor		2,200	77,334		2,200	78,912	4,400	156,246	B
LABOR BURDEN	Rate	Base			Base		Base		
Fringe Benefits	39.5%	77,334	30,547		78,912	31,170	156,246	61,717	
Overhead	83.6%	77,334	64,651		78,912	65,970	156,246	130,621	
			--------			--------		--------	
Total Burden			95,198			97,140		192,338	B
OTHER DIRECT COSTS		Units			Units		Units		
Communications			773			789		1,562	B
M. Kress	41.25	485	20,006	41.25	485	20,006	970	40,013	B
K. Ko	37.50	533	19,988	37.50	533	19,988	1,066	39,975	B
Stellar Computer	24.00	834	20,016	24.00	834	20,016	1,668	40,032	B
Travel			2,053			3,455		5,508	C
			--------			--------		--------	
Total ODCs			62,836			64,254		127,090	
SUBTOTAL	Rate	Base	235,368		Base	240,306	Base	475,674	
G & A	10.0%	235,368	23,537		240,306	24,031	475,674	47,568	B
			--------			--------		--------	
TOTAL COST			258,905			264,337		523,242	
FEE	10%	258,905	25,891		264,337	26,434	523,242	52,325	
FCCM - Onsite Labor	0.00635	77,334	491		78,912	501	156,246	992	B&D
FCCM - G & A Pool	0.00292	235,368	687		240,306	702	475,674	1,389	B&D
			--------			--------		--------	
TOTAL COST PLUS FEE			285,974			291,974		$577,948	
								========	

An Employee-Owned Company

REFERENCE B

PRICING NOTES

An Employee-Owned Company

REFERENCE B

1-624-71-910-02
15 March 1990

PRICING NOTES

The cost estimate and/or pricing presented in this cost proposal was developed following the procedures outlined in SAIC's Cost Estimating System Manual (CESM). The CESM sets forth SAIC's policies, procedures and methodologies with respect to cost estimating and pricing. The CESM has been reviewed by our cognizant ACO and has been deemed to adequately describe the corporate wide estimating policies and procedures. It has also been reviewed by our cognizant DCAA and was deemed to be generally adequate and compliant with the requirements of DFAR 215.811-75 and 215.811-76.

1. COGNIZANT AGENCIES

Science Applications International Corporation and its subsidiaries, are under the audit cognizance of the Defense Contract Audit Agency, 10260 Campus Point Drive, San Diego, California 92121, and the administrative cognizance of the Defense Contract Administration Services Management Area, San Diego, 7675 Daggett Street, Suite 200/300, San Diego, California 92111-2241. The points of contact are:

DCAA - Ms. Celia Cohan (619)535-7411

ACO - Mr. William J. Johnson (619)495-7484

The direct and indirect rates used in this proposal are recognized by DCAA and DCASMA for forward pricing purposes.

2. INDIRECT RATES

The indirect rates used in this proposal are based upon detailed data supplied to SAIC's cognizant DCAA Auditor and DCAS Administrative Contracting Officer. They are applied in this manner:

Rate	Base
Labor Overhead (Onsite & Offsite)	Direct Labor not performed in a multi-user Secured Facility
Fringe Benefits	Direct Labor
General and Administrative	All direct and indirect costs excluding Direct Material

3. DIRECT LABOR

The proposed Direct Labor hours are an engineering estimate.

The proposed Direct Labor bid rates are the average (arithmetic mean) of the actual salaries for those employees within each bid level as of May 1989. Each bid rate has been escalated 2% per annum to the mid-point of the period of performance. This escalation accounts for the anticipated annual increase of each bid level rate pool. The annual increase includes individuals entering and leaving each pool as well as salary adjustments for those who remain in each pool.

4. TRAVEL

The trips required for this effort are delineated in Reference C. The proposed airfares are the average coach fares based on historical data for roundtrip coach fares to the destination cities. The other proposed travel rates are in accordance with our established travel policy. All travel costs are escalated 4% per annum.

5. COMMUNICATIONS

Communications expense includes postage, courier services, graphics and reproduction costs. It is estimated that the Group's historical average, one percent of Direct Labor dollars, shall be required in the performance of this effort.

6. STELLAR GRAPHICS WORKSTATION

The Plasma Technology Division's Stellar Graphics Workstation is a category A Service Center and will be used to support this effort. The estimated rate is $24.00 per hour of usage.

7. CONSULTANTS

Michael Kress and Kwok Ko will assist in this effort as consultants. Their current agreements with SAIC stipulate rates of $41.25 and $37.50 per hour respectively. These rates may increase over the life of the contemplated contract therefore these are considered to be an estimated rate. Also this is an estimated number of hours and the actual may vary. Any changes shall be addressed as they occur.

8. FACILITIES CAPITAL COST OF MONEY (FCCM)

The FCCM factors in this proposal are based upon detailed data supplied to SAIC's cognizant DCAA Auditor and DCAS Administrative Contracting Officer. They are applied in this manner:

BASE	FACTOR
Onsite Direct Labor Dollars (Onsite Overhead Pool)	0.00635
All Direct and Indirect Costs Excluding Direct Material (G&A Pool)	0.00292

DD Form 1861 is included as Reference D.

9. CAS NONCOMPLIANCE ISSUES/SF1411 (EXPLANATION OF BLOCK 14C)

On March 22, 1989, SAIC's cognizant Administrative Contracting Officer (ACO) made a final determination of noncompliance with

CAS 409.50(h) and with CASB Disclosure Statement, Item 5.1.0. The determination involves two issues.

The first issue pertains to the materiality of tangible capital asset residual values when the residual values are less than ten percent of the asset acquisition cost. CAS 409.50(h) requires that "no depreciation cost shall be charged which would significantly reduce book value of a tangible capital asset below its residual value." The dispute arose because residual values are estimated to be zero for tangible capital assets other than automobiles. It is understandable that when a residual value is determined to be zero, it may appear that residual value was not considered at all. To resolve this matter we will provide information which demonstrates the immateriality of residual values associated with the asset categories in question and we will clarify disclosure of our practices. Further, to avoid potential future disagreements, we intend to seek an advance agreement specifying the amount that is mutually agreed to be insignificant.

The second issue relates to disclosure of our methods for estimating the future service lives of tangible capital assets. DCAA concluded that estimated service lives are not based on historical experience, primarily based on the lack of documentation regarding the company's periodic assessment of the actual service lives. To resolve this matter we will provide information demonstrating our estimated service lives, as adjusted for specific factors which are expected to influence future service lives, are supported by actual historical experience. Additionally, we will propose revisions to procedures and disclosures which clarify our policies and practices.

In addition, SAIC's cognizant DCAA has recommended an initial determination of noncompliance with CAS 401. SAIC's response has been provided and the matter is currently under discussion with our cognizant ACO.

Should you desire additional information regarding these issues, please do not hesitate to contact any of the following individuals:

John W. Armstrong
Corporate Vice President
Director, Contracts and Pricing
(619) 535-7315

Adelaide K. Mayhew
Vice President
Deputy Director, Contracts and Pricing
(619) 458-2630

Donald J. Bouma
Director of Government Accounting
(619) 552-4628

REFERENCE C

TRAVEL

REFERENCE C - TRAVEL
1-624-71-910-02
15 April 1990- 14 April 1992

YEAR	FROM/TO	AIRFARE	NO. OF TRIPS	NO. OF PEOPLE	NO. OF DAYS	NO. OF CARS	NO. OF R/T MILES	PER DIEM RATE	PURPOSE OF TRIP
ONE	1. Washington, DC/ Tampa, FL	$500	1	2	5	1		$78	Meetings
TWO	2. Washington, DC/ San Diego, CA	$622	1	2	5	1		$107	Meetings
TWO	3. Washington, DC/ Williamsburg, VA		1	2	3		350	$96	Sherwood Theoretical Mtgs.

YEAR	FROM/TO	TOTAL AIRFARE	AUTO RE TAL	AIRPORT PARKING	LOCAL MILEAGE	TOTAL TRANSPOR TATION	PER DIEM	COMM	TOTAL PER DIEM	ESCAL @ 0.00%	SUBTOTAL	GRAND TOTAL
ONE	1. Washington, DC/ Tampa, FL	$1,000	,165	$30	$0	$1,195	$780	$25	$805	$53	$2,053	$2,053
TWO	2. Washington, DC/ San Diego, CA	$1,244	$165	$30	$0	$1,439	$1,070	$25	$1,095	$169	$2,703	
TWO	3. Washington, DC/ Williamsburg, VA	$0	$0	$30	$84	$114	$576	$15	$591	$47	$752	$3,455
	TOTALS	$2,244	$330	$90	$84	$2,748	$2,426	$65	$2,491	$269	$5,508	$5,508

AIRLINE GUIDE RATE DATE: Historical Data

AIRFARE - AVERAGE COACH CLASS R/T FARE

PER DIEM - INCLUDES MEALS AND LODGING
BASED ON FEDERAL TRAVEL REGULATIONS
MAXIMUM PER DIEM RATE EFFECTIVE 09-Oct-88

AUTO RENTAL	$33.00 /DAY
MILEAGE	$0.24 /MILE
AIRPORT PARKING	$15.00 /PERSON/TRIP
COMMUNICATION	$5.00 /PERSON/EVERY 2 DAYS

ESCALATION:

Year 1	2.67%
Year 2	6.67%

SAIC
An Employee-Owned Company

REFERENCE D

FORM DD 1861

An Employee-Owned Company

REFERENCE D

CONTRACTOR FACILITIES CAPITAL COST OF MONEY

Form Approved
OMB No. 0704-0267
Expires Oct 31, 1989

1. CONTRACTOR NAME Science Applications International Corporation	2. CONTRACTOR ADDRESS 10260 Campus Point Drive San Diego, CA 92121
3. BUSINESS UNIT Company 1	
4. RFP/CONTRACT PIIN NUMBER	5. PERFORMANCE PERIOD 15 April 1990 - 14 April 1992

6. DISTRIBUTION OF FACILITIES CAPITAL COST OF MONEY

POOL (A)	ALLOCATION BASE (B)	FACILITIES CAPITAL COST OF MONEY FACTOR (C)	FACILITIES CAPITAL COST OF MONEY AMOUNT (D)
Onsite Labor Overhead	$156,246	0.00635	$992
G&A	$475,674	0.00292	$1,389
TOTAL			$2,381
TREASURY RATE			9.125%
FACILITIES CAPITAL EMPLOYED (TOTAL DIVIDED BY TREASURY RATE)			$26,095

7. DISTRIBUTION OF FACILITIES CAPITAL EMPLOYED

	PERCENTAGE	AMOUNT
LAND	5%	$1,305
BUILDINGS	6%	$1,566
EQUIPMENT	89%	$23,224
FACILITIES CAPITAL EMPLOYED	100%	$26,095

Equivalent of DD Form 1861, Aug 1987

REFERENCE E

TERMS AND CONDITIONS

SAIC
An Employee-Owned Company

REFERENCE E

1-624-71-910-02
15 March 1990

TERMS, CONDITIONS AND OTHER STATEMENTS

1. GENERAL

With regard to terms and conditions other than those set forth herein and except for those provisions required by applicable Government law or statute, it is assumed that agreement as to the applicable provisions remains subject to final negotiation of any resulting contract.

2. PROPOSAL VALIDITY

This proposal is offered on a Cost Plus Fixed-Fee basis and shall remain valid for thirty (30) days.

3. AUTHORIZED NEGOTIATORS

Persons authorized to negotiate this proposal and administer any resulting contract are:

Primary	Alternate
Linda S. Spokane	Karen L. Marshall
Contracts Representative	Contracts Manager
(703)734-4031	(703)734-5889

4. CONTRACTOR ADDRESS

The contractor address to be used on the face of all contract documents is:

"Science Applications International Corporation
10260 Campus Point Drive
San Diego, CA 92121

c/o Science Applications International Corporation
1710 Goodridge Drive
McLean, VA 22102
Attn: Linda S. Spokane, M/S 2-3-1
Technology Research Group"

It is requested that this address be used in order to reduce mail routing delays for UNCLASSIFIED documents.

5. CONSULTANT APPROVAL

This proposal is intended to be notification to the Contracting Officer of intent to use the proposed consultants pursuant to FAR 52.244-2, Subcontracts, subparagraph a., and it is requested that any resulting contract contain the Contracting Officer's approval and consent for use of these consultants pursuant to subparagraph c. thereof.

6. FEE RETENTION REDUCTION

It is requested that the fee retention (per FAR 52-216.8) of any resulting contract be reduced from fifteen percent to zero percent. Our cognizant DCAA is currently four years behind in their incurred cost audit of SAIC indirect rates. The most current negotiated indirect rates are for SAIC FY84 which ended 27 January 1984. We are therefore unable to close any contracts that have a period of performance that has ended since 28 January 1984 (the beginning of SAIC FY85). This delay prohibits SAIC from collecting the fee retention on completed contracts for unreasonably long periods of time, and diminishes the value of the retention once released. (Assuming a nominal rate of interest of nine percent per annum the discounted value of a dollar withheld for five years is approximately sixty cents.) It is not believed that granting this request will represent any added risk for the purpose of protecting the Government's interests. As of 28 April 1989 the Government is holding $10.4 million in fee retentions due SAIC. It is requested that a special provision be included addressing this issue to read essentially:

"The amount of fee to be retained pursuant to FAR 52.216-8 shall be zero percent. The Government is currently withholding an adequate amount of fee retention to protect its interests. Withholding of zero percent of fee shall require no specific instruction from the Contracting Officer."

APPENDIX A

APPENDIX A.1

ICRF - Edge Plasma Investigations in Phaedrus B

R. Majeski, T. Tanaka, T. Intrator, and N. Hershkovitz
University of Wisconsin, Madison, Wisconsin USA

K. Ko, W. Grossman, and A. Drobot,
Science Applications International, MacLean, Virginia USA

ABSTRACT

We describe experiments which investigate the characteristics of a test ICRF coupler. The rf magnetic fields near the antenna are measured in vacuum and in plasma. Results are modelled using the code ANTENA in plasma; details of the vacuum fields are modelled with the code ARGUS. For the plasma experiments, the antenna is mounted in the central cell of the Phaedrus-B tandem mirror. ICRF modification of the edge plasma potential at the Faraday shield and coupling to electrostatic modes are also investigated.

INTRODUCTION

The interaction between an ICRF coupler and the edge plasma in tokamaks is responsible for impurity influxes, changes in the scrape-off length, and possibly edge electron heating during ICRF. These processes are still not understood. Here we present measurements, in a plasma similar to that found in the scrape-off layer of medium-sized tokamaks, of the local rf fields, electrostatic potentials, and particle currents collected by an operating low power ICRF coupler. We tentatively conclude that an electrostatic ion Bernstein wave is excited by the coupler in addition to the expected fast wave modes.

DESCRIPTION OF PHAEDRUS-B AND THE MODEL ANTENNA.

Phaedrus-B [1] is an ICRF stabilized and heated tandem mirror, with 200-400 kW of rf power coupled through two antennas operated near the ion cyclotron frequency. Only the central cell rf sources are operated. The central cell, where the model antenna is installed (75 cm from central cell midplane), is 3.2 m long (length of the uniform ~ 0.9 kG magnetic field), with limiters at 17 cm radius. The data presented here will be at peak densities of $\lesssim 5 \times 10^{12} cm^{-3}$, with T_i, T_e ~ 20-40 eV. The density drops to ~ $5 \times 10^{11} cm^{-3}$ at the limiter radius. Plasma density at the Faraday shield is ~ $5 - 20 \times 10^{10} cm^{-3}$.

The data presented here were taken with two different model antenna configurations (Types A and B). Both are fast wave antennas and utilize 60° 10 cm wide current straps. The straps are fed at one end, with current return through the 20 cm wide backplane. The Faraday shield structure in the case of the Type A antenna is constructed of aluminum, with a single layer (25% transmission) of cylindrical front elements at a 17 cm radius (current strap radius 19 cm) and staggered double layers of slats for the Faraday shield sides. The Type B single-layer shield is of copper plated stainless steel, with front elements of rectangular cross section. Both shield assemblies include endplates to enclose the antenna leads, and are 20 cm wide. The Type B Faraday shield assembly is electrically isolated from the antenna backplane, and is connected via a low inductance strap to a separate electrical feedthrough. For the experiments described here the Type B Faraday shield was grounded at the feedthrough, and current driven to the Faraday shield is monitored by a current transformer. This shield was installed at a radius of 16.5 cm with the current strap at 18.5 cm.

The entire model antenna assembly is mounted on a carriage which translates 120° in azimuth. The carriage, installed in the Phaedrus-B central cell, with the Type B antenna and Faraday shield installed, is shown in Figure 1. Excitation power is ~ 3 kW, with antenna currents in the 100-200 A (p-p) range.

In addition to the antenna system installed in Phaedrus-B, identical Faraday shield/antenna assemblies have been constructed for test stand measurements in air.

TEST STAND MEASUREMENTS.

Extensive air measurements of all three components of the rf magnetic fields over the full Faraday shield have been made for the Type A shield [2]. Comparison of these measurements with field maps using the bare strap show that the component most strongly modified by the Faraday shield is the rf B_θ component. Figure 2 (a through c) shows the effect of a transition from an open, slotted frame structure to a closed frame structure on the θ component of the rf magnetic field. In the case of a closed frame, the θ component of the rf field is highly localized near the leads, and the peak value increases by 50%.

Some modelling of the vacuum field distribution has been performed with the code ARGUS. In Figure 3 we show an axial profile of the $\hat{z}$ component of the rf magnetic field taken 2 mm above the bare strap and backplane assembly. Data and simulation are in excellent agreement. Here the field profile above the strap is proportional to the current distribution in the strap, while the position of the point at which the field reverses sign is sensitive to the return current distribution in the backplane as well.

PLASMA FIELDS.

Using the Type A coupler operated at 3.5 MHz (2.4 Ω_{ci}), we have observed that the plasma fields within a few cm radius of the Faraday shield are virtually unchanged by the presence of plasma. The effects of wave propagation begin to be apparent at ~ 5 cm distance from the shield face, in agreement with modelling using the code ANTENA [2].

During experiments with the Type A coupler, we also observed excitation of an electrostatic mode which we have tentatively identified as an ion Bernstein wave. This mode is observed at higher frequency (7 MHz, or 4.8 Ω_{ci}), in shots with high gas fueling, lowered main ICRF power (~ 100 kW), and low density (1-2 x 10^{12} cm^{-3}). Electron temperature for this mode of operation in Phaedrus-B is (~ 10-20 eV). The mode is observed with an electrostatic probe [3], and unlike the fast wave fields detected with a B-dot probe has a highly modulated envelope. Interferometric measurements near the model coupler yield a k_r of 1 - 3 cm^{-1}, with phase decreasing as the probe is moved away from the coupler, as expected for a backwards mode such as the ion Bernstein wave. $T_i \sim T_e$ for this mode of operation, so that $k_\perp \rho_i$ is in the range of 0.4 - 1. We also find that the amplitude of the mode varies azimuthally, and is greatest near the ends of the coupler, at the azimuthal location of the leads. Although excitation of an IBW by a fast wave coupler via mode coupling has been previously reported [3], in Phaedrus-B the IBW is seen to coexist with fast wave excitation. Here several fast wave eigenmodes, including the m=0, are above cutoff.

We have measured the increase in the plasma floating potential with a capacitive probe in the Faraday shield gap (near the axial edge of the shield) for the Type B coupler, as a function of the strap current. The plasma potential is found to increase linearly with strap current (Fig. 4). The Type B coupler has an isolated Faraday shield which permits monitoring of the current. Collected current to scales as $I^{1.5}_{antenna}$ and therefore as $\Phi^{1.5}_{f-p}$, which is suggestive of a Child-Langmuir relationship. In Fig. 6 the floating potential of a high impedance Langmuir probe adjacent to the Faraday shield blade/gap region is plotted as a function of azimuthal position. The measurement was taken at a distance of 4 mm axially from the Faraday shield assembly, at a radius of $r_{Faraday\ shield} + d_{blade} / 2$, where d_{blade} is the thickness of the Faraday shield blade. The asymmetry in the potential in the gap region, which is also seen on capacitive probe measurements, appears to be due to a slight tilt of the Faraday shield blade with respect to the confining magnetic field. In the low potential region, the probe is on a field line which transits the Faraday shield gap. In the high potential region, the probe is on a field line which terminates near the midpoint of the blade, where the inductively induced voltage on the blade, and presumably the plasma self-bias, peaks. Similar effects are thought to contribute to high sputtering rates at the Faraday shield [4], [5].

CONCLUSIONS.

We have several observations on the interaction of a fast wave coupler with the edge plasma. The vacuum measurements draw attention to the effect of surrounding the antenna leads in a conducting frame on the B_θ rf field components. The use of solid septa to reduce inductive coupling between neighboring pairs of phased antenna straps would have a similar effect. Observation of an ion Bernstein wave excited in the edge plasma by a fast wave coupler implies an additional heating channel for electrons. Here it should be emphasized that we have as yet made no estimates of the relative power launched in IBW vs. fast waves. We have found that a Faraday shield is a net electron collector, which should produce a positive plasma self-bias. This is confirmed by probe measurements of the plasma floating potential during excitation of the coupler. The increase in floating potential scales with the strap rf current, and is not confined to the gap region for Faraday shields of this geometry. The increase in collected electron current scales approximately with the (strap rf current)$^{1.5}$, and therefore with the plasma (self-bias potential)$^{1.5}$, which suggests that the evolution of the collected current and plasma self bias follow a Child-Langmuir law. This is a straight forward picture of the interaction of an ICRF coupler with the edge plasma, at least at low powers, and points to increased ion impact energy and sputtering through the rf self-bias.

This research has been supported by U.S. DOE Grant DE-FG02-88ER53264.

REFERENCES

[1] BREUN, R.A., et. al., Plasma Physics and Controlled Nuclear Fusion Research, 1986 (Proc. 11th Int. Conf. Kyoto, 1986), Vol. 1, IAEA, Vienna (1987) 263.

[2] HERSHKOVITZ, N., R. MAJESKI, T. TANAKA, T. INTRATOR, Radio Frequency Power in Plasmas (Proc. 8th Topical Conference Irvine, 1989), AIP New York (1989) 270.

[3] SKIFF, F., M. ONO, P. COLESTOCK, K.L. WONG, Phys. Fluids 28 (1985) 2453.

[4] PERKINS, F.W., Nucl. Fusion 29 (1989) 583.

[5] EMMERT, G.A., Bull. Am. Phys. Soc. 33 (1988) 1875.

LIST OF FIGURES

Figure 1. The carriage-mounted model antenna mounted in the Phaedrus-B central cell. Also visible is one of the two pairs of dual half-turn antennas utilized for the main ICRF. This set was not active in these experiments.

Figure 2. Contours of the $\hat{\theta}$ component of the rf magnetic field in the θ-z plane at constant radius (1 cm from the Faraday shield) for three Faraday shield constructions.

A. Slotted face and sides, no end plates. Peak field is 28 (relative units).

B. Slotted face and sides, solid endplates. Peak field is 31.

C. Slotted face, solid sides and end plates. Peak field is 47.

Figure 3. Axial profile of the $\hat{z}$ component of the rf magnetic field 2 mm above the antenna strap. Stars denote measurements; the solid line is modelling by the code ARGUS. Note field reversal near z=6 cm.

Figure 4. Scaling of probe floating potential with model antenna strap current. The line is a linear fit to the data (stars) with intercept -2.7 V an slope 0.74 V/A rms.

Figure 5. Scaling of excess collected electron current with the 3/2 power of the strap current. The line is a linear fit to the data (stars) with intercept -1.7×10^{-2} A and slope 3.2×10^{-3} A/A$^{3/2}$.

Figure 6. Probe floating potential as a function of azimuthal position, immediately adjacent to the Faraday shield gap. The stars are data; the solid bars denote the ends of the Faraday shield bars. The bars are axially slightly misaligned with the confining magnetic field; as a result, the bar ending at 2-3 cm is tilted approximately 3mm into the gap region.

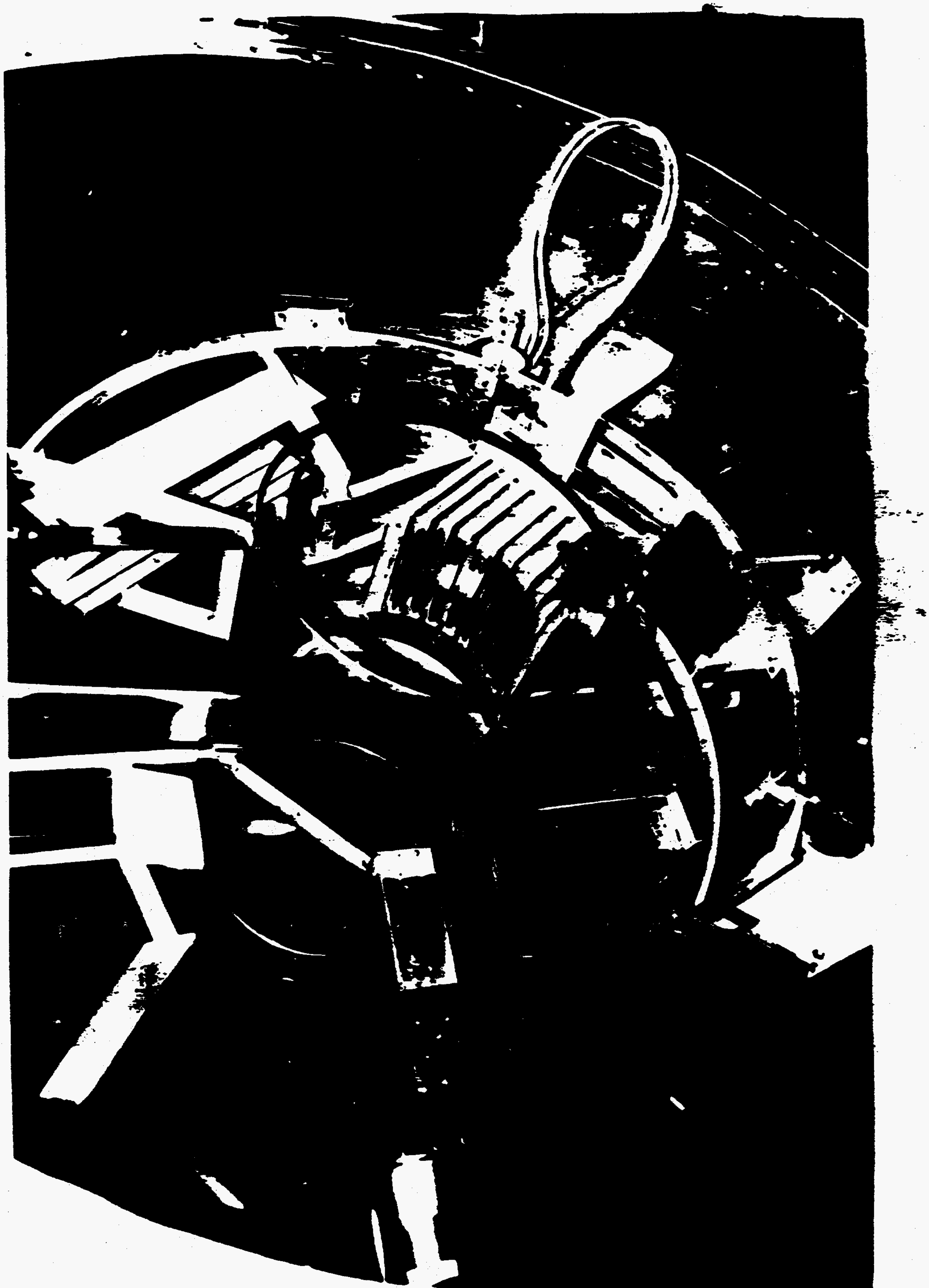


Figure 1.

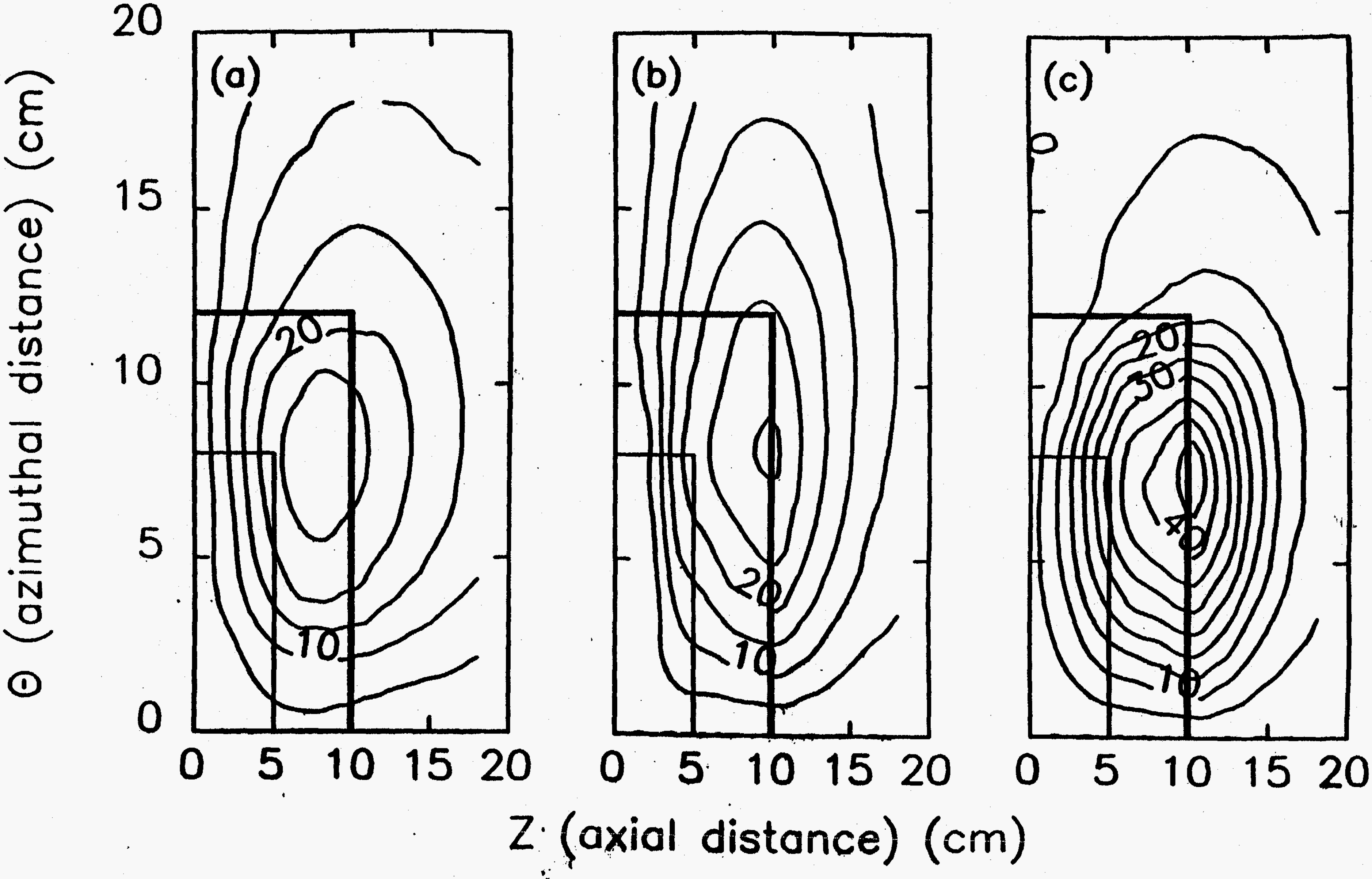
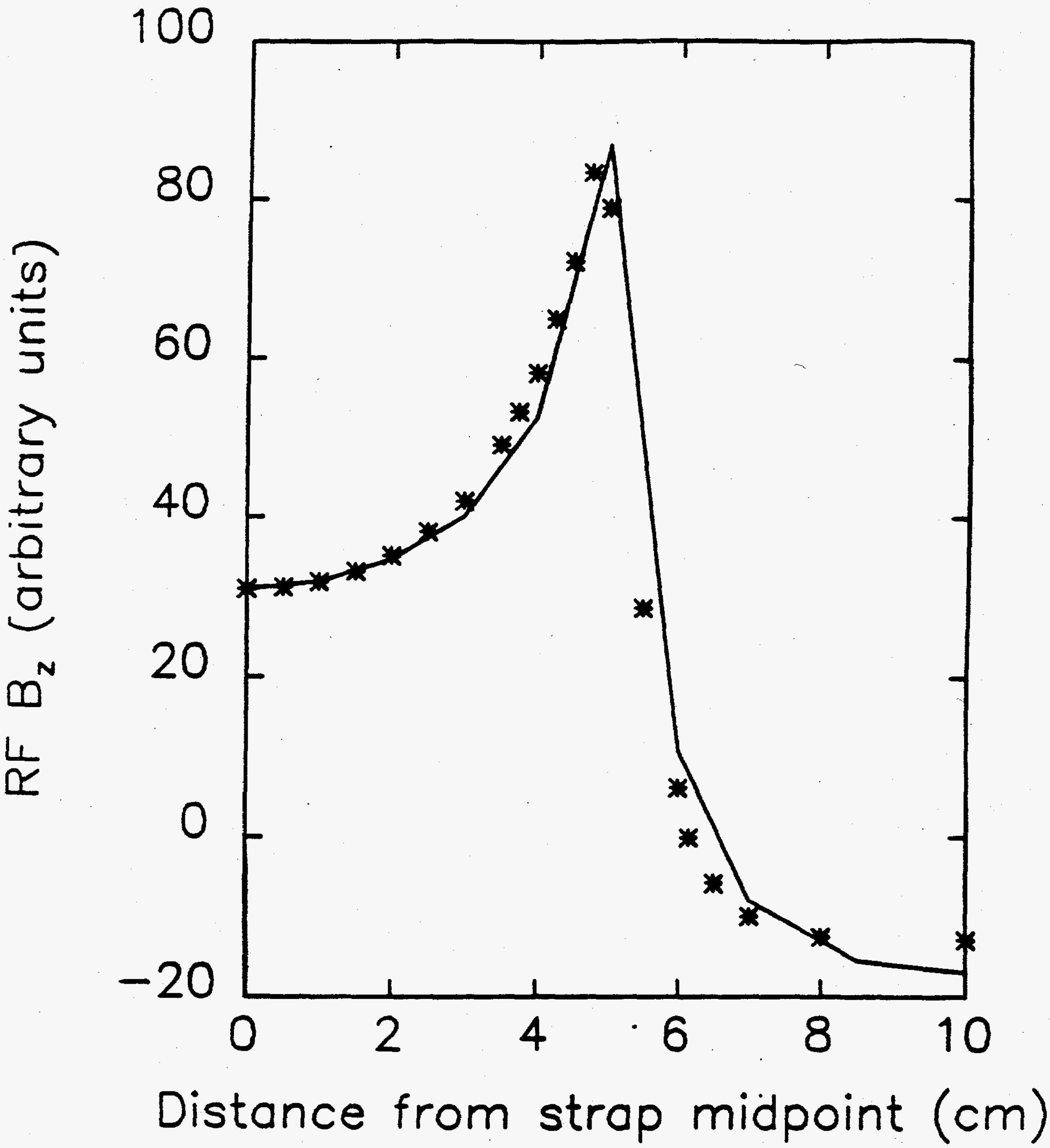
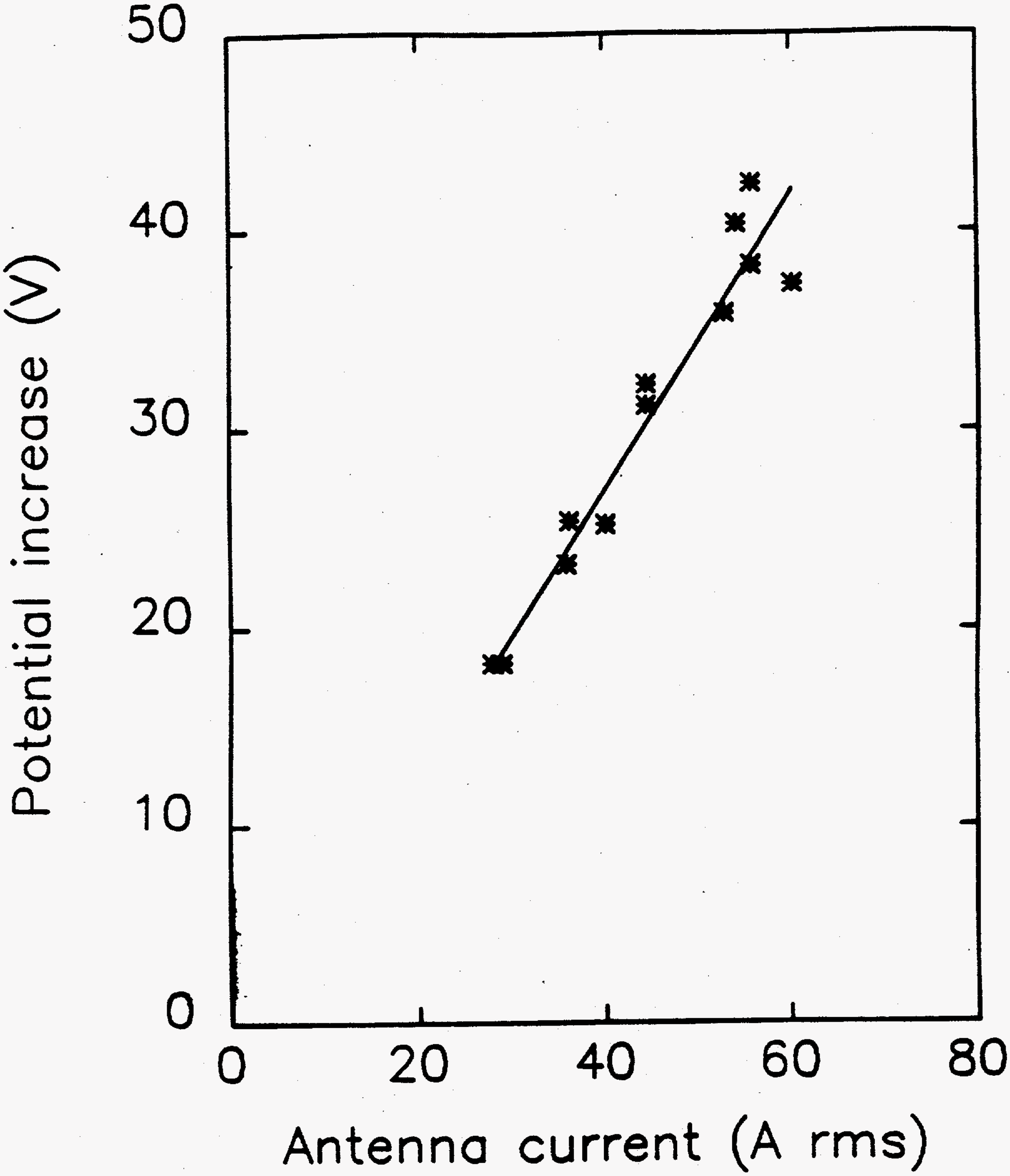

Θ (azimuthal distance) (cm)
20
15
10
5
0
(a)
(b)
(c)
20
10
20
10
0
20
30
40
10
0
5
10
15
20
Z (axial distance) (cm)

Figure 2.



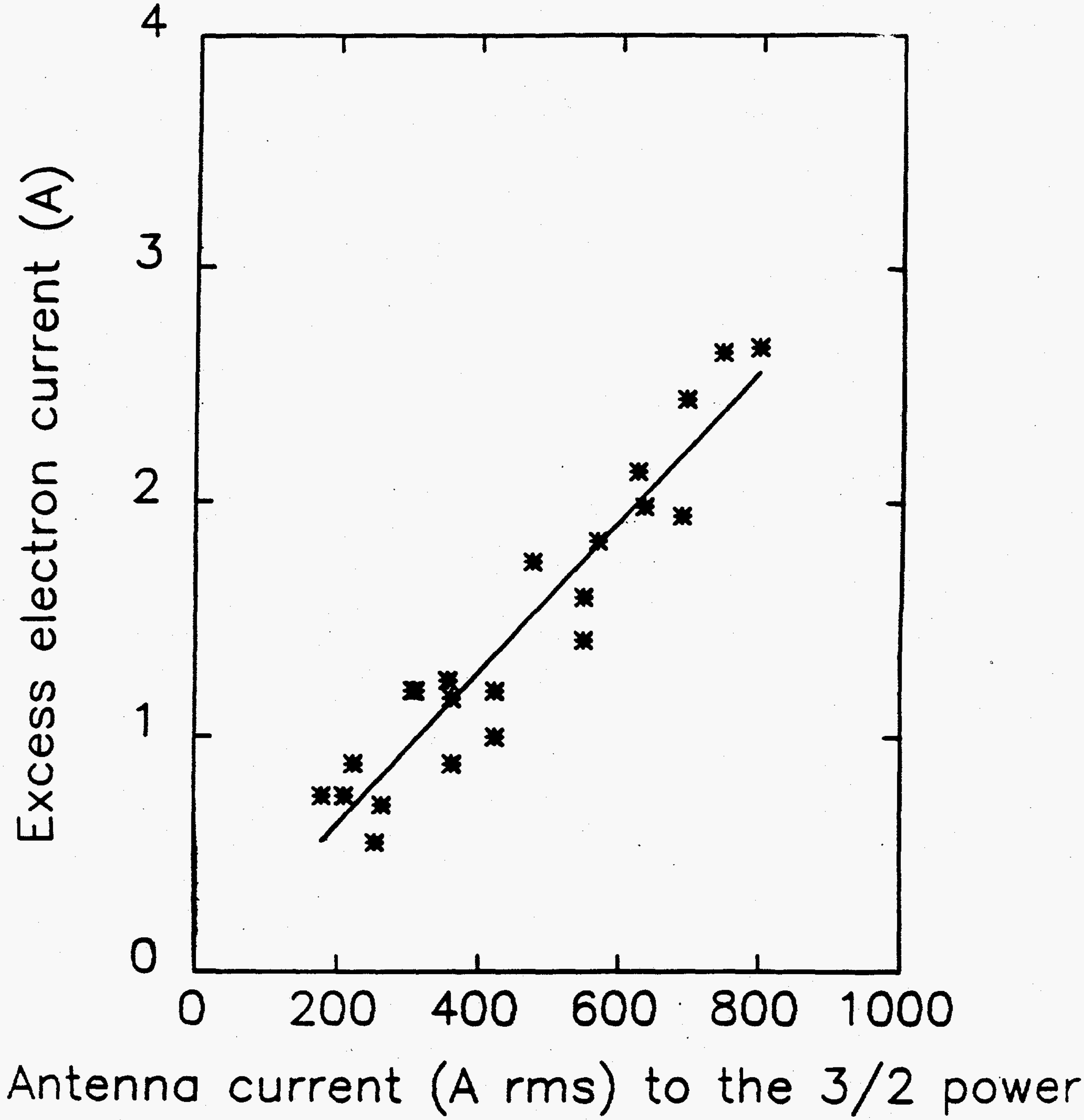
100
80
60
40
20
0
−20
RF B_z (arbitrary units)
0
2
4
6
8
10
Distance from strap midpoint (cm)

Figure 3.



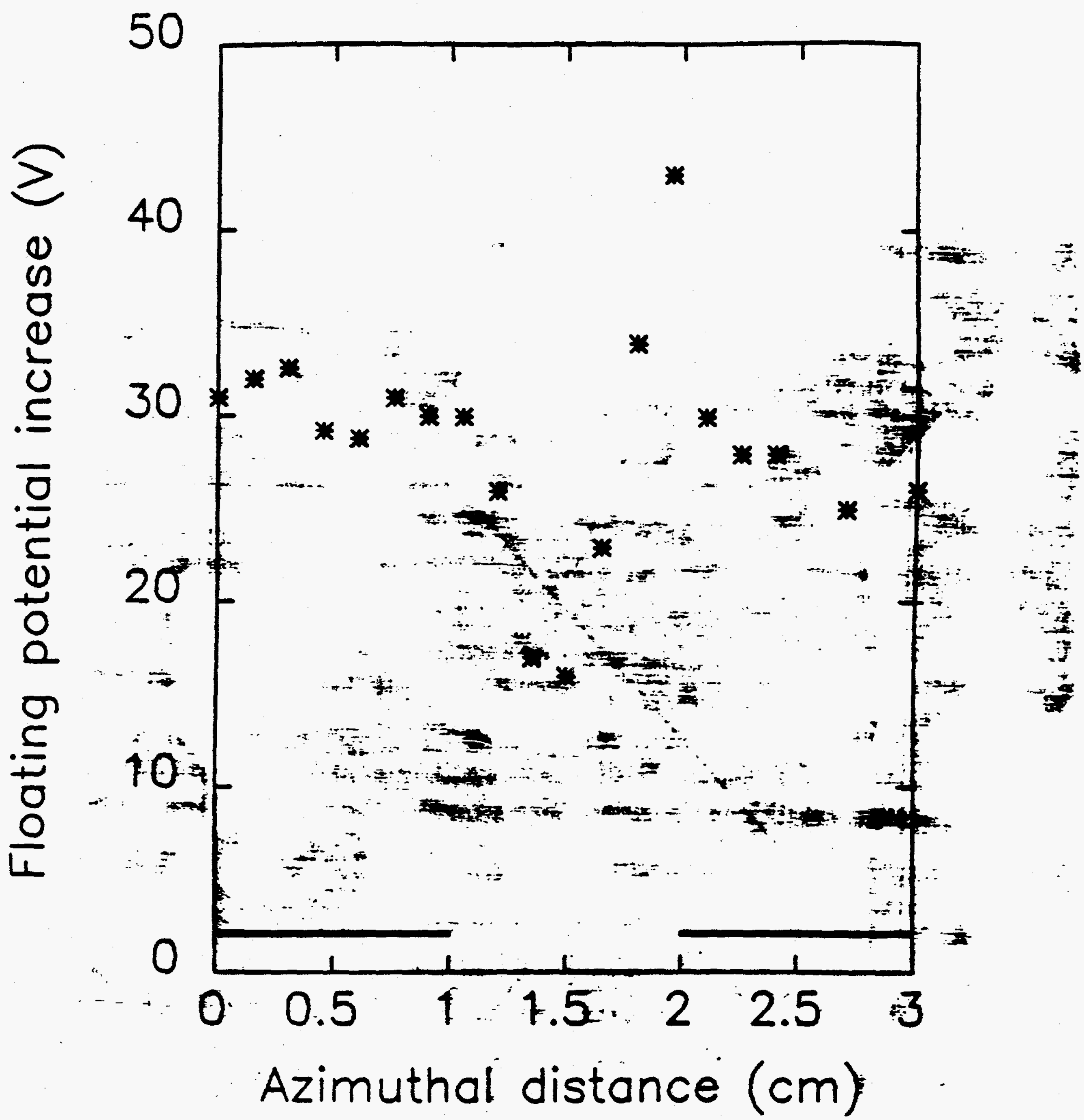
50
40
30
20
10
0
Potential increase (V)
0
20
40
60
80
Antenna current (A rms)

Figure 4



4
3
2
1
0
Excess electron current (A)
0
200
400
600
800
1000
Antenna current (A rms) to the 3/2 power

Figure 5.



Floating potential increase (V)
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
3
Azimuthal distance (cm)

Figure 6.

APPENDIX A.2

Dick Majeski

3-D NUMERICAL MODELING OF ICRF ANTENNAS IN PHAEDRUS-B

Kwok Ko*, William Grossmann, and Adam Drobot

Science Applications International Corporation
McLean, Virginia

and

Richard Majeski, T. Tanaka, and Noah Hershkowitz

University of Wisconsin
Madison, Wisconsin

* Present address:

SLAC
P.O. Box 4349
Stanford, CA 94305

Future Plans

- High-power operation with plasma in RFTF is planned to more directly demonstrate the power-handling capabilities of the folded waveguide.
- Effects on edge plasma density and temperature, and dc and rf sheath potentials will be measured in RFTF for direct comparison with similar measurements using a loop antenna.[3]
- A demonstration experiment on a large tokamak, such as TFTR or Tore Supra, is desirable.

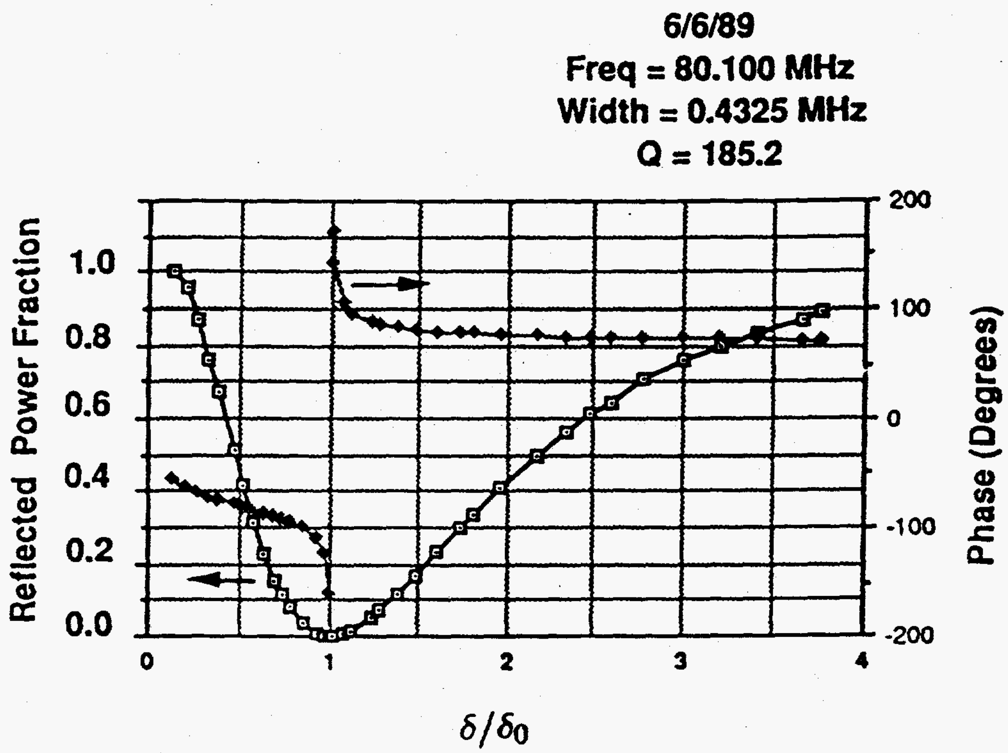
[3] J. B. O. Caughman II, "The Distribution of Ion Energies Incident on an ICRH Antenna Faraday Shield," Ph.D. thesis, University of Illinois at Urbana-Champaign (1989)

Summary

- The folded waveguide produces an rf magnetic field pattern very similar to that of a loop antenna. Thus, we expect coupling to a plasma to be efficient.
- The electrostatic field of the folded waveguide is 2 orders of magnitude less than that of a loop antenna. This is because circulating power is in the interior of a FWG, well separated from the plasma surface. This may have a favorable effect on impurity production and allow higher coupled power flux for the FWG than for a loop antenna.
- Coupling measurements verify that the FWG behaves electrically like a simple, unfolded, resonant cavity.
- High-power operation has been demonstrated.

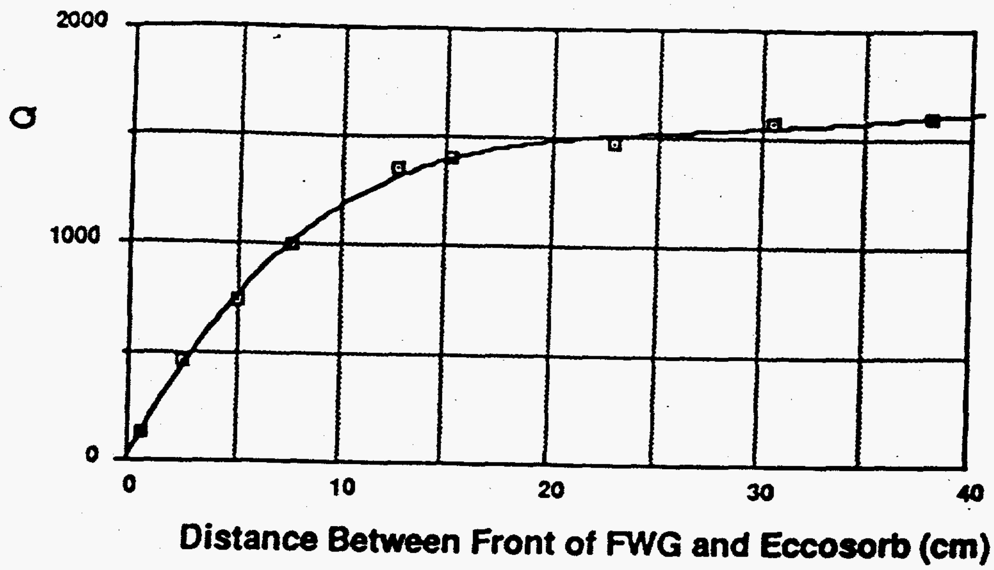
High-Power Tests

- Achieved 200 kW pulsed in vacuum. So far no breakdown limit has been found during vacuum tests. For expected plasma loading, this would imply multi-megawatt operation.
- Multipacting observed in the interior of the FWG for power levels between 1 and 15 watts, but disappeared after conditioning.
- At higher power (10–100 kW) a discharge in the vicinity of the top and bottom exterior surfaces of the FWG was observed. This too could be eliminated after conditioning.
- At high gas pressure (1.5×10^{-4} Torr) 100 kW pulses were sustained without breakdown.

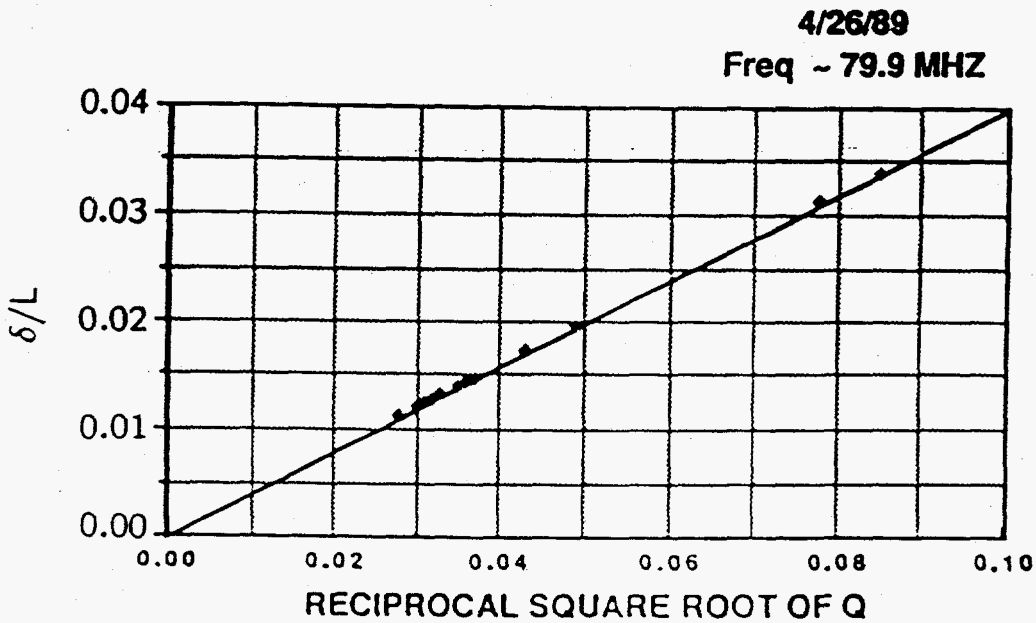


- Variation of measured reflection coefficient with vane-toucher position is consistent with intended tuning mechanism. I.e., there is cancellation of input reactance at the matching position.

Coupling Measurements



- Load was varied by changing distance between FWG and plastic RF load.



- Variation of vane-toucher position for optimum match (measured points) agrees well with model (solid line).

Simple Calculation of Optimum Coupler Position

The voltage applied to the central conductor is related to the input power P by

$$V_{coax} = \left(2\ P\ \ Z_0\right)^{\frac{1}{2}}$$

Z_0 is the characteristic impedance of the feed line.

The voltage on the central vane, at the position of the coupler (d), is related to the maximum electric field by

$$V_{coupler} = a\ E_{max} \sin \frac{\pi \delta}{L}$$

L is the length of the vane, and a is the separation between the side wall and the vane. The two voltages, V_{coax} and $V_{coupler}$, must be equal

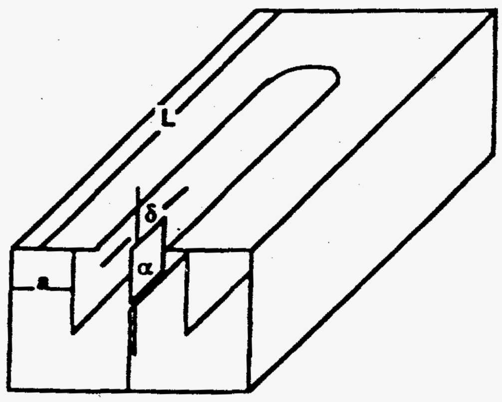
The cavity Q is the energy stored in the cavity, divided by the energy delivered per cycle

$$Q = \frac{2\pi f}{P} \int \varepsilon_0\ E^2\ d(vol)$$

By carrying out the integration over the cavity volume, one finds a relationship between the optimum position for the vane toucher and the cavity Q.

$$\delta = \frac{L}{\pi} \ \sin^{-1} \left(\frac{a\ W\ L\ \pi\ \varepsilon_0\ Z_0\ f}{a^2\ Q}\right)^{\frac{1}{2}}$$

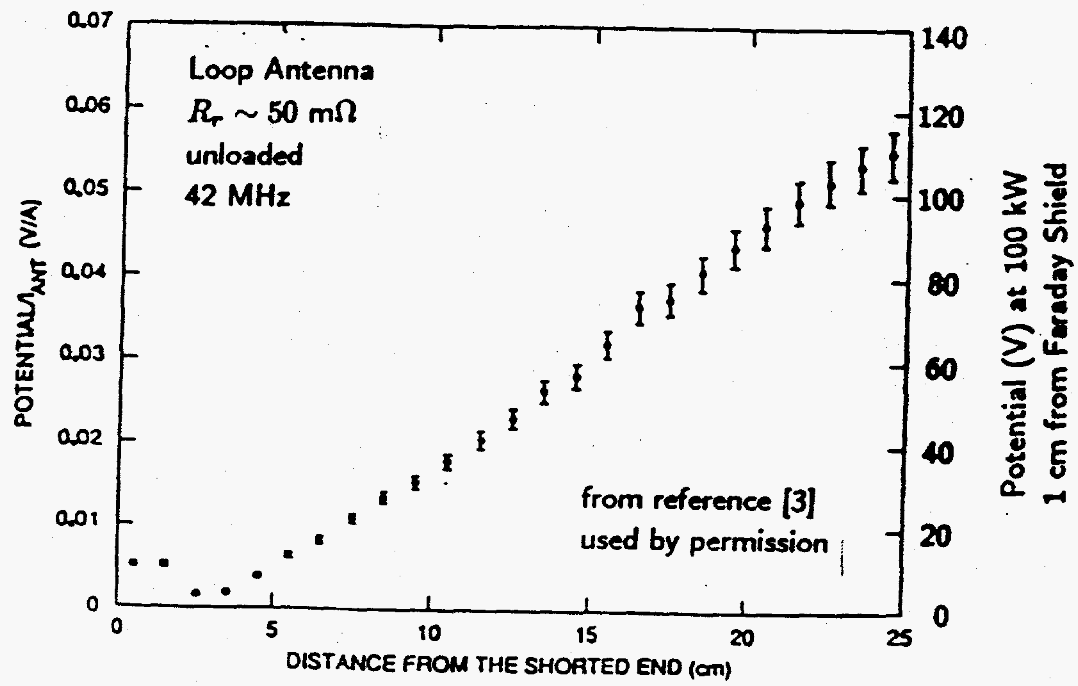
Geometry for Coupling Loop

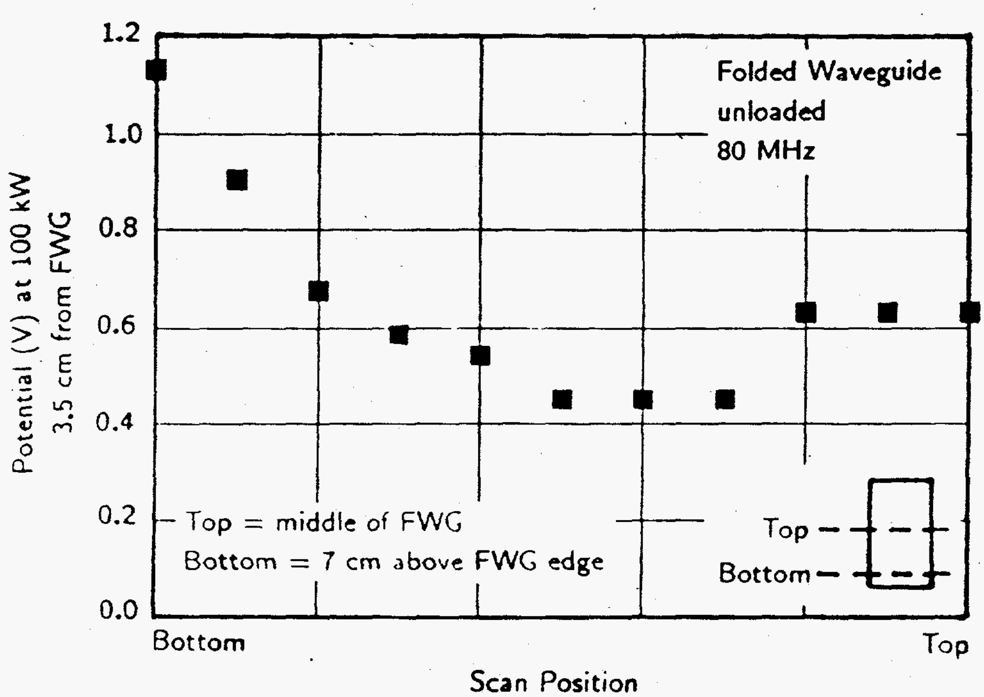


Discussion of Electric Field Comparison

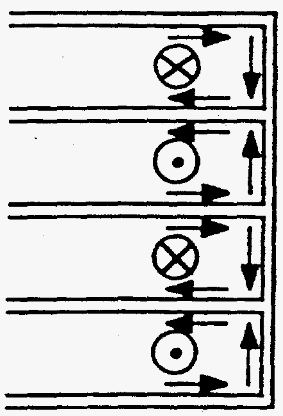
- Measurements on loop antenna were made in air at low power, and then scaled for 100 kW, but measurements on FWG were made at 100 kW under vacuum (4×10^{-6} Torr).
- Peaking of signal near bottom edge of FWG may be related to ionization observed in that region.
- Frequencies were not the same.
- Probe was closer to Faraday shield on loop antenna than to surface of FWG, but distance from current strap on loop antenna was about the same as distance to surface of FWG.
- Nevertheless, the difference in potential is two orders of magnitude, which is quite significant.

Electric Fields
Comparison with Loop Antenna

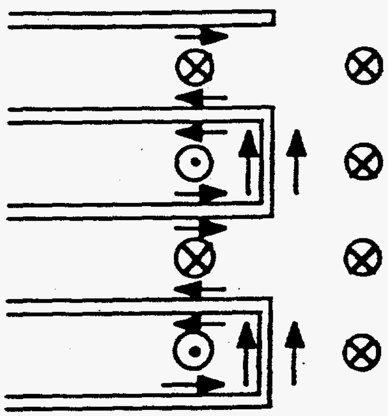




Discussion on Smoothness of Magnetic Field



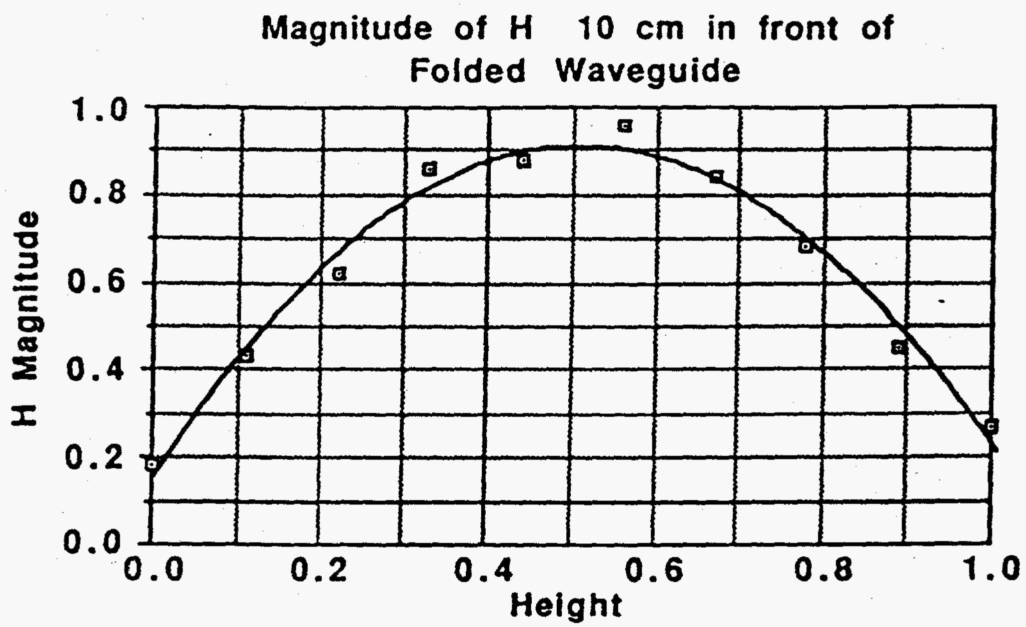
Longitudinal Section Through a Folded Waveguide Structure with a Closed Face



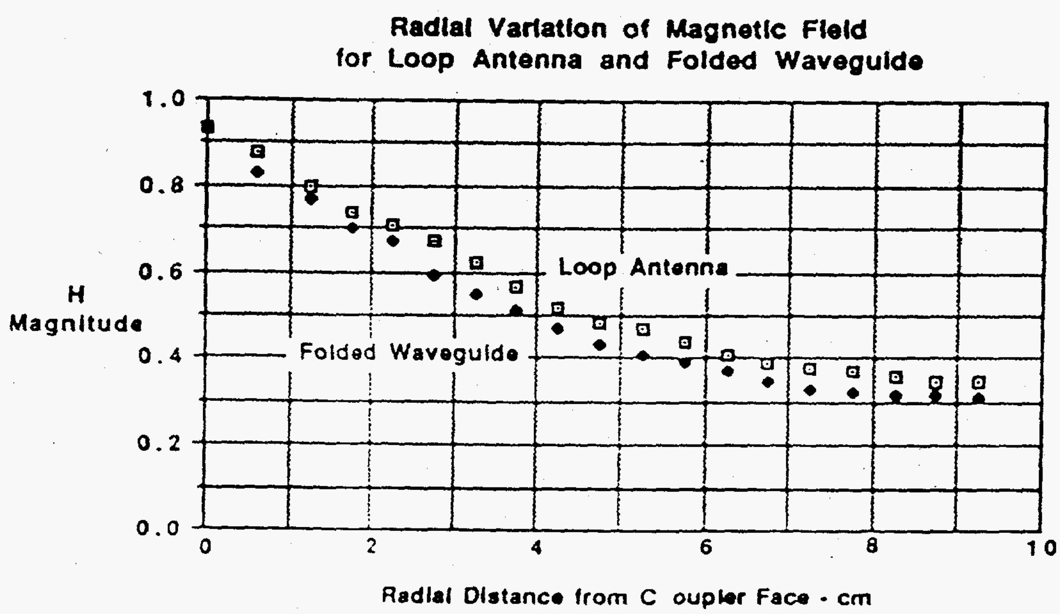
Section Through a Folded Waveguide Structure with Two Open Regions

- The FWG is driven at a frequency such that the distance from front plate to back plate is one-half of a guide wavelength when front face is closed, and only slightly perturbed from this distance when openings are present. This results in current maxima and voltage minima at each end. With openings, nearly all of the current must flow along outside face as indicated because, since opening is near a voltage minimum, significant displacement current cannot flow. Thus, even the closed sections contribute to the coupled field.

Vertical and Radial Variation of RF Magnetic Field

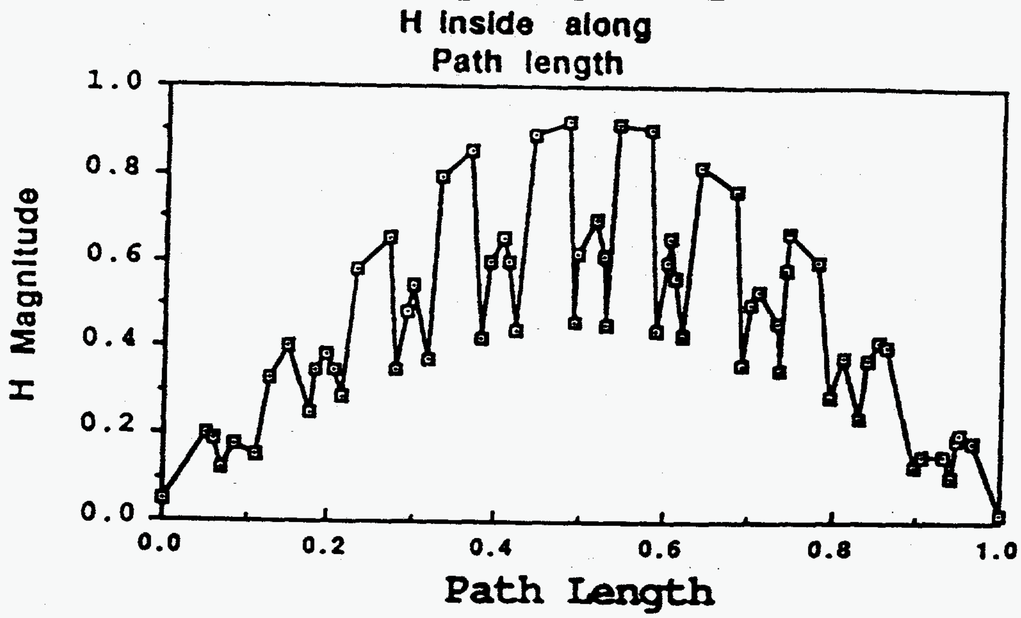


- Variation with height is smooth.

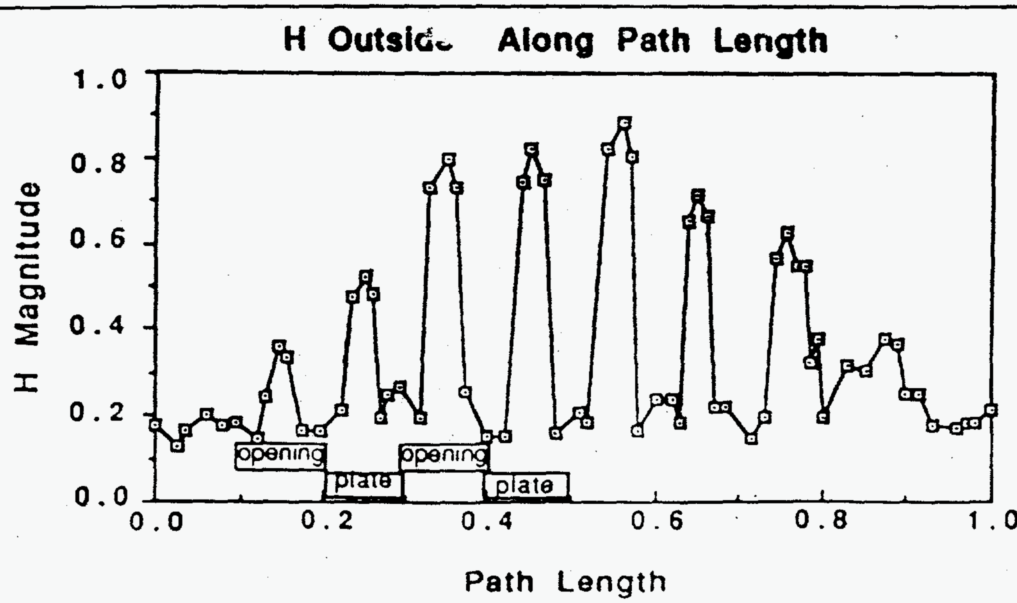


- "Radial" profile is very similar to that of a loop antenna.

Variation of Magnetic Field Along Zig-Zag Path



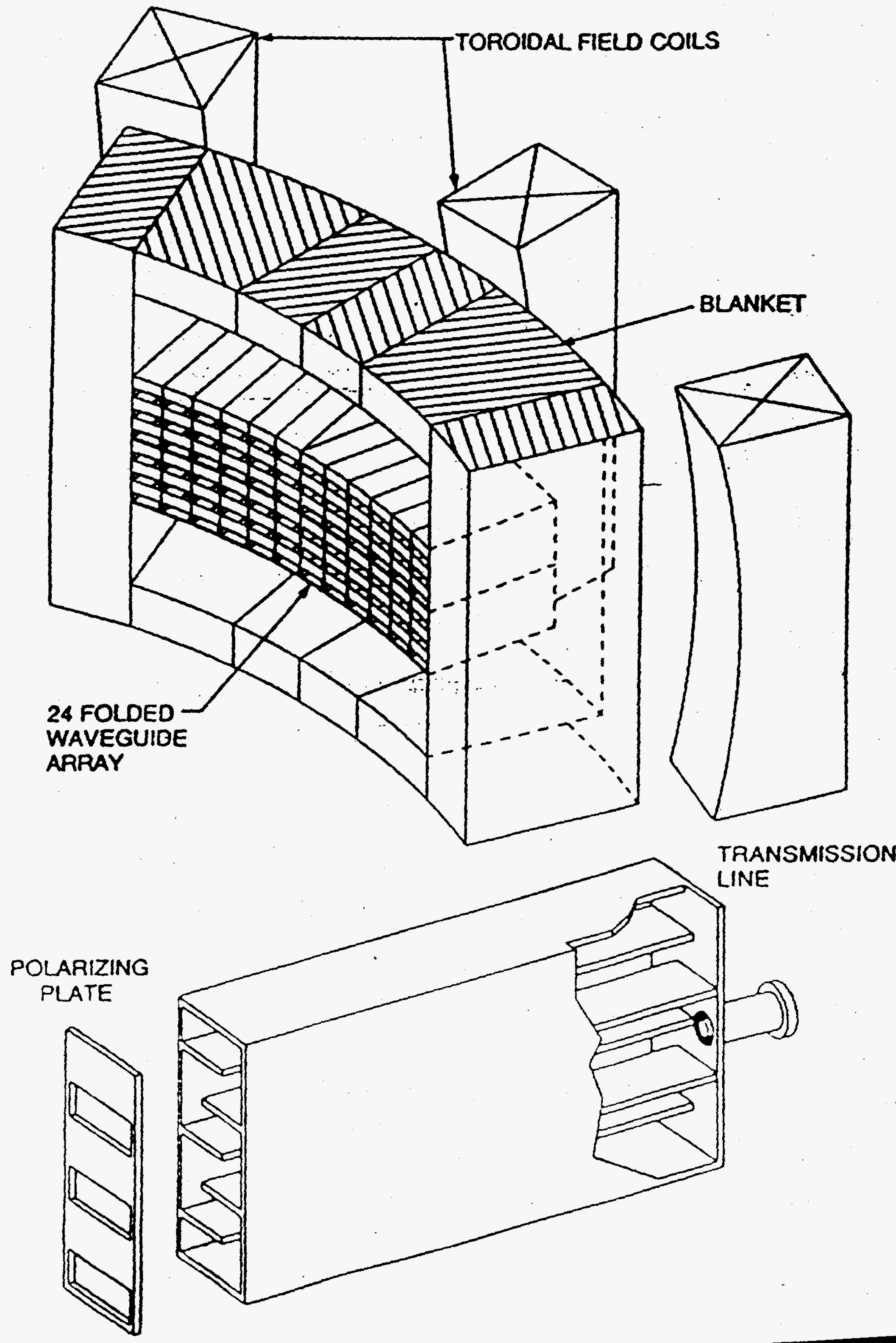
- With FWG closed off using solid plate, magnetic field measured just inside the front wall has this dependence and *reverses direction* from one fold to the next.



- With polarizing plate attached, magnetic field measured just outside the plate has this dependence and *does not reverse direction* from one fold to the next.

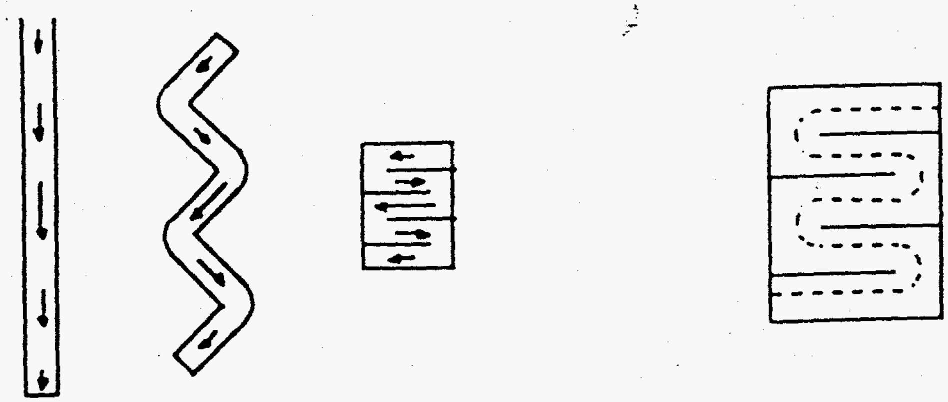
FOLDED WAVEGUIDE LAUNCHER FOR FAST WAVE CURRENT DRIVE IN ITER

ORNL-DWG 89-2873 FED

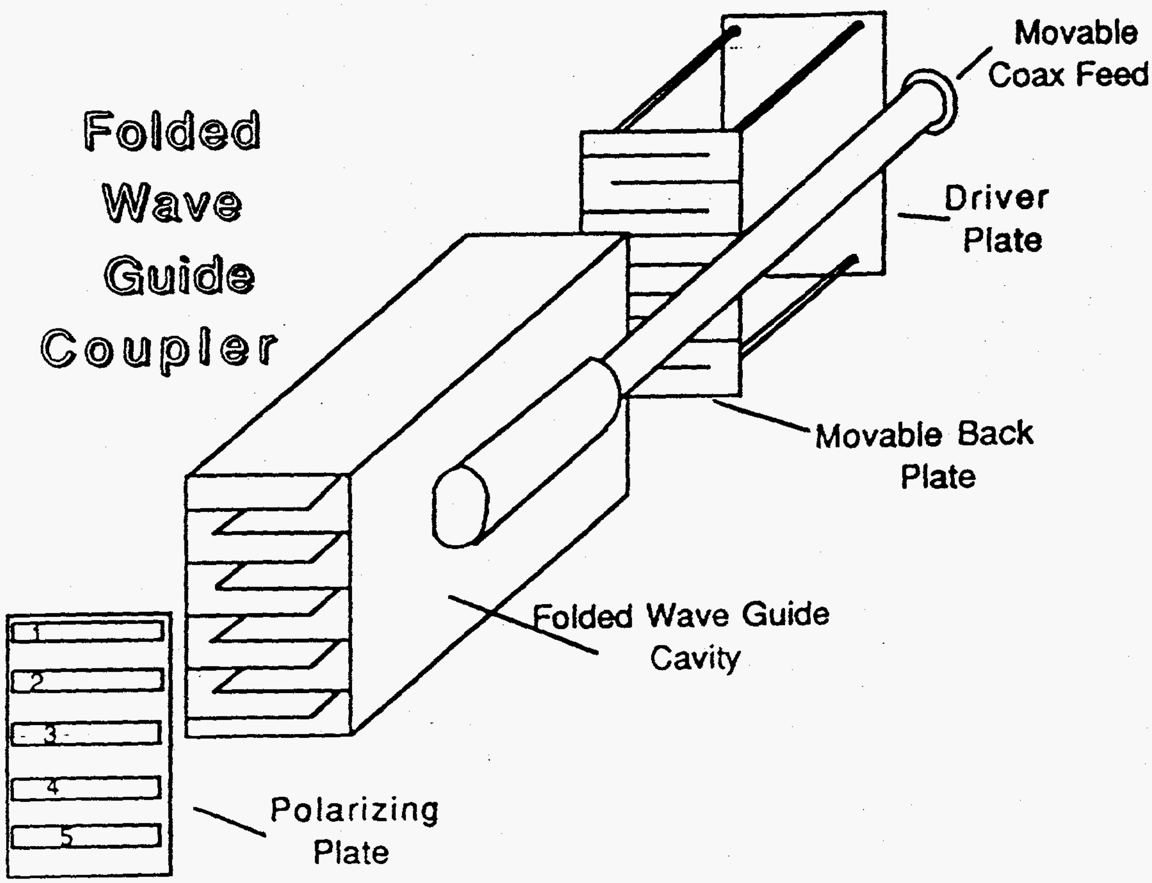


Folded Waveguide Parameters

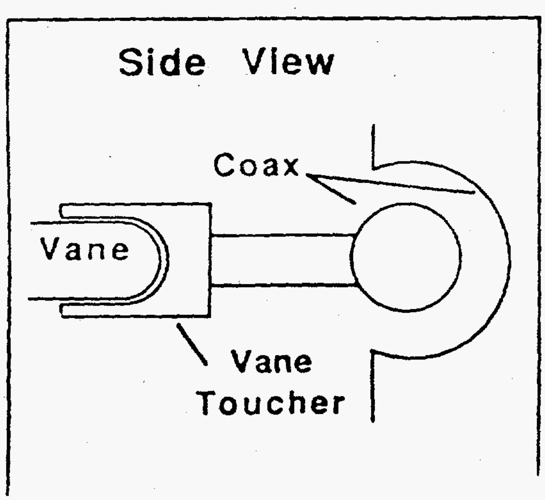
Number of Folds	10
Width of Fold	27.5 cm
Vane Thickness	1.59 cm
Length of Vane	304.8 cm
Material	Al 6061
Number of Vanes	9
Width of Vane	21.9 cm
Vane-to-Vane Distance	5.32 cm
Back-Plate Motion Range	68.6 cm
Copper Coating	1.27×10^{-3} cm



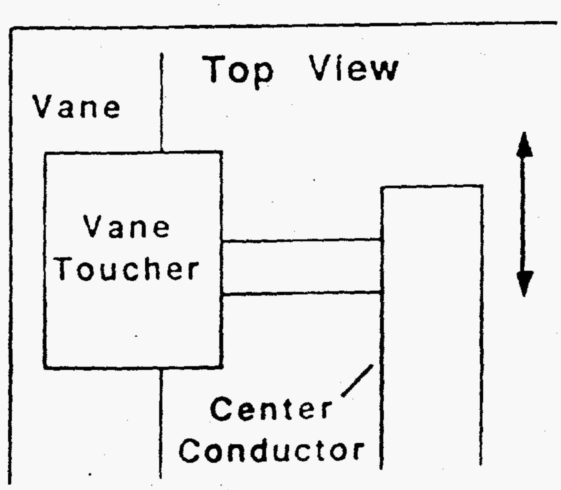
(a) (b) (c)



Folded Wave Guide Coupler
Movable Coax Feed
Driver Plate
Movable Back Plate
Folded Wave Guide Cavity
1
2
3
4
5
Polarizing Plate



Side View
Coax
Vane
Vane Toucher



Top View
Vane
Vane Toucher
Center Conductor

Potential Advantages of the Folded Waveguide Structure as an ICRF Coupler

- Relatively simple structure. Should be easy to withstand disruption forces because there is no current strap to support.
- Easy to cool, because cooling channels can reach any part of the structure by passing only through metal.
- May not require a separate Faraday shield, which further simplifies the mechanical and thermal design issues.
- Insulators are not required in the vicinity of the plasma.
- Particularly attractive at higher frequency ($>$ 80 MHz) where loop antennas begin to have difficulty.

G.R. Haste, P.L. Nguyen, D.J. Hoffman, T.D. Shepard, "Folded Waveguide Development," Bull. Am. Phys. Soc 34 (1989) p. 2093 1989 APS DPP Report 654.

The Folded Waveguide Concept

- The basic idea involves "folding" a simple rectangular waveguide that has a much greater width than height in order to form a more compact structure.
- This is an adaptation of a concept known as a "folded waveguide" (FWG) reported by Barrow and Schaevitz in connection with low-frequency waveguide transmission systems.[1]
- T. L. Owens proposed using a resonant structure based on the FWG concept to couple ICRF power to a fusion device.[2]

[1] W. L. Barrow and H. Schaevitz, "Hollow pipes of relatively small dimensions," *AIEE Trans.*, vol. 60, p. 119 (1941)

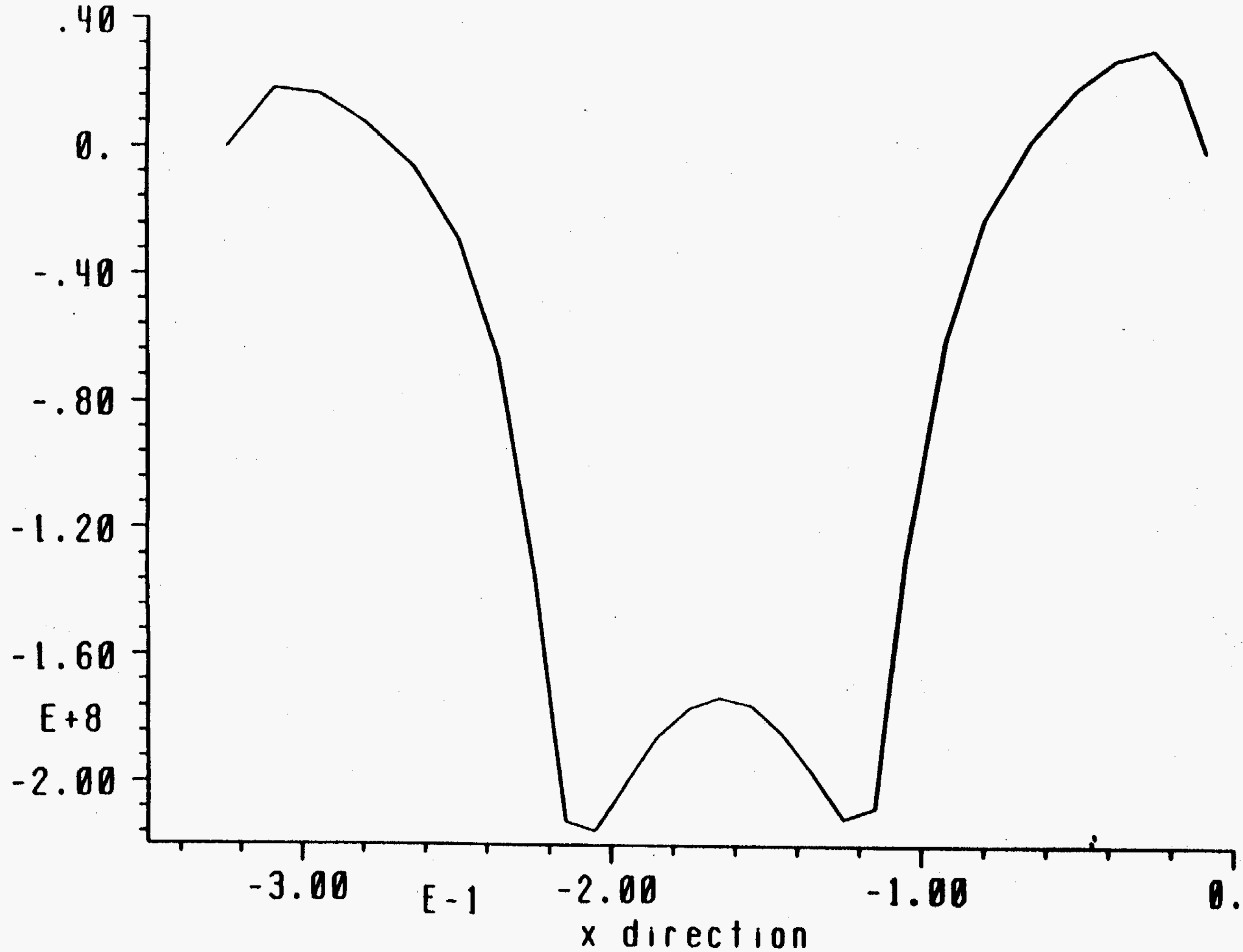
[2] T. L. Owens, "A Folded Waveguide Coupler for Plasma Heating in the Ion Cyclotron Range of Frequencies," *IEEE Trans. Plasma Sci.*, vol. PS-14, p. 934 (1986)

* Research sponsored by the Office of Fusion Energy, U.S. Department of Energy, under contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

APPENDIX D

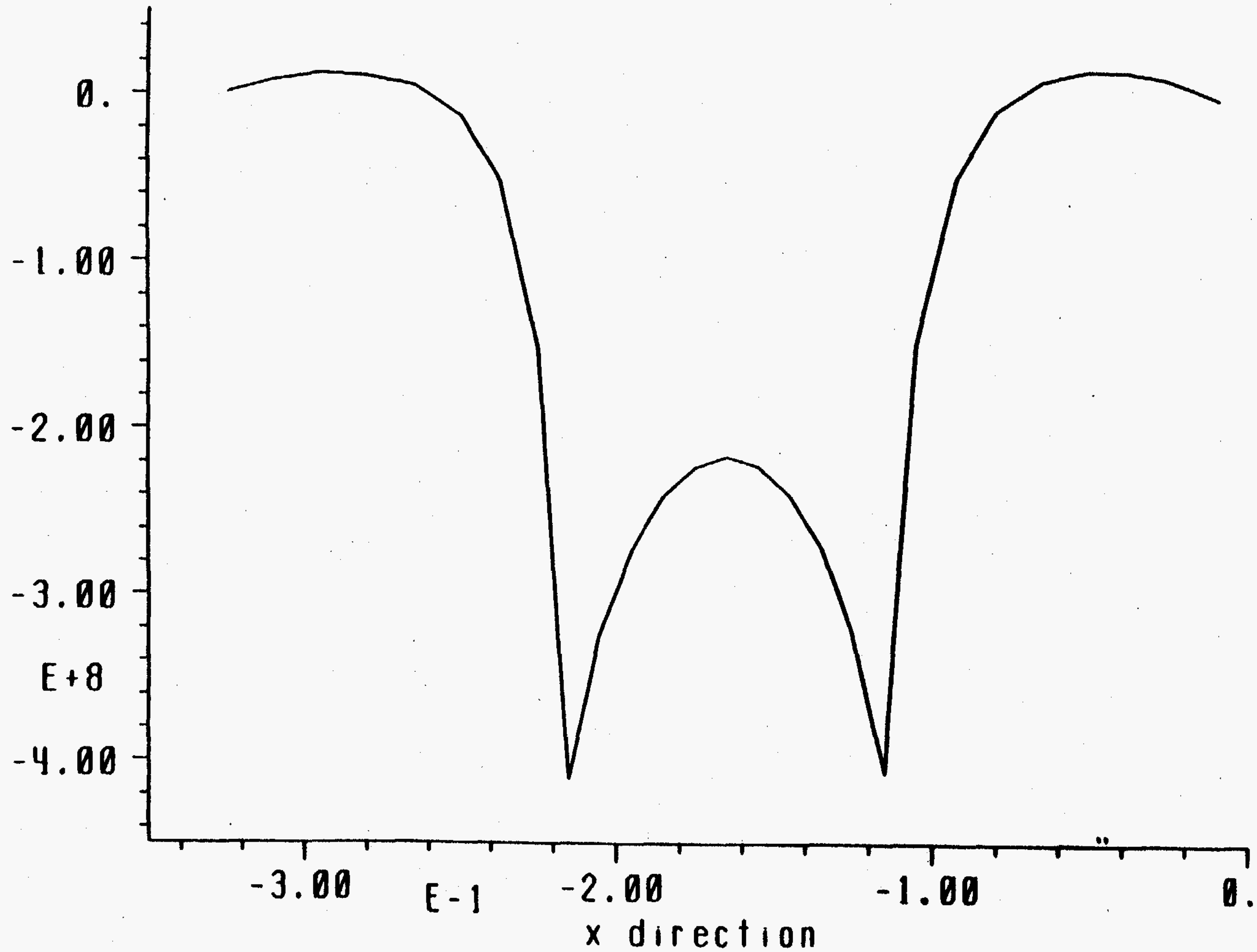
CONCLUSIONS

- VACUUM FIELDS CAN BE COMPUTED FOR REALISTIC ANTENNA CONFIGURATIONS
- FIELD CONTOURS AND PROFILES CAN BE USED TO PROVIDE INSIGHT AND UNDERSTANDING OF CURRENT ANTENNA GEOMETRY
- COMPUTATIONAL TOOLS CAN PROVIDE VALUABLE INFORMATION DURING DESIGN, ANALYSIS AND EVALUATION PHASE OF FUTURE ANTENNA EFFORTS



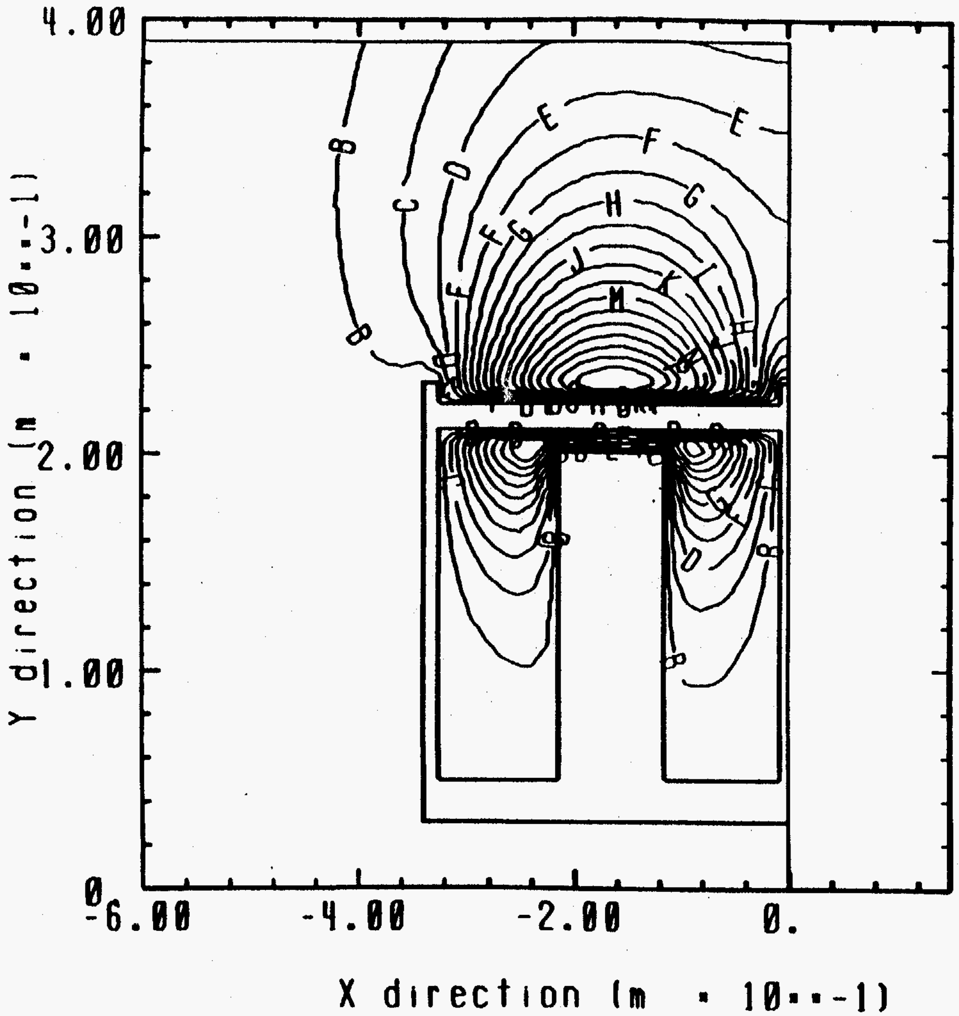
B_x PROFILE IN BETWEEN TWO FARADAY BARS; LOWEST AND NEXT TO LOWEST, (0 - 0)

Science Applications International Corporation
An Employee-Owned Company



B_x PROFILE IN FRONT OF STRAP AT MID-PLANE (0 - 0)

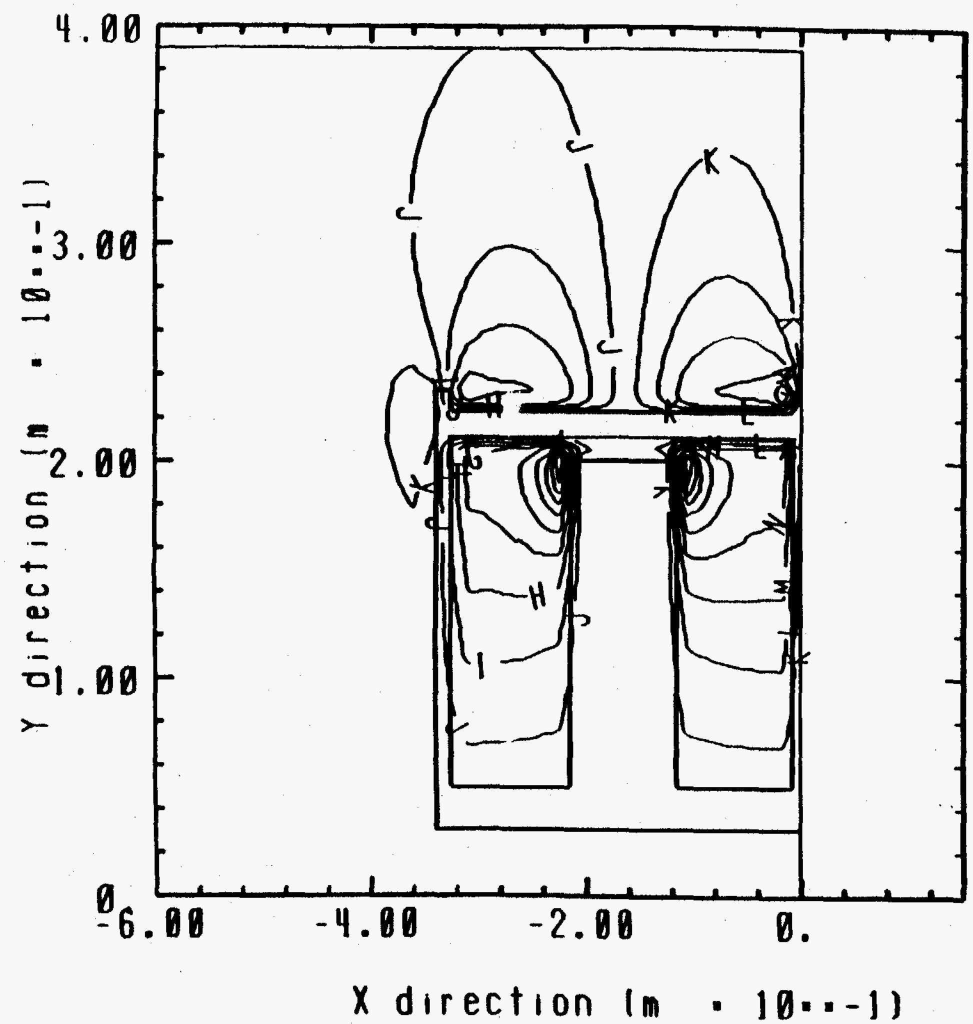
Science Applications International Corporation
An Employee-Owned Company



Contour Levels	
A:	-7.9559e-04
B:	1.9194e-03
C:	4.6344e-03
D:	7.3493e-03
E:	1.0064e-02
F:	1.2779e-02
G:	1.5494e-02
H:	1.8209e-02
I:	2.0924e-02
J:	2.3639e-02
K:	2.6354e-02
L:	2.9069e-02
M:	3.1784e-02
N:	3.4499e-02
O:	3.7214e-02
P:	3.9929e-02
Q:	4.2644e-02
R:	4.5359e-02
S:	4.8074e-02
T:	5.0789e-02

E_z CONTOURS AT MID-PLANE, z = 0 (0 - 0)

SAIC Science Applications International Corporation
An Employee-Owned Company



Contour Levels

A:	-3.1425e+08
B:	-2.8122e+08
C:	-2.4819e+08
D:	-2.1516e+08
E:	-1.8213e+08
F:	-1.4910e+08
G:	-1.1607e+08
H:	-8.3041e+07
I:	-5.0011e+07
J:	-1.6982e+07
K:	1.6048e+07
L:	4.9078e+07
M:	8.2107e+07
N:	1.1514e+08
O:	1.4817e+08
P:	1.8120e+08
Q:	2.1423e+08
R:	2.4726e+08
S:	2.8029e+08
T:	3.1331e+08

B_y CONTOURS AT MID-PLANE, z = 0, (0 - 0)

Science Applications International Corporation
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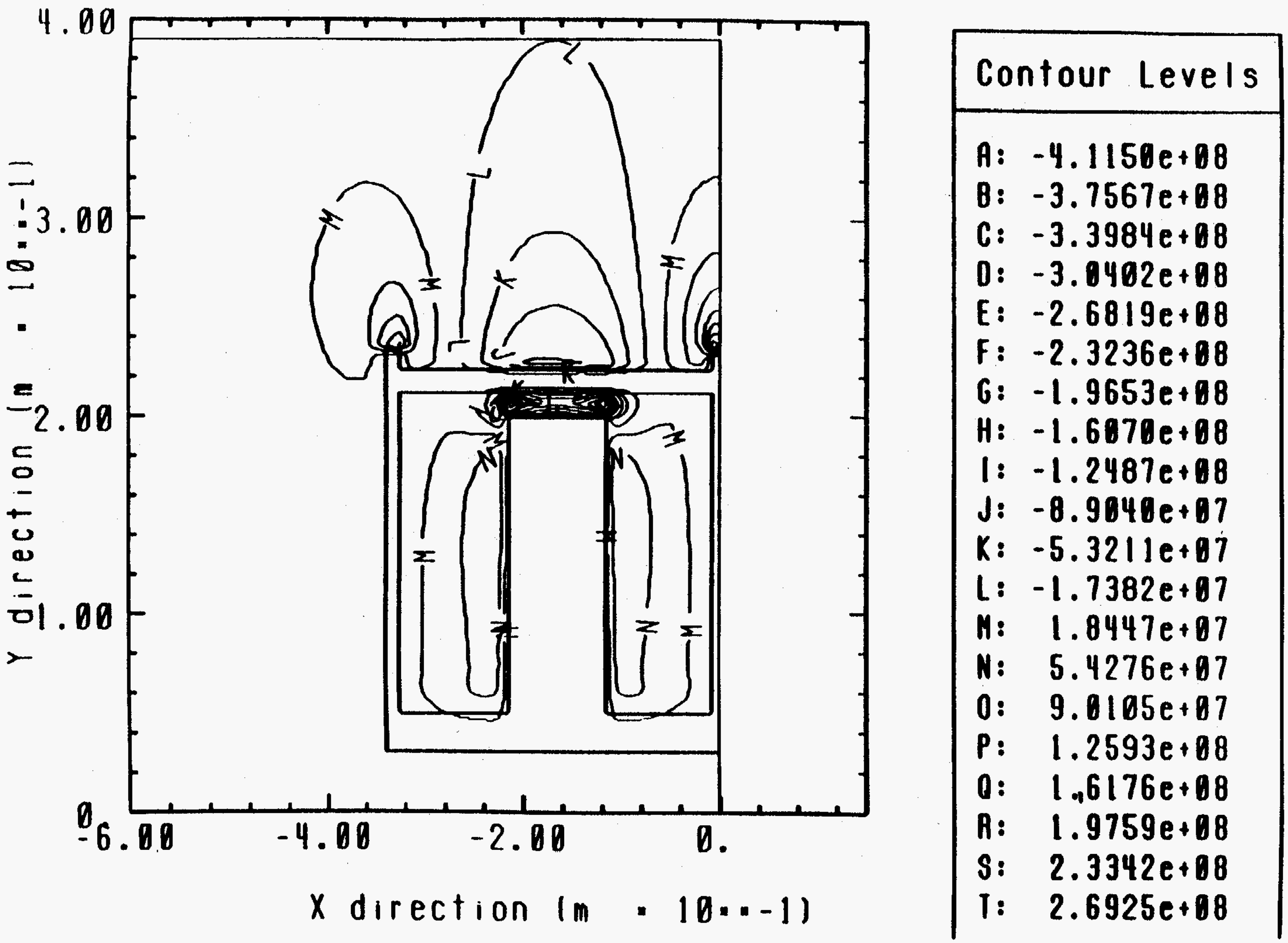
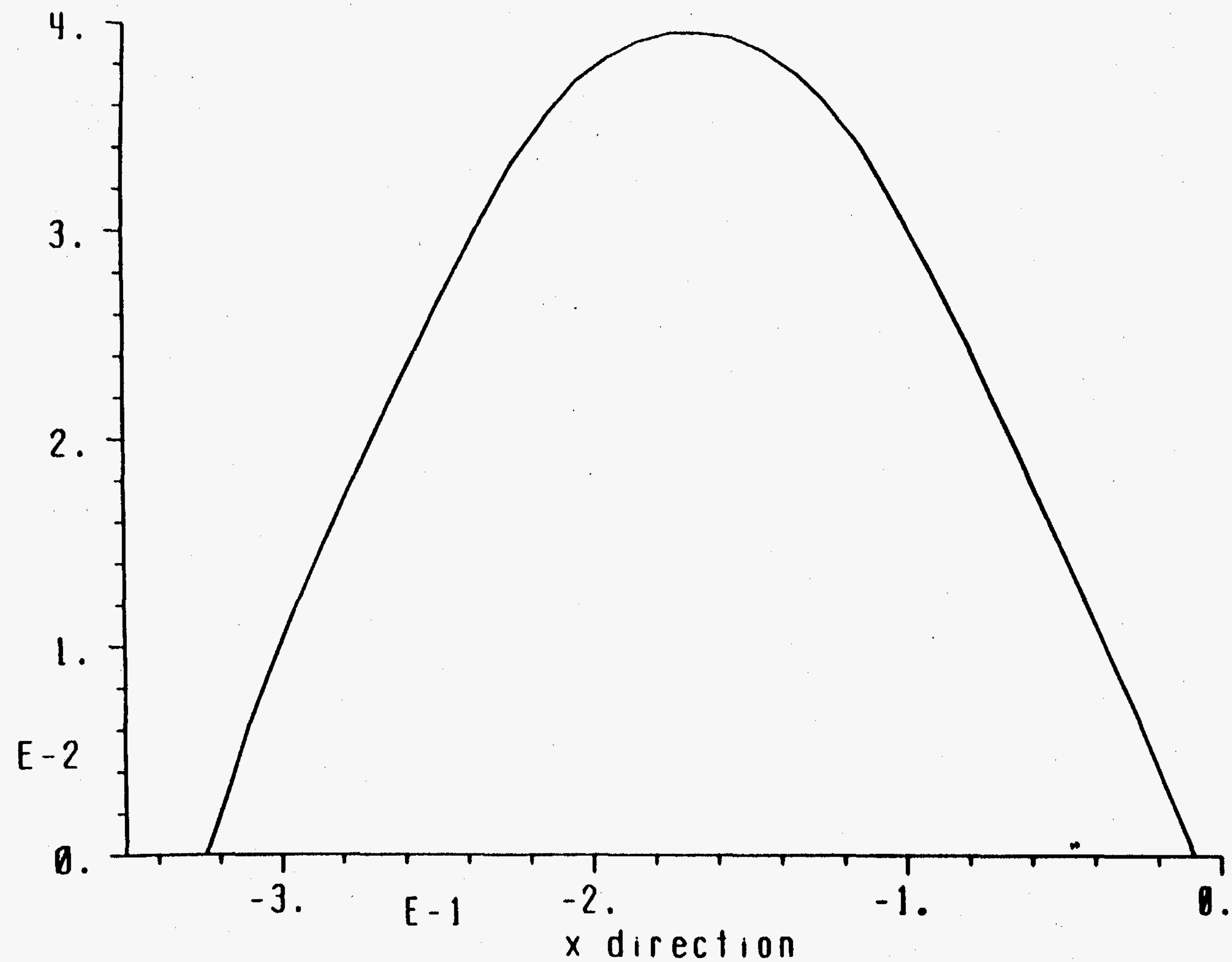


B_x CONTOURS AT MID-PLANE, z = 0 (0 - 0)



E_z PROFILE IN FRONT OF FARADAY SHIELD, $z = 0$ ($0 - \pi$)

Science Applications International Corporation
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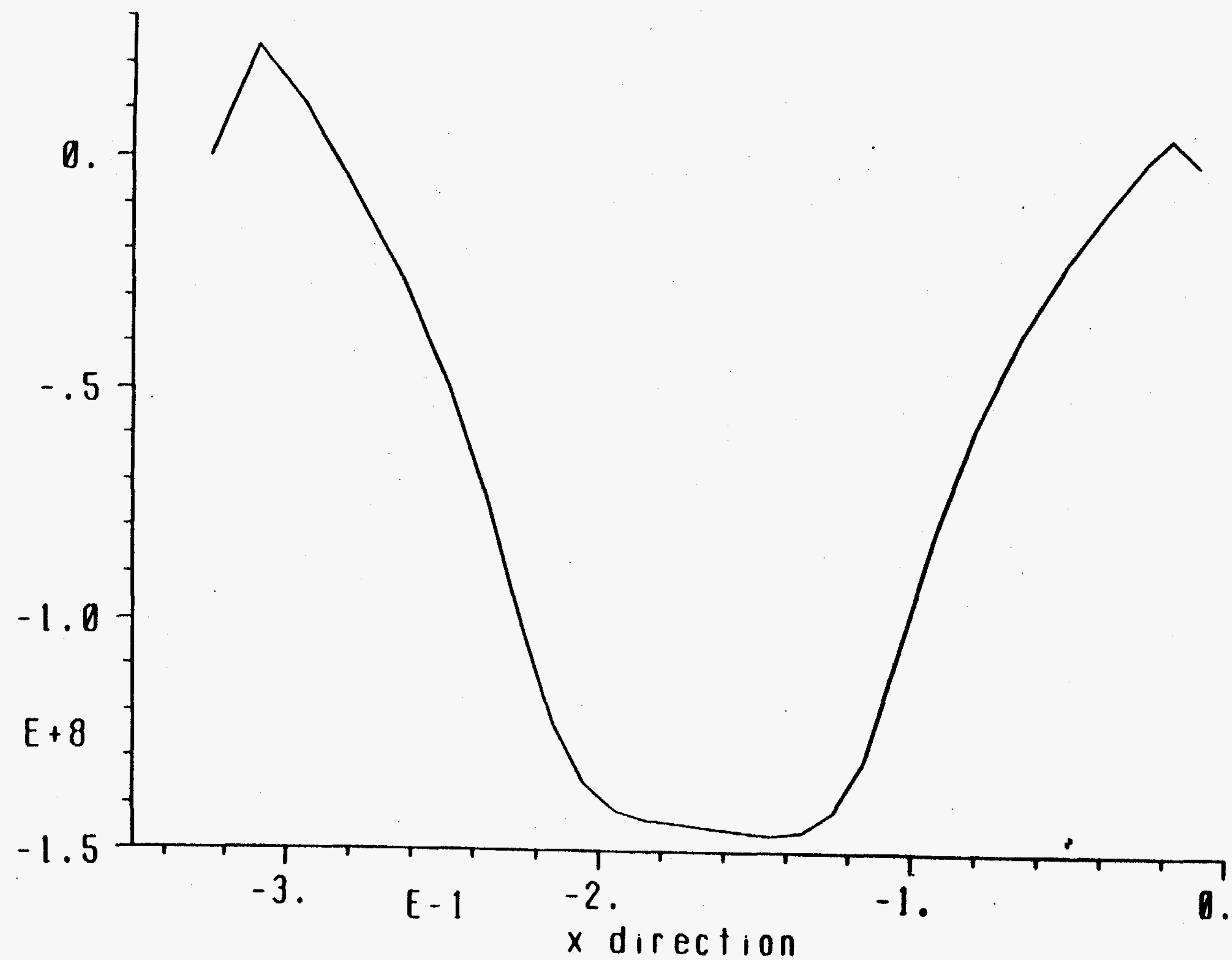
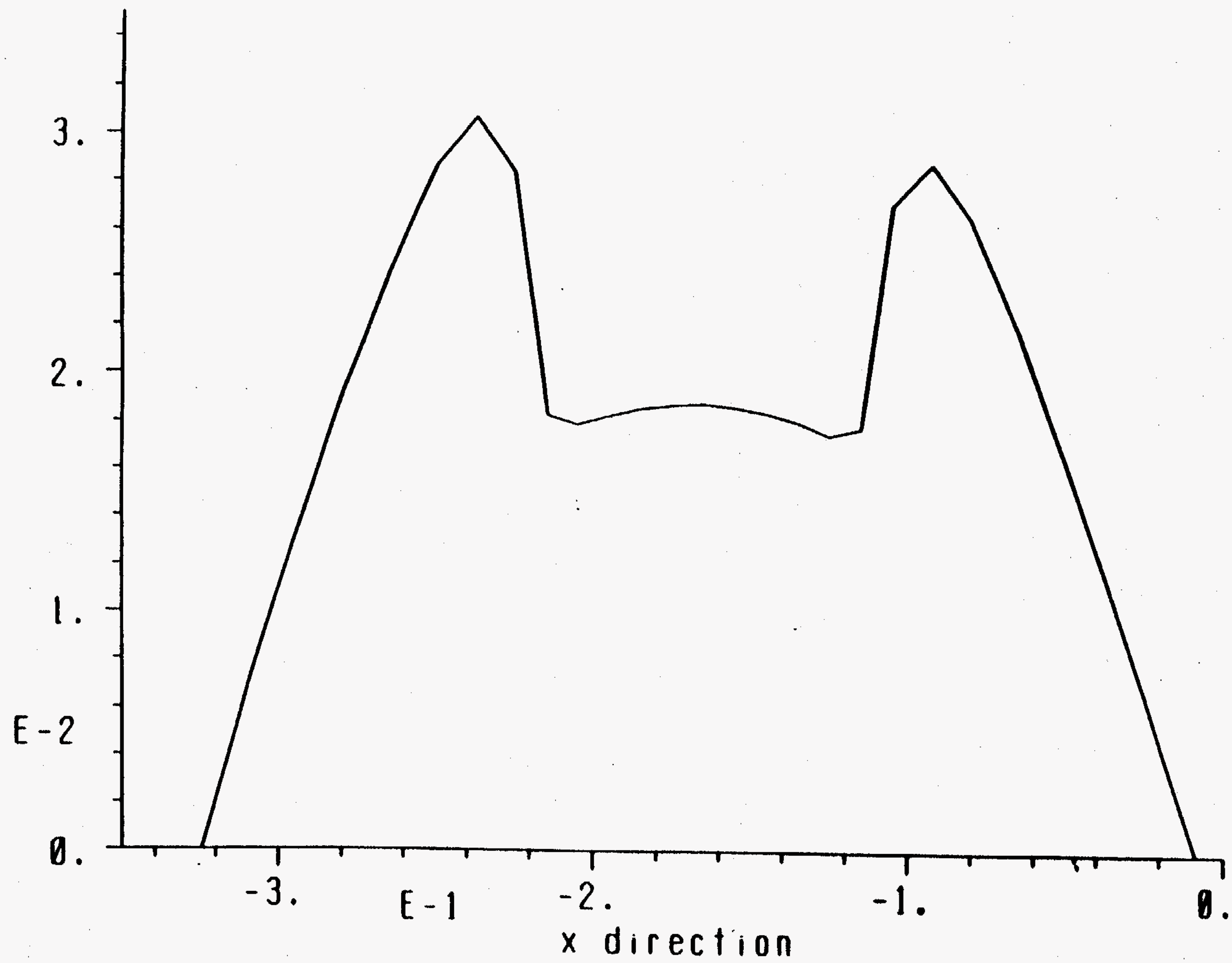


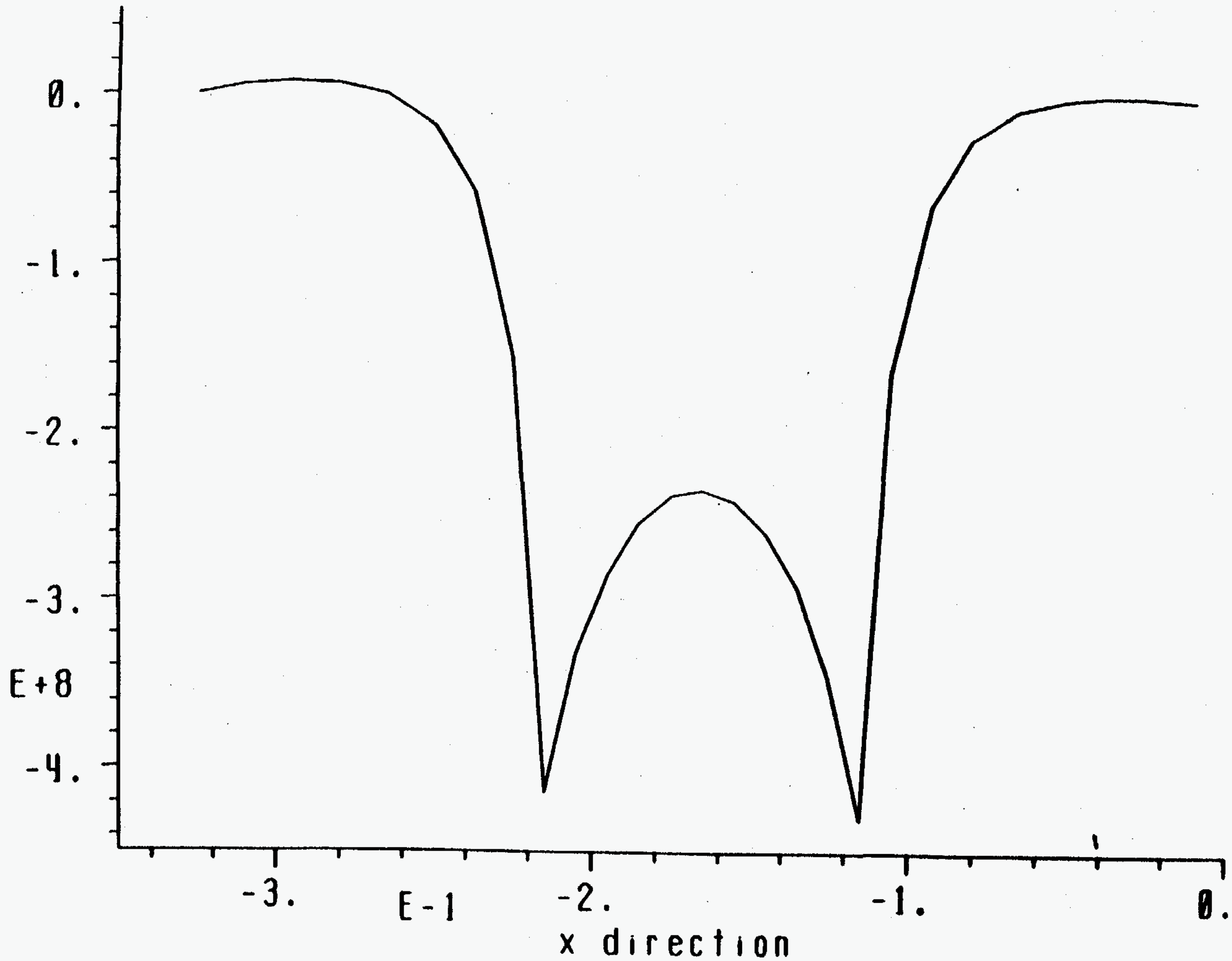
B_x PROFILE IN FRONT OF FARADAY SHIELD, z = 0 (0 - π)

Science Applications International Corporation
An Employee-Owned Company



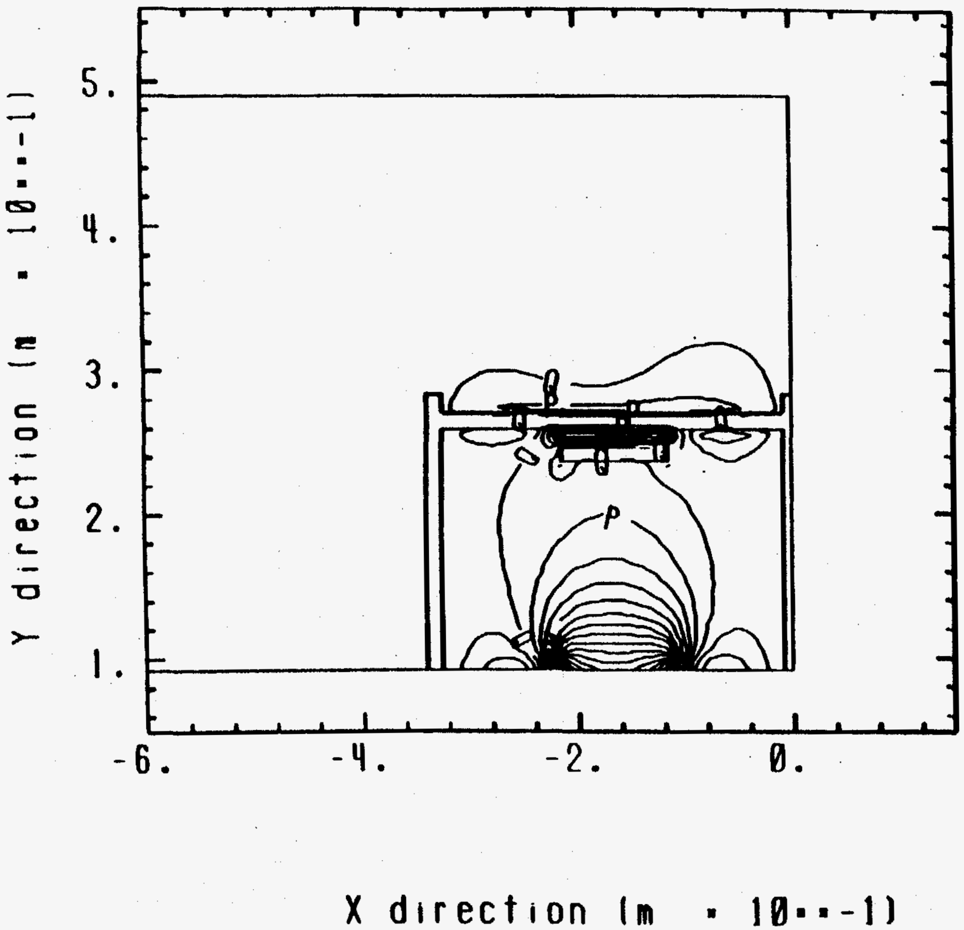
E_z PROFILE IN FRONT OF STRAP IN MID-PLANE $(0 - \pi)$

Science Applications International Corporation
An Employee-Owned Company



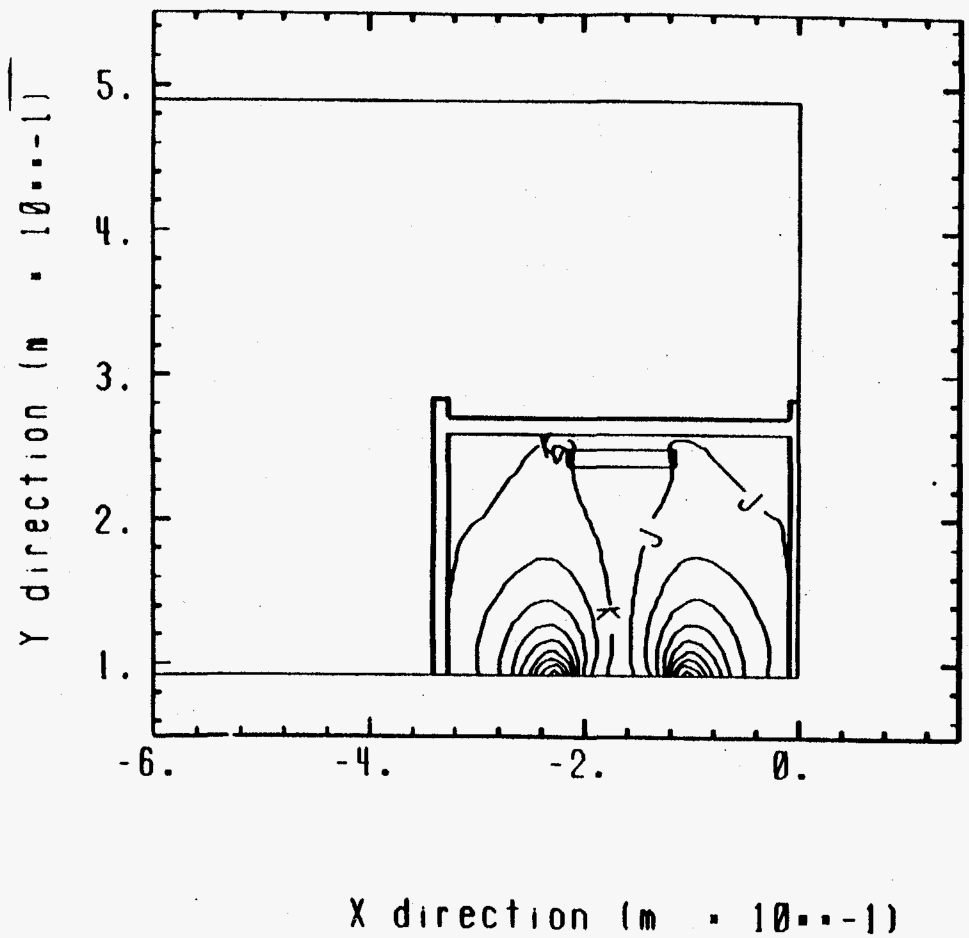
B_x PROFILE IN FRONT OF STRAP AT MID-PLANE (0 - π)

Science Applications International Corporation
An Employee-Owned Company



Contour Levels	
A:	-3.4976e-02
B:	-3.2818e-02
C:	-3.0660e-02
D:	-2.8502e-02
E:	-2.6343e-02
F:	-2.4185e-02
G:	-2.2027e-02
H:	-1.9869e-02
I:	-1.7711e-02
J:	-1.5553e-02
K:	-1.3394e-02
L:	-1.1236e-02
M:	-9.0780e-03
N:	-6.9199e-03
O:	-4.7617e-03
P:	-2.6035e-03
Q:	-4.4539e-04
R:	1.7128e-03
S:	3.8709e-03
T:	6.0291e-03

E_y CONTOURS AT 4TH FARADAY BAR FROM TOP (0 - π)



Contour Levels	
A:	-3.1712e-02
B:	-2.8362e-02
C:	-2.5012e-02
D:	-2.1662e-02
E:	-1.8312e-02
F:	-1.4962e-02
G:	-1.1612e-02
H:	-8.2616e-03
I:	-4.9116e-03
J:	-1.5615e-03
K:	1.7886e-03
L:	5.1386e-03
M:	8.4887e-03
N:	1.1839e-02
O:	1.5189e-02
P:	1.8539e-02
Q:	2.1889e-02
R:	2.5239e-02
S:	2.8589e-02
T:	3.1939e-02

E_x CONTOURS AT 4TH FARADAY BAR FROM TOP (0 - π)

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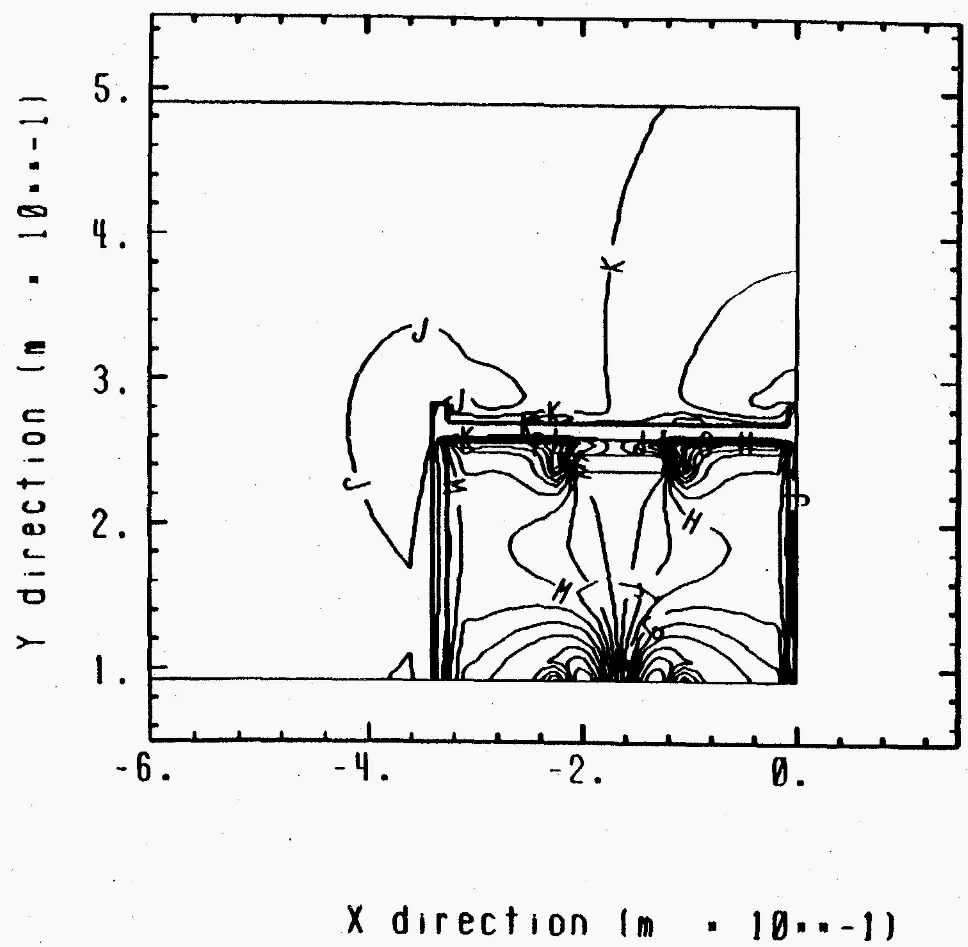

Contour Levels

A:	-8.3558e+07
B:	-7.4782e+07
C:	-6.6006e+07
D:	-5.7230e+07
E:	-4.8455e+07
F:	-3.9679e+07
G:	-3.0903e+07
H:	-2.2127e+07
I:	-1.3351e+07
J:	-4.5753e+06
K:	4.2006e+06
L:	1.2976e+07
M:	2.1752e+07
N:	3.0528e+07
O:	3.9304e+07
P:	4.8080e+07
Q:	5.6856e+07
R:	6.5631e+07
S:	7.4407e+07
T:	8.3183e+07

B_z CONTOURS AT 4TH FARADAY BAR FROM TOP (0 - π)

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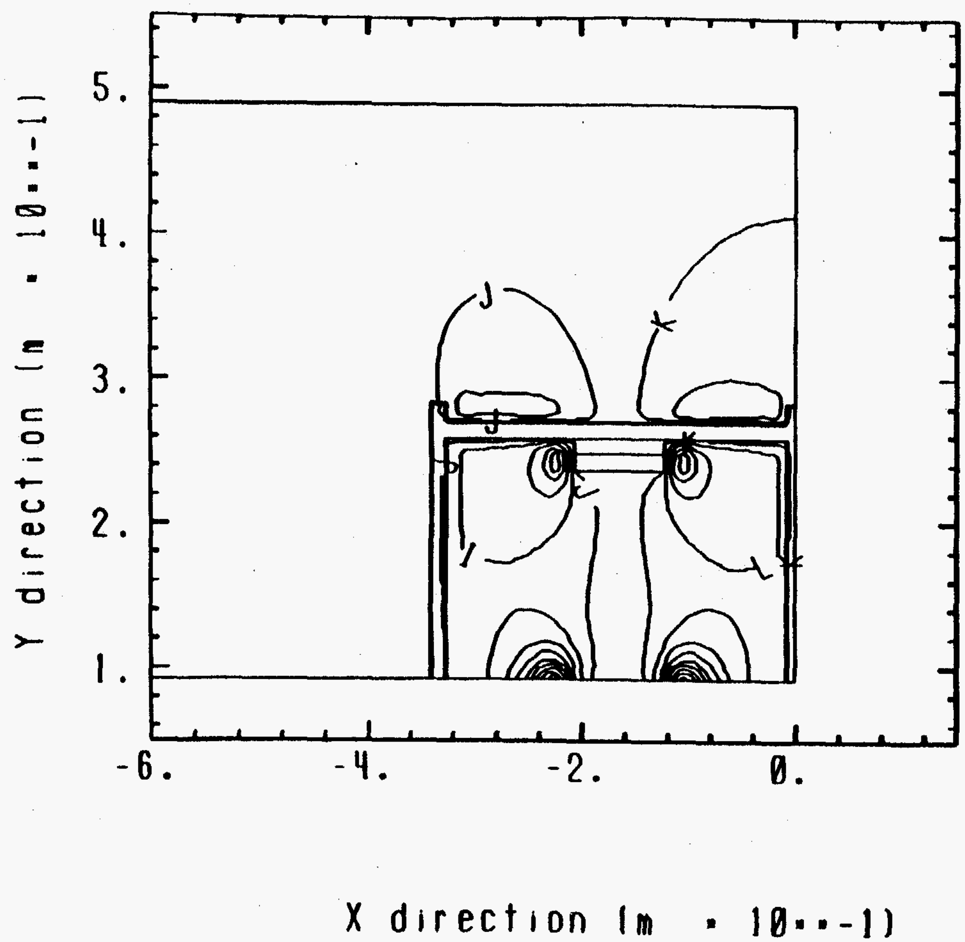

Contour Levels	
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B:	-3.5646e+08
C:	-3.1449e+08
D:	-2.7251e+08
E:	-2.3054e+08
F:	-1.8857e+08
G:	-1.4660e+08
H:	-1.0463e+08
I:	-6.2659e+07
J:	-2.0688e+07
K:	2.1284e+07
L:	6.3255e+07
M:	1.0523e+08
N:	1.4720e+08
O:	1.8917e+08
P:	2.3114e+08
Q:	2.7311e+08
R:	3.1508e+08
S:	3.5705e+08
T:	3.9902e+08

B_y CONTOURS AT 4TH FARADAY BAR FROM TOP (0 - π)

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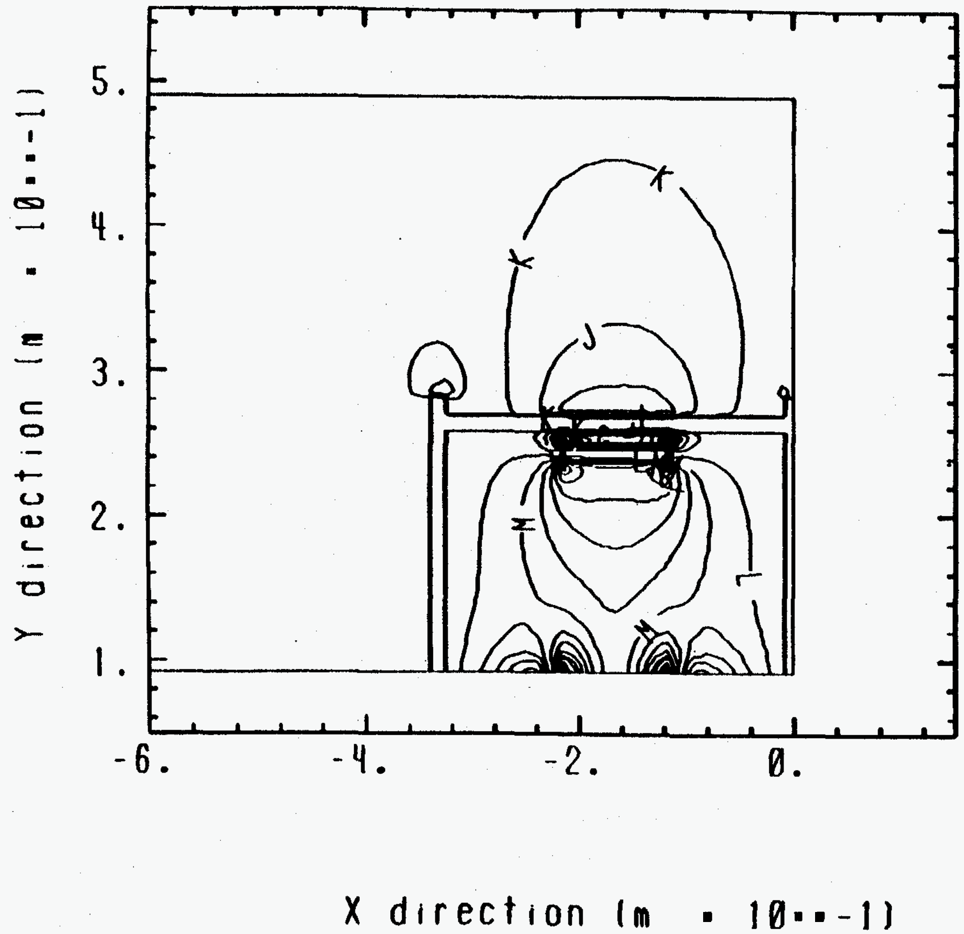

Contour Levels	
A:	-3.2238e+08
B:	-2.9137e+08
C:	-2.6035e+08
D:	-2.2933e+08
E:	-1.9832e+08
F:	-1.6730e+08
G:	-1.3629e+08
H:	-1.0527e+08
I:	-7.4254e+07
J:	-4.3238e+07
K:	-1.2222e+07
L:	1.8793e+07
M:	4.9809e+07
N:	8.0825e+07
O:	1.1184e+08
P:	1.4286e+08
Q:	1.7387e+08
R:	2.0489e+08
S:	2.3590e+08
T:	2.6692e+08

B_x CONTOURS AT 4TH FARADAY BAR FROM TOP (0 - π)

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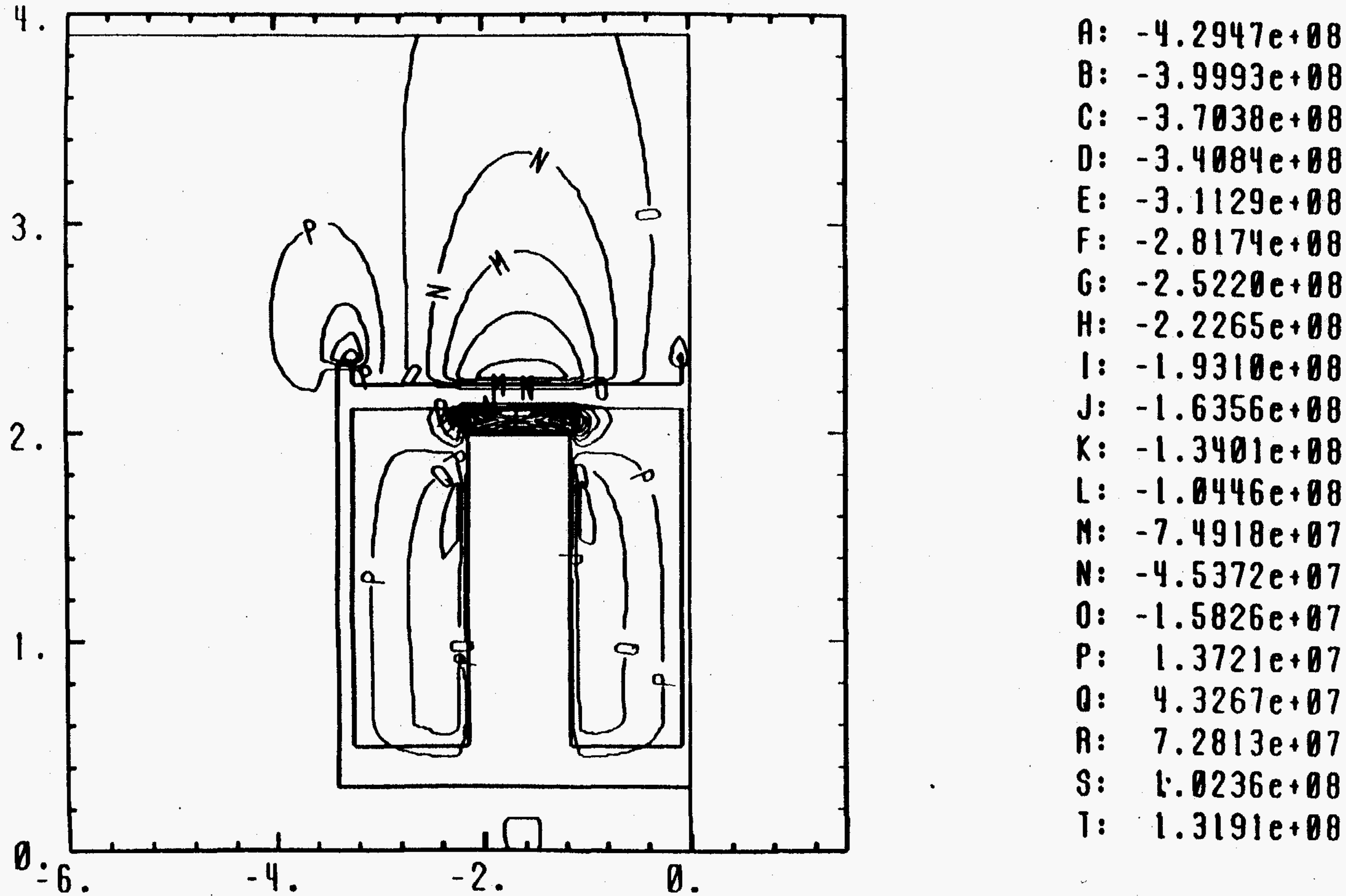
B_x



MAGNETIC FIELD CONTOUR AT z = 0, (0 - π)

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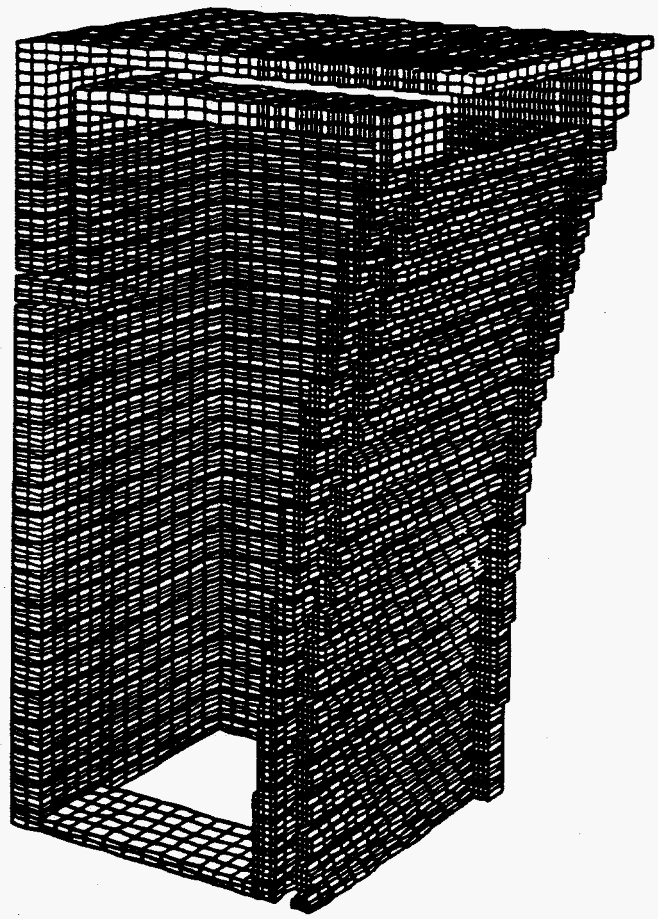
TFTR SIMULATIONS

- 0 - π PHASING (75, 120 μs)
- 0 - 0 PHASING (75, 120 μs)

TFTR ANTENNA QUADRANT



ARGUS GEOMETRY

CUT-AWAY VIEW OF CURRENT STRAP, POWER LEAD AND FARADAY BARS

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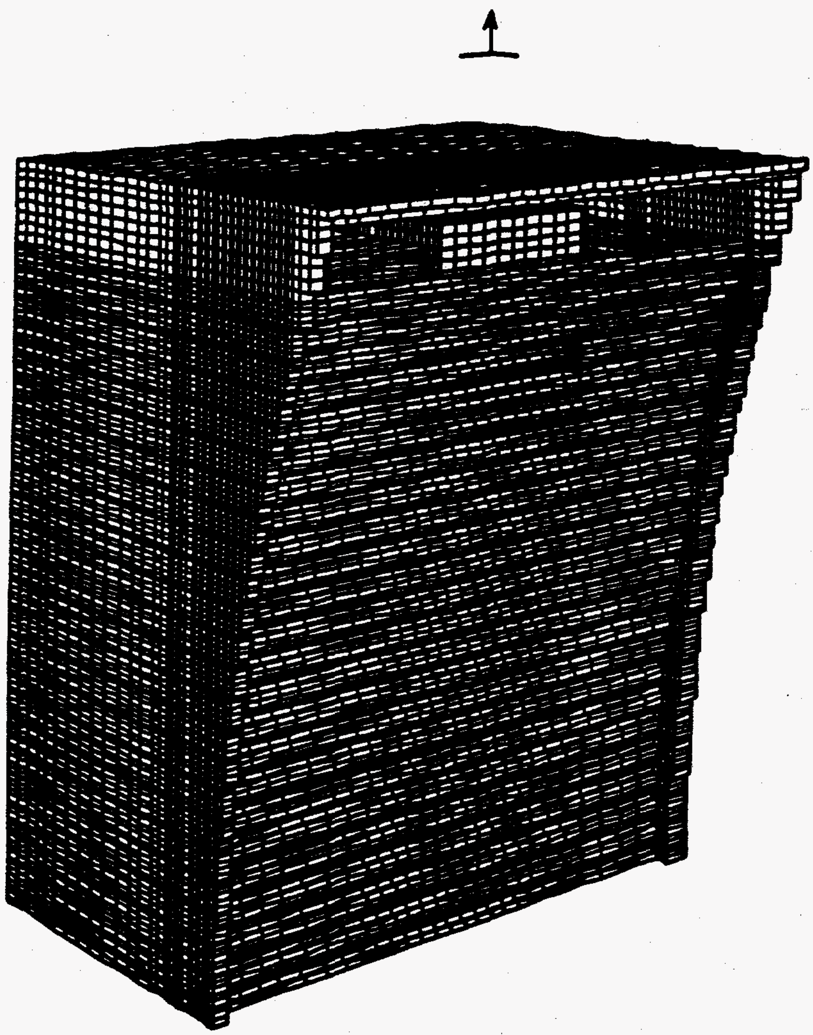
TFTR ANTENNA QUADRANT



ARGUS GEOMETRY

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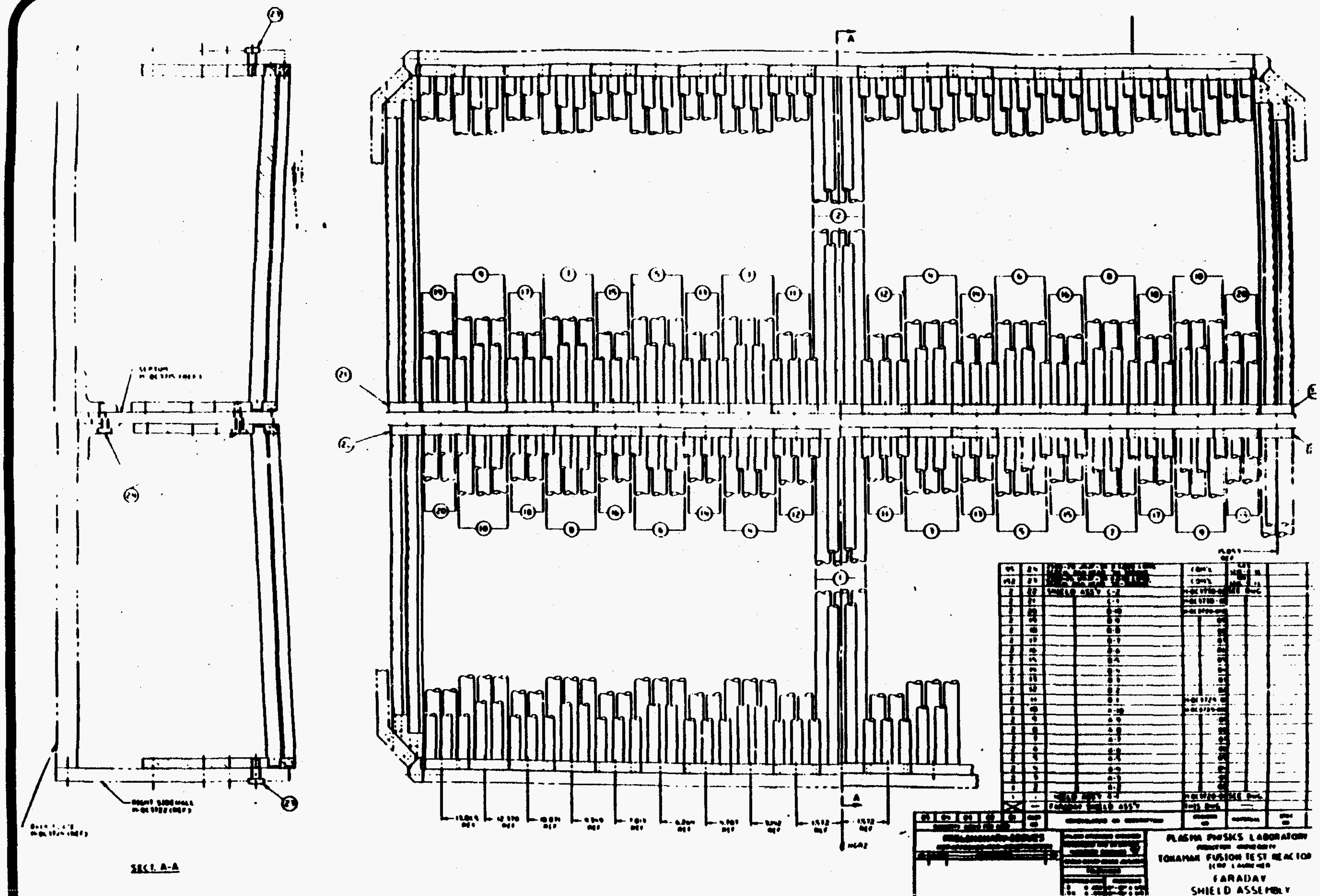

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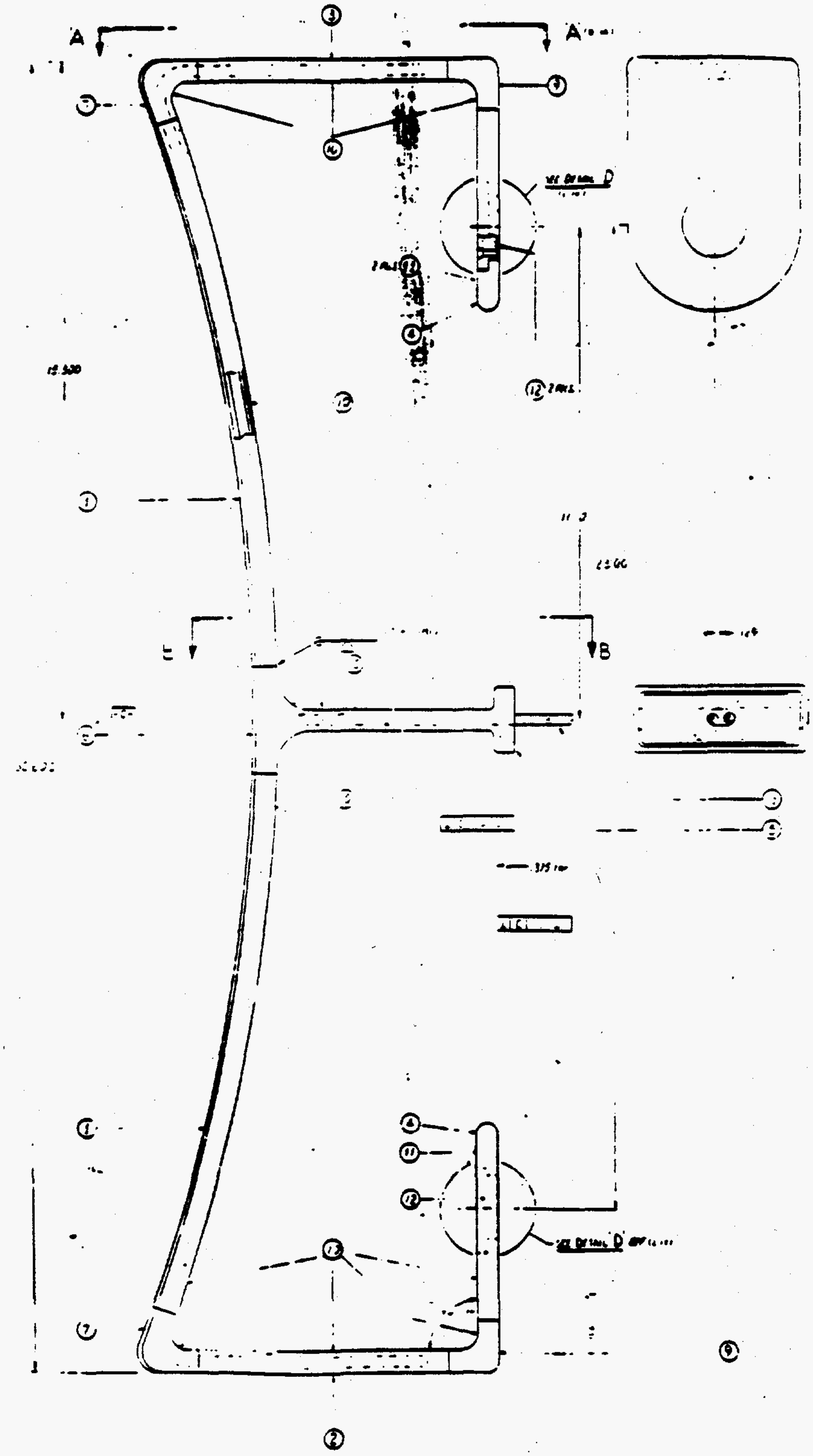

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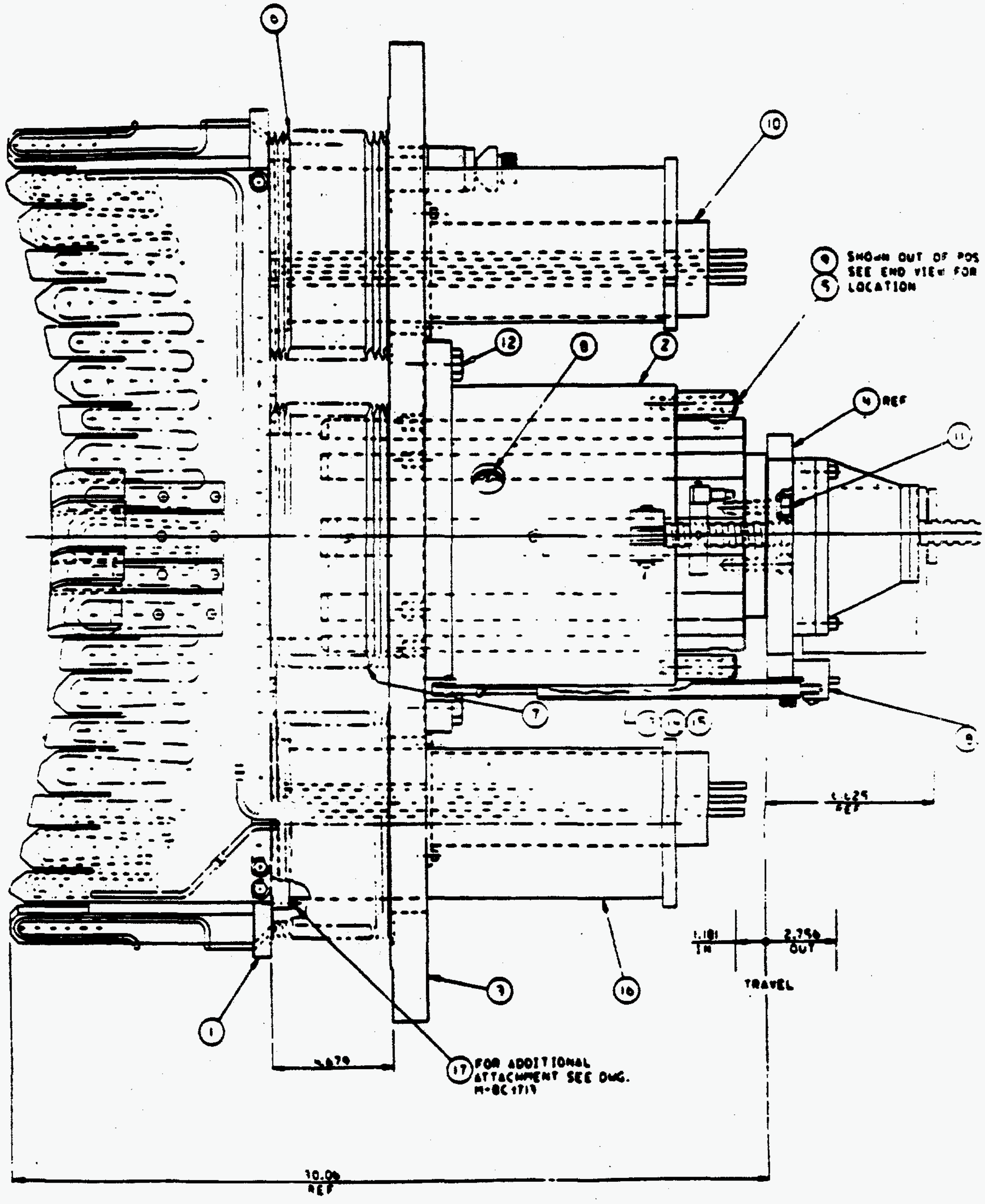

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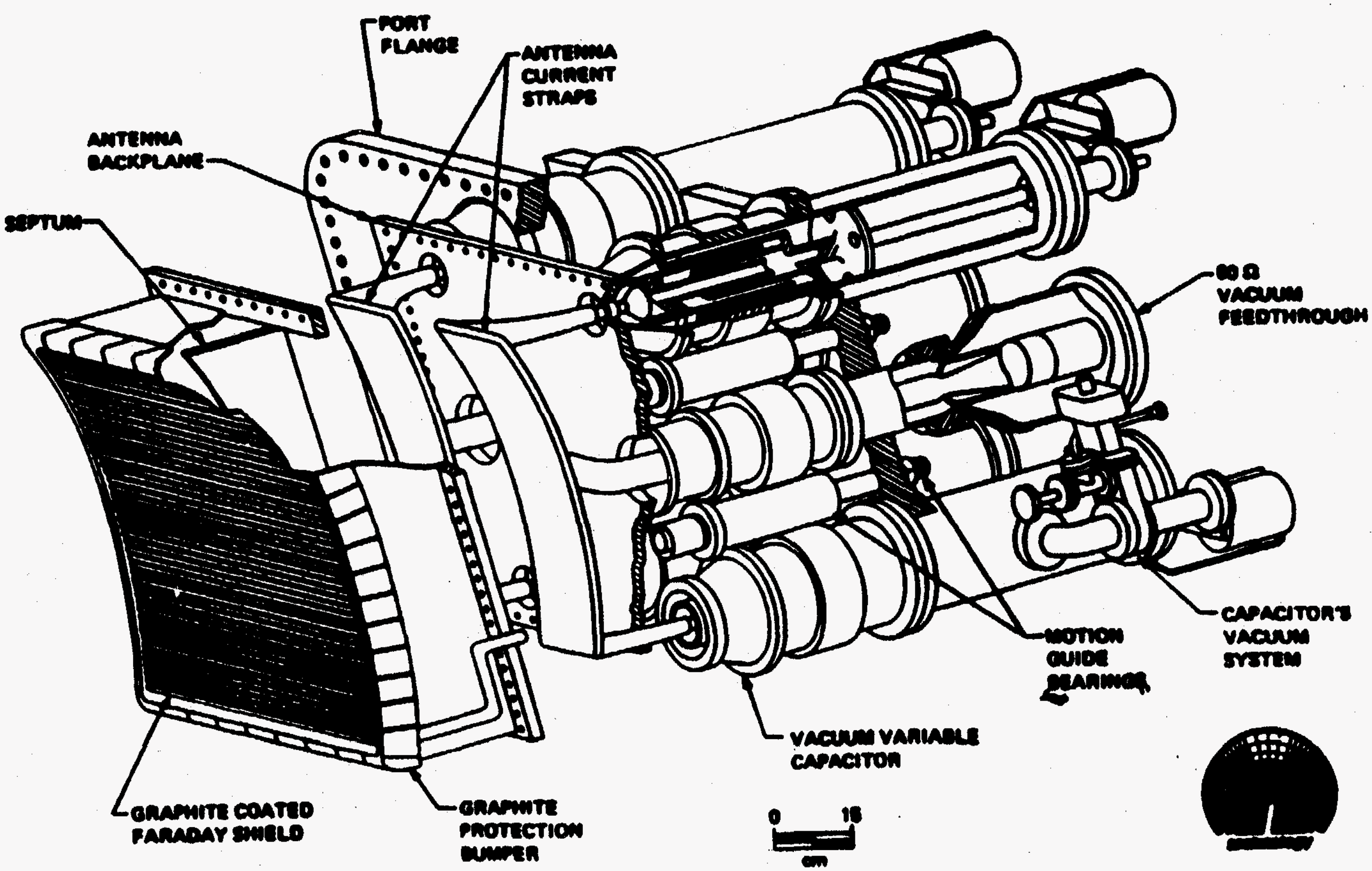
TFTR SIMULATIONS

GEOMETRY MODELING



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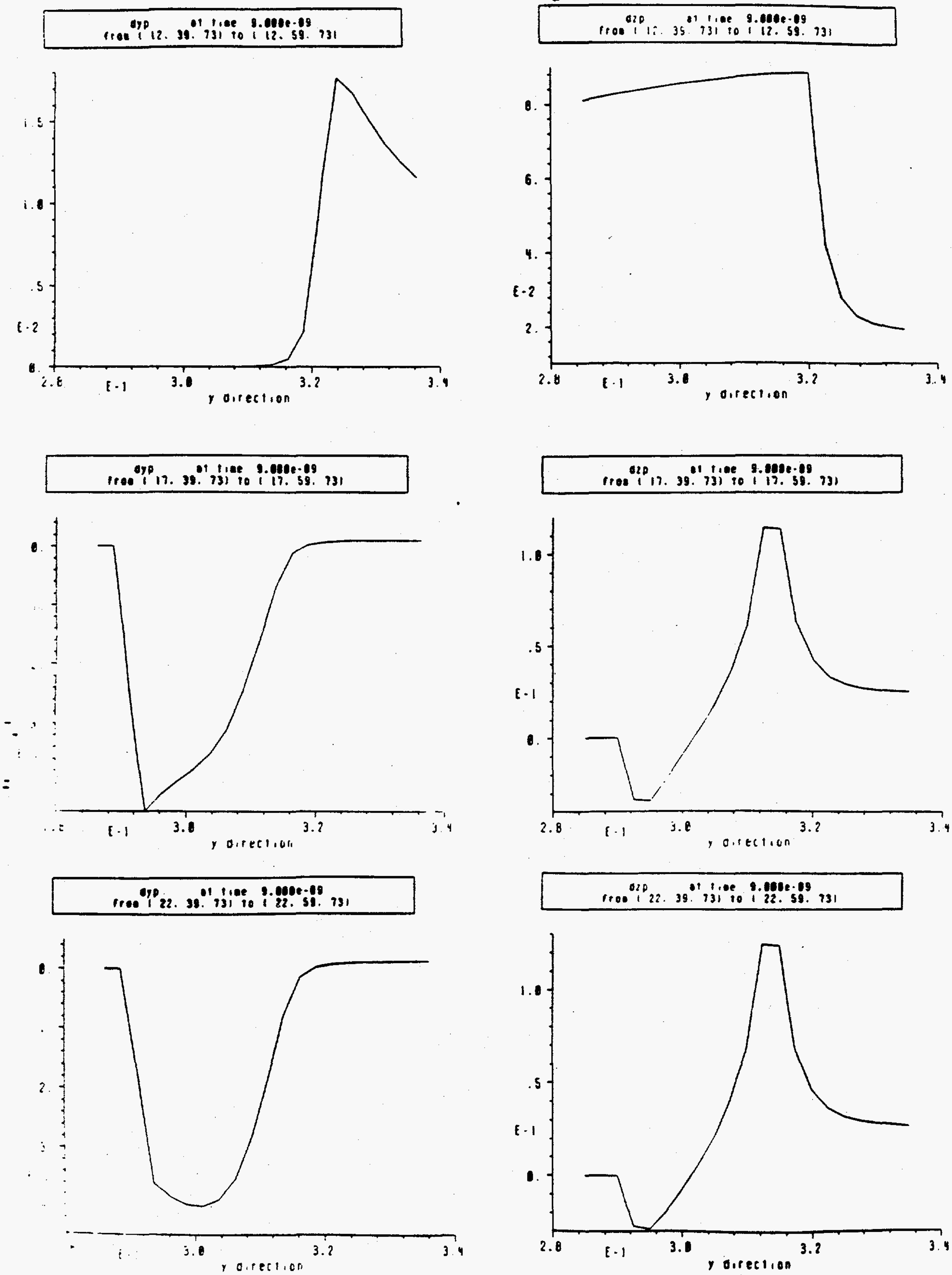
APPENDIX C



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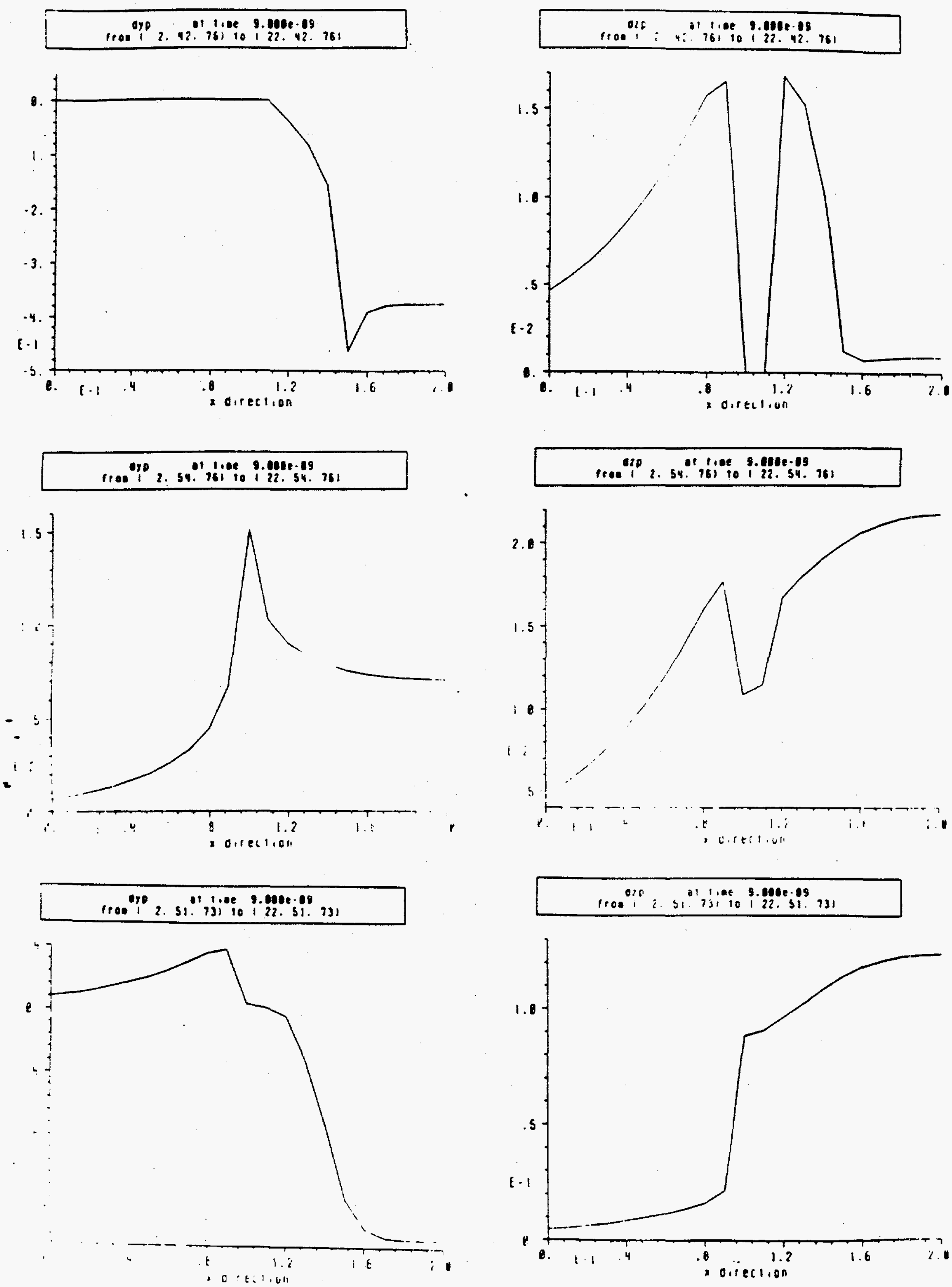

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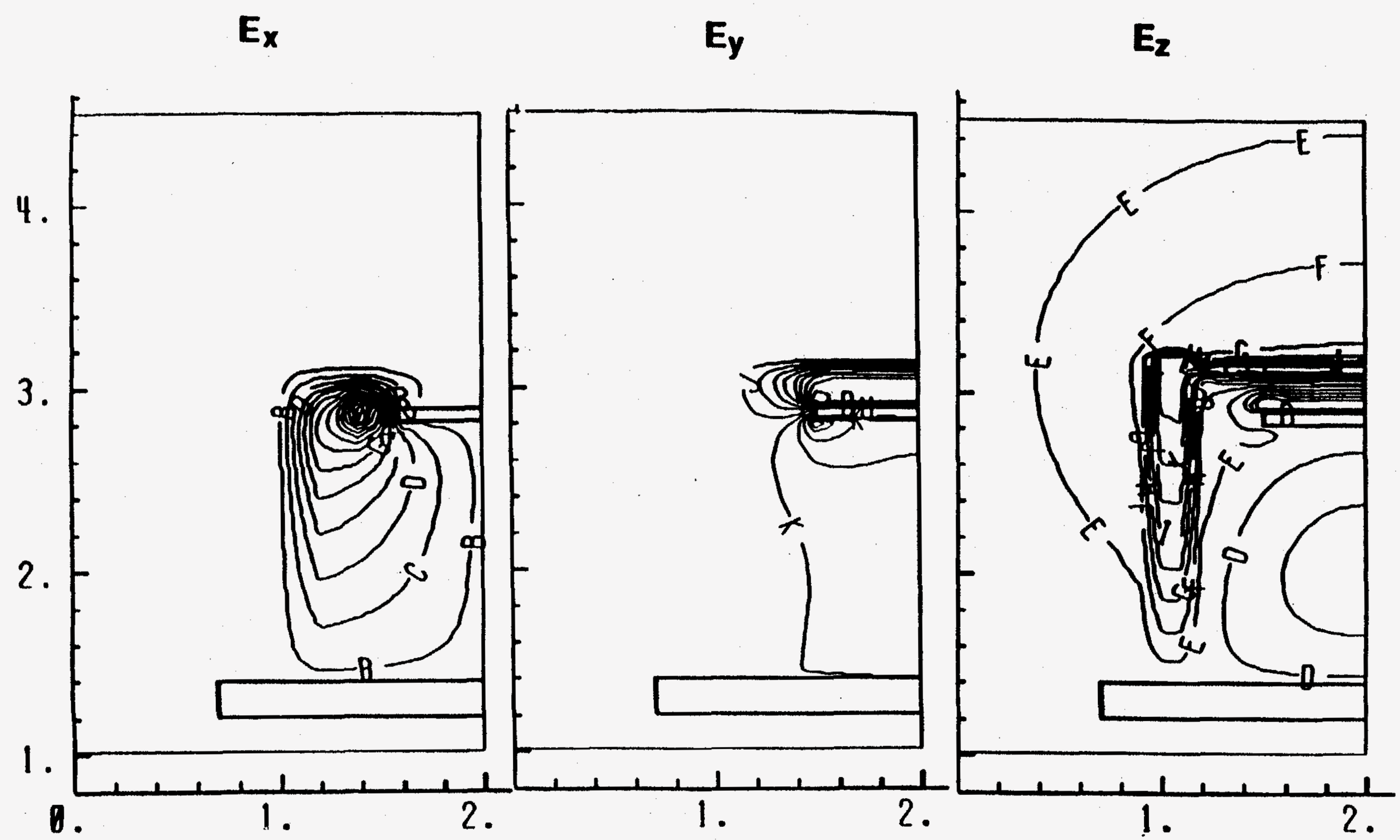
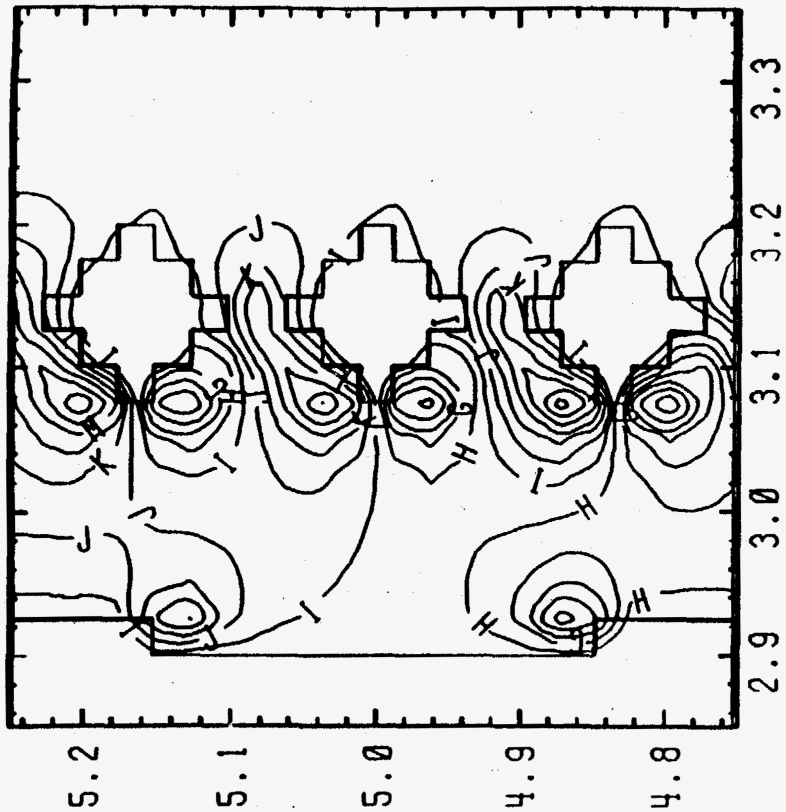


ELECTRIC FIELD CONTOURS CALCULATED AT THE CENTER CROSS-SECTION OF THE ANTENNA



Contour Levels

A: -2.4139e-01
B: -2.0921e-01
C: -1.7703e-01
D: -1.4484e-01
E: -1.1266e-01
F: -8.0478e-02
G: -4.8296e-02
H: -1.6114e-02
I: 1.6069e-02
J: 4.8251e-02
K: 8.0433e-02
L: 1.1262e-01
M: 1.4480e-01
N: 1.7698e-01
O: 2.0916e-01
P: 2.4134e-01

E_z CONTOURS CALCULATED AT MID-PLANE OF THE ANTENNA

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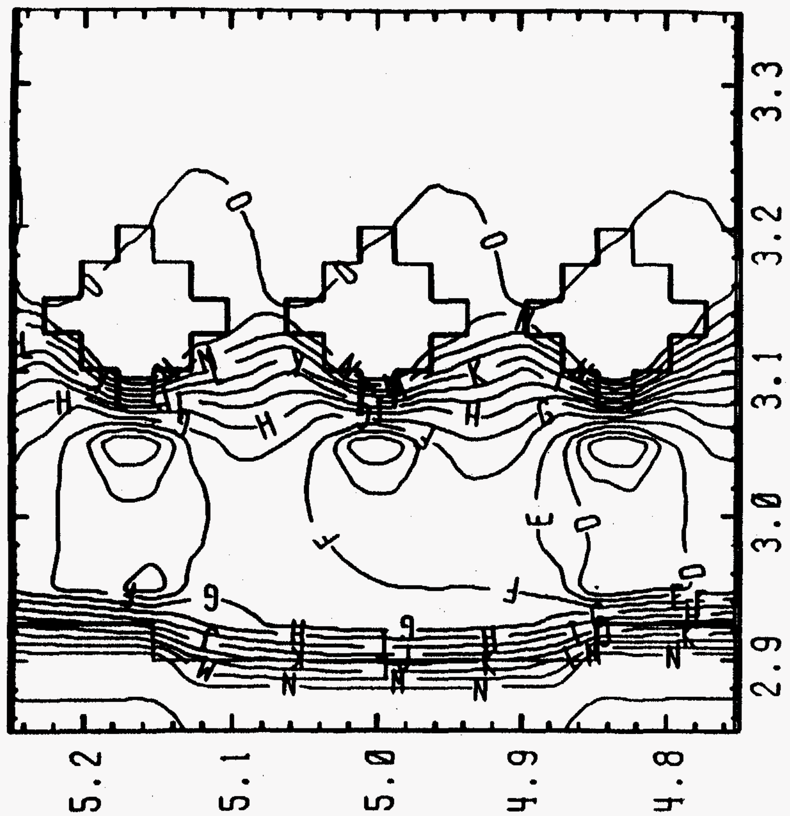

Contour Levels

A:	-5.9714e-01
B:	-5.5428e-01
C:	-5.1143e-01
D:	-4.6857e-01
E:	-4.2572e-01
F:	-3.8286e-01
G:	-3.4000e-01
H:	-2.9715e-01
I:	-2.5429e-01
J:	-2.1143e-01
K:	-1.6858e-01
L:	-1.2572e-01
M:	-8.2866e-02
N:	-4.0009e-02
O:	2.8469e-03
P:	4.5703e-02

E_y CONTOURS CALCULATED AT MID-PLANE OF THE ANTENNA

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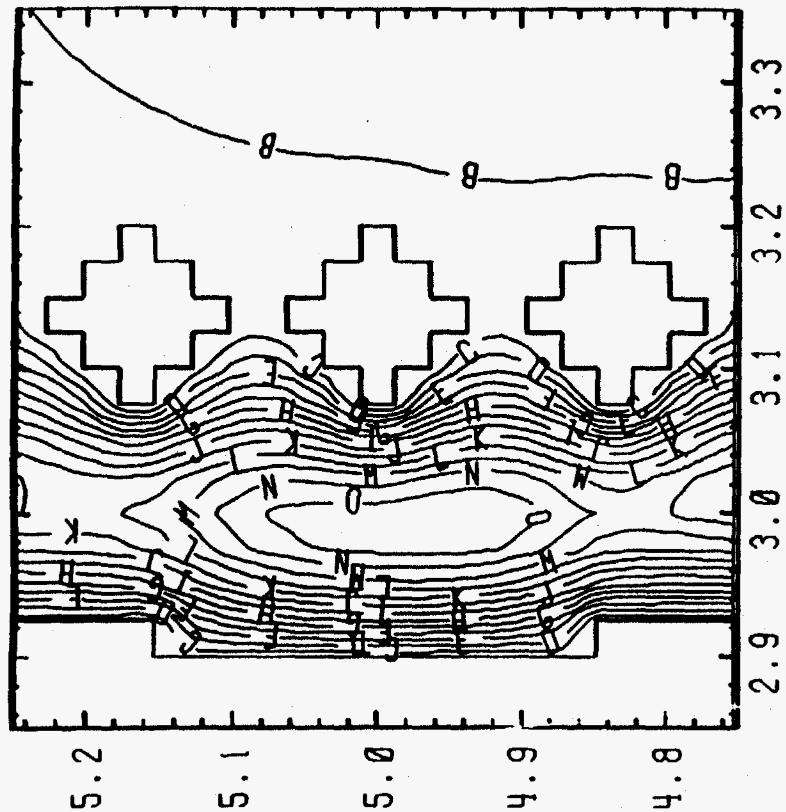

Contour Levels	
A:	-1.0114e-04
B:	-2.6514e-05
C:	4.8115e-05
D:	1.2274e-04
E:	1.9737e-04
F:	2.7200e-04
G:	3.4663e-04
H:	4.2126e-04
I:	4.9589e-04
J:	5.7052e-04
K:	6.4514e-04
L:	7.1977e-04
M:	7.9440e-04
N:	8.6903e-04
O:	9.4366e-04
P:	1.0183e-03

E_x CONTOURS CALCULATED AT MID-PLANE OF THE ANTENNA

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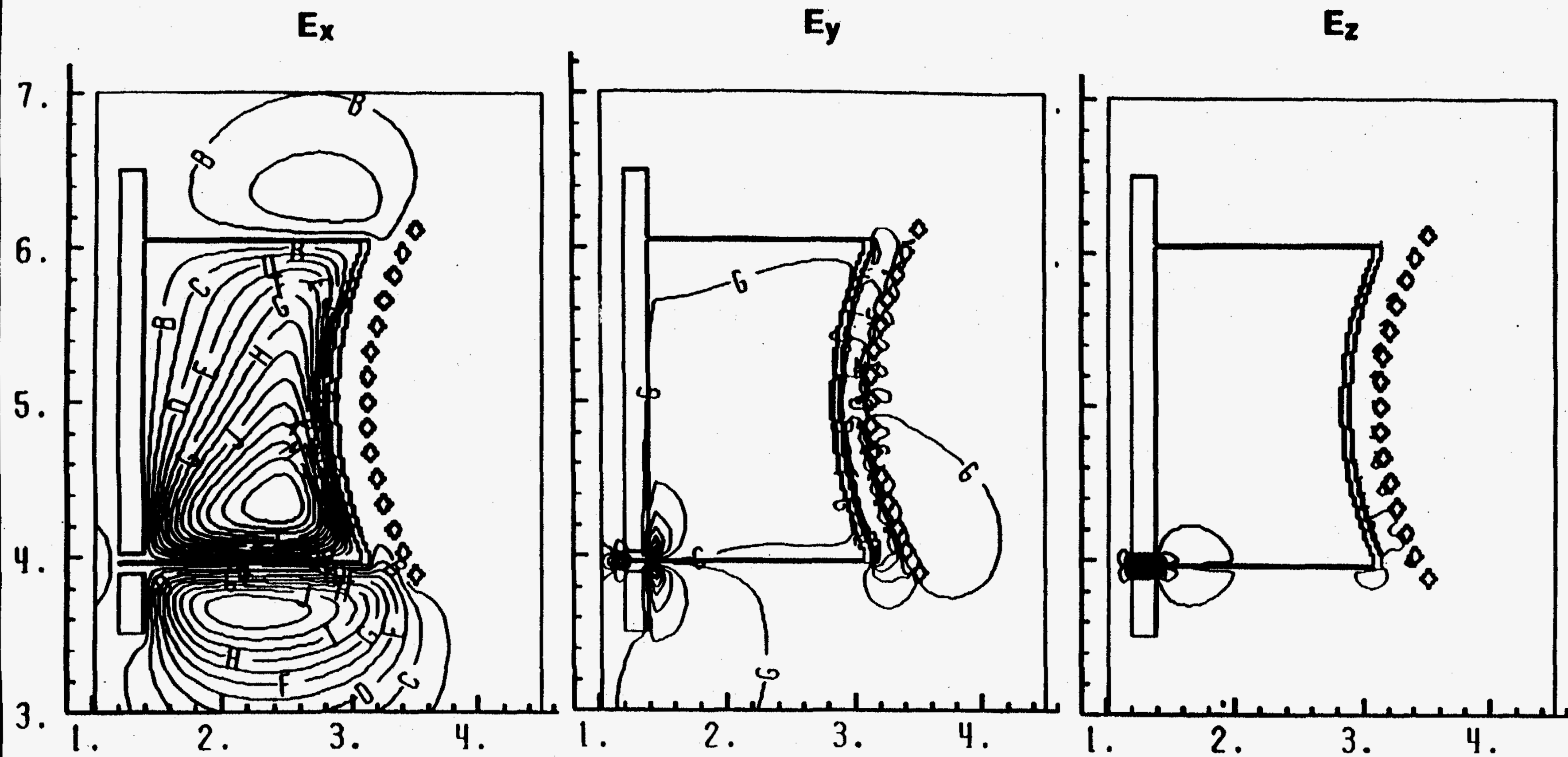
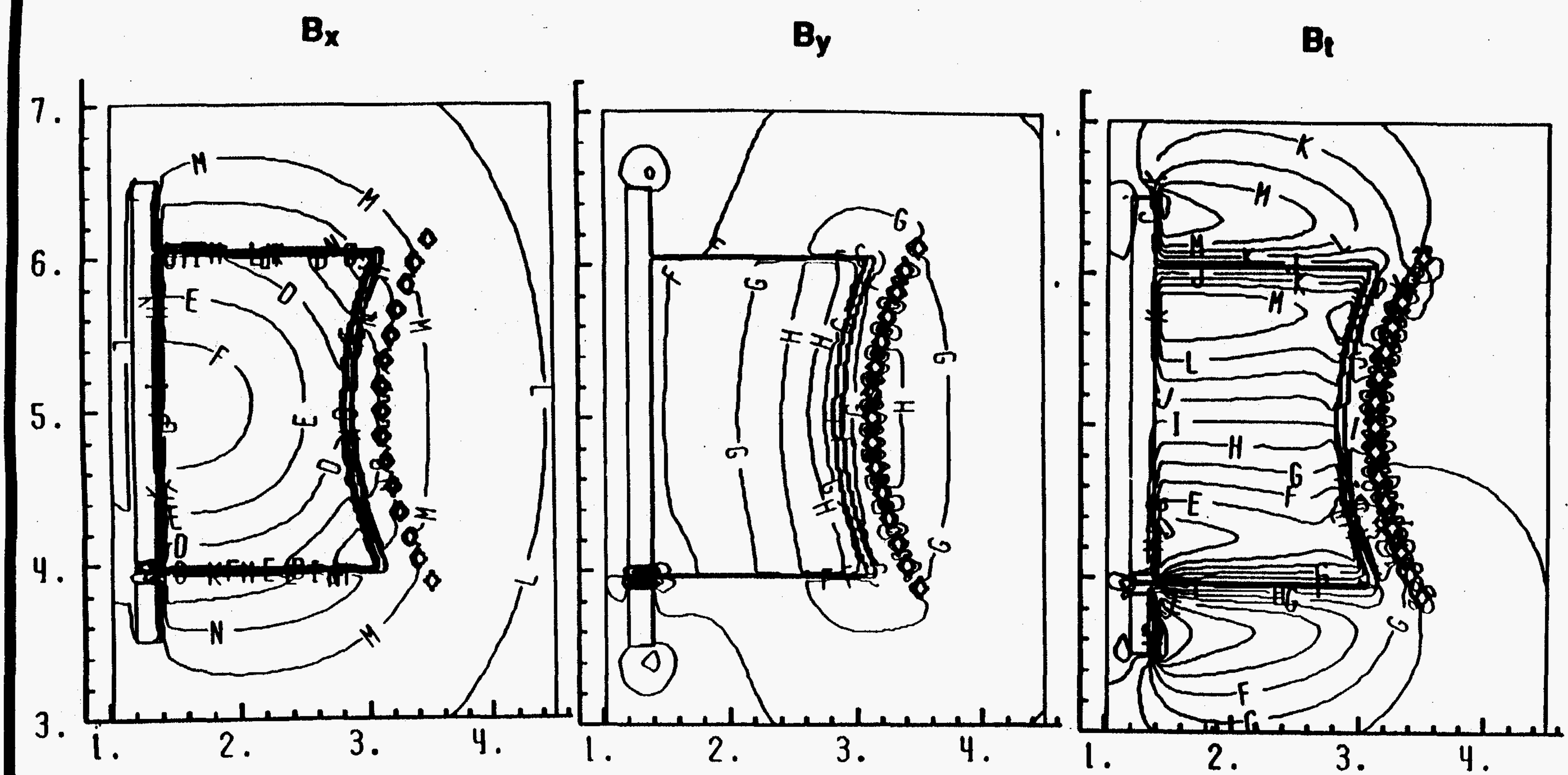


ELECTRIC FIELD CONTOURS CALCULATED AT THE MID-PLANE OF THE ANTENNA



MAGNETIC FIELD CONTOURS CALCULATED AT THE MID-PLANE OF THE ANTENNA

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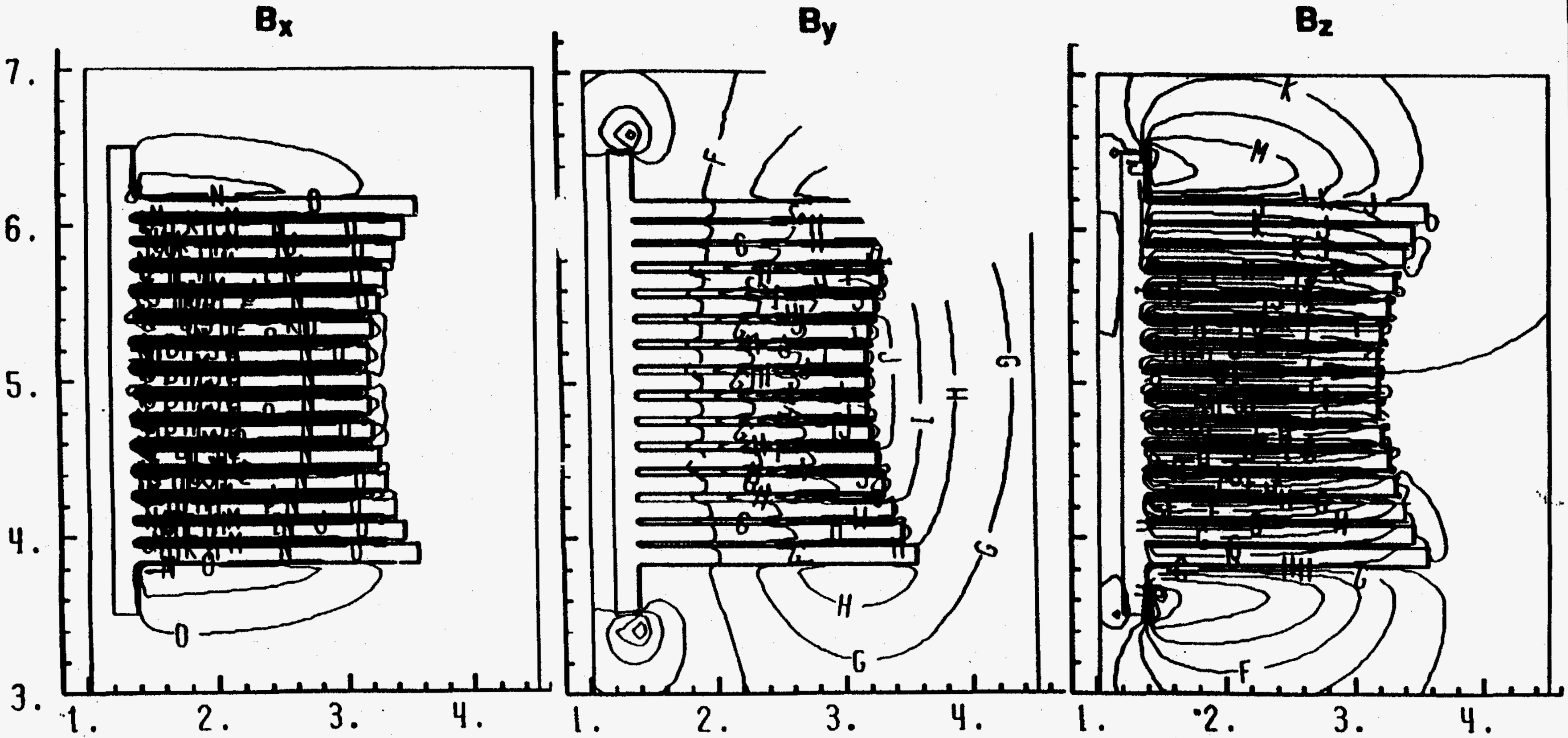

MAGNETIC FIELD CONTOURS CALCULATED JUST OUTSIDE THE FARADAY SHIELD SUPPORTS

Science Applications International Corporation
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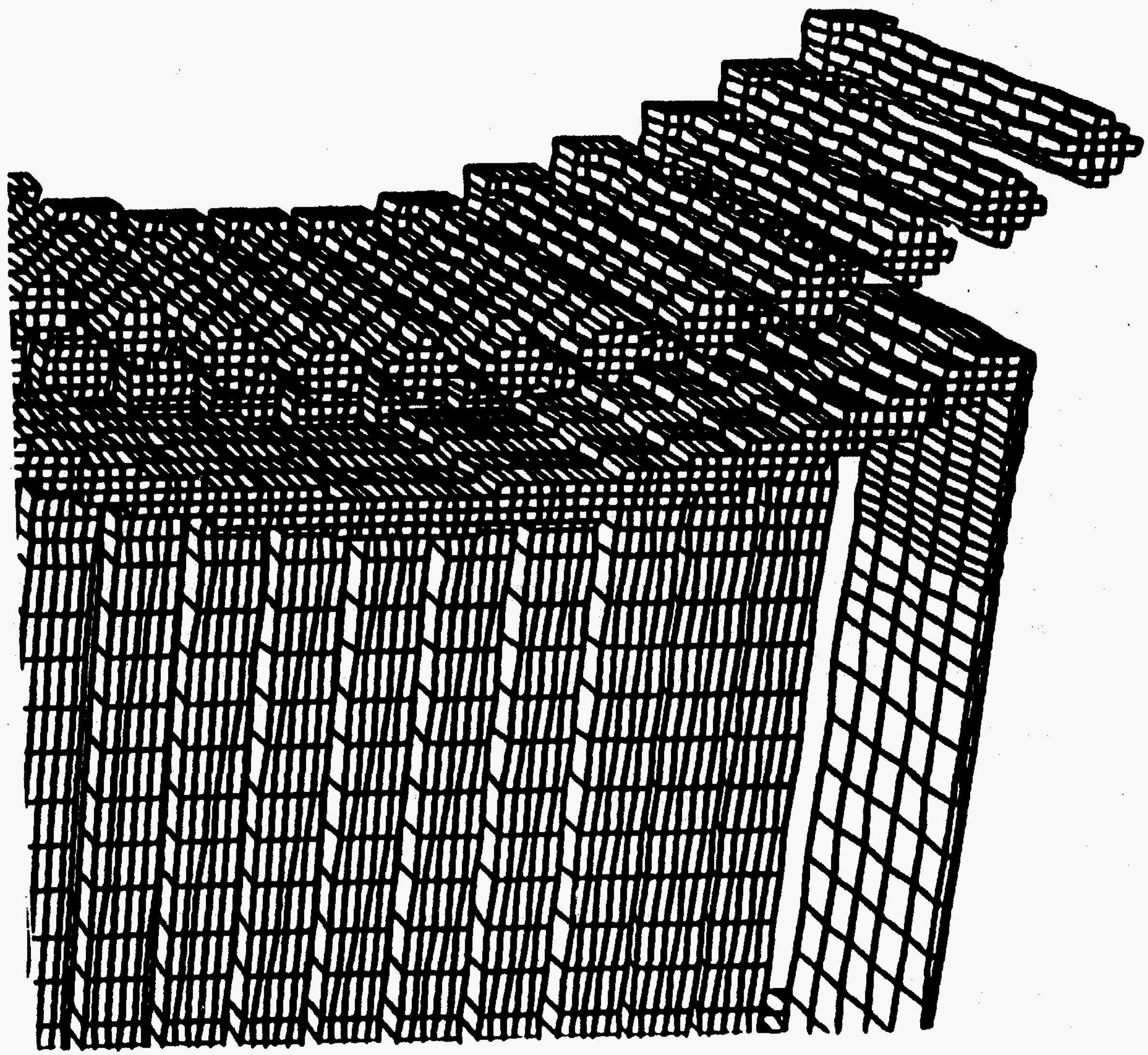
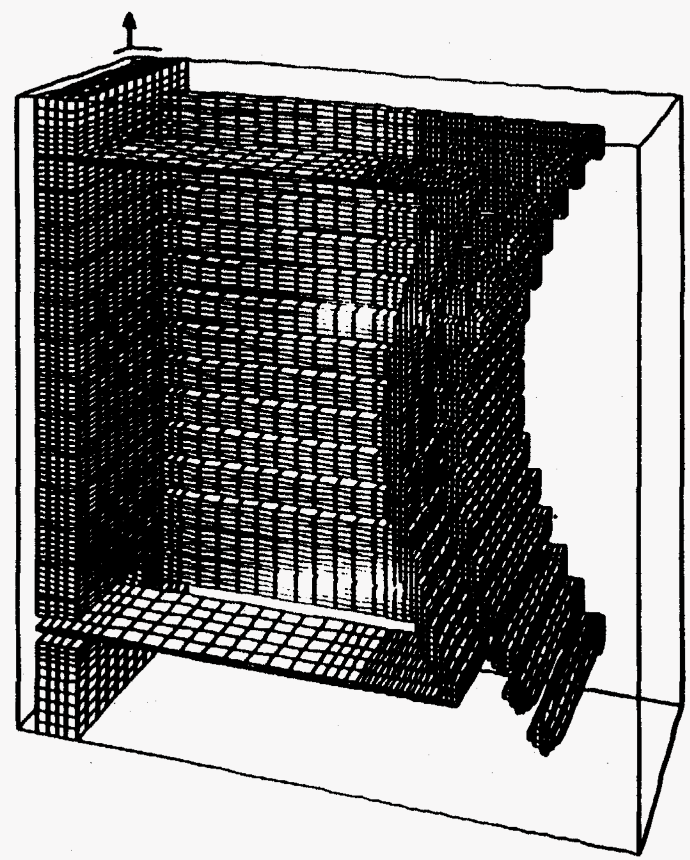


DETAIL VIEW OF U. WISCONSIN ANTENNA SHOWING
FARADAY SHIELD AND SUPPORTS



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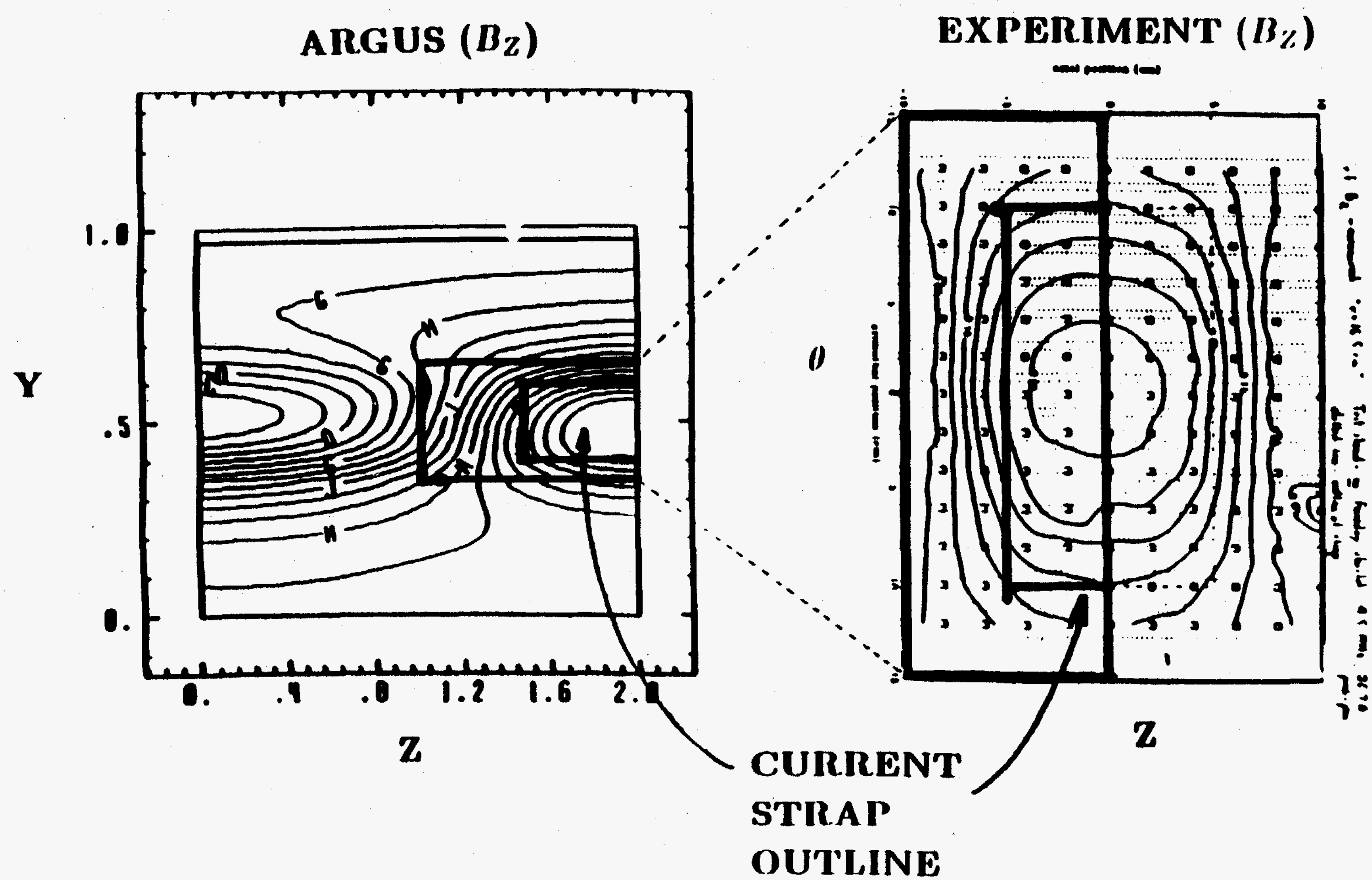
REVIEW OF
SAIC - U. WISCONSIN PROJECT

- RECENT RESULTS
  - IMPROVED GEOMETRY FOR FARADAY SHIELD AND GAP SPACING
  - IMPROVED RESOLUTION FOR GAP - SHIELD REGION
  - ANTENNA "K" SPECTRUM DATA REDUCED FROM CALCULATIONS

FIELD CONTOURS ON PLANE 4CM ABOVE STRAP



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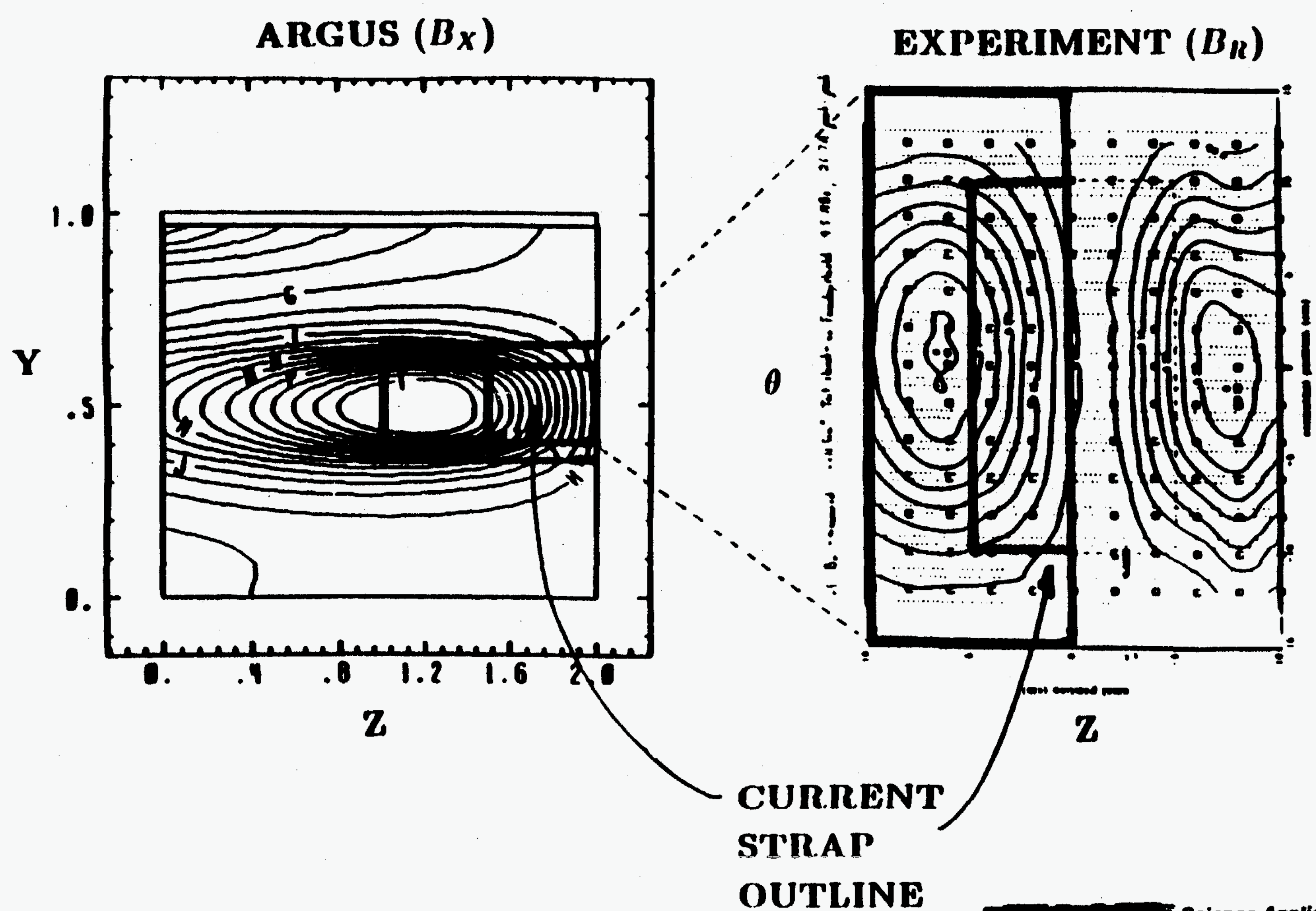
FIELD CONTOURS ON PLANE 4CM ABOVE STRAP



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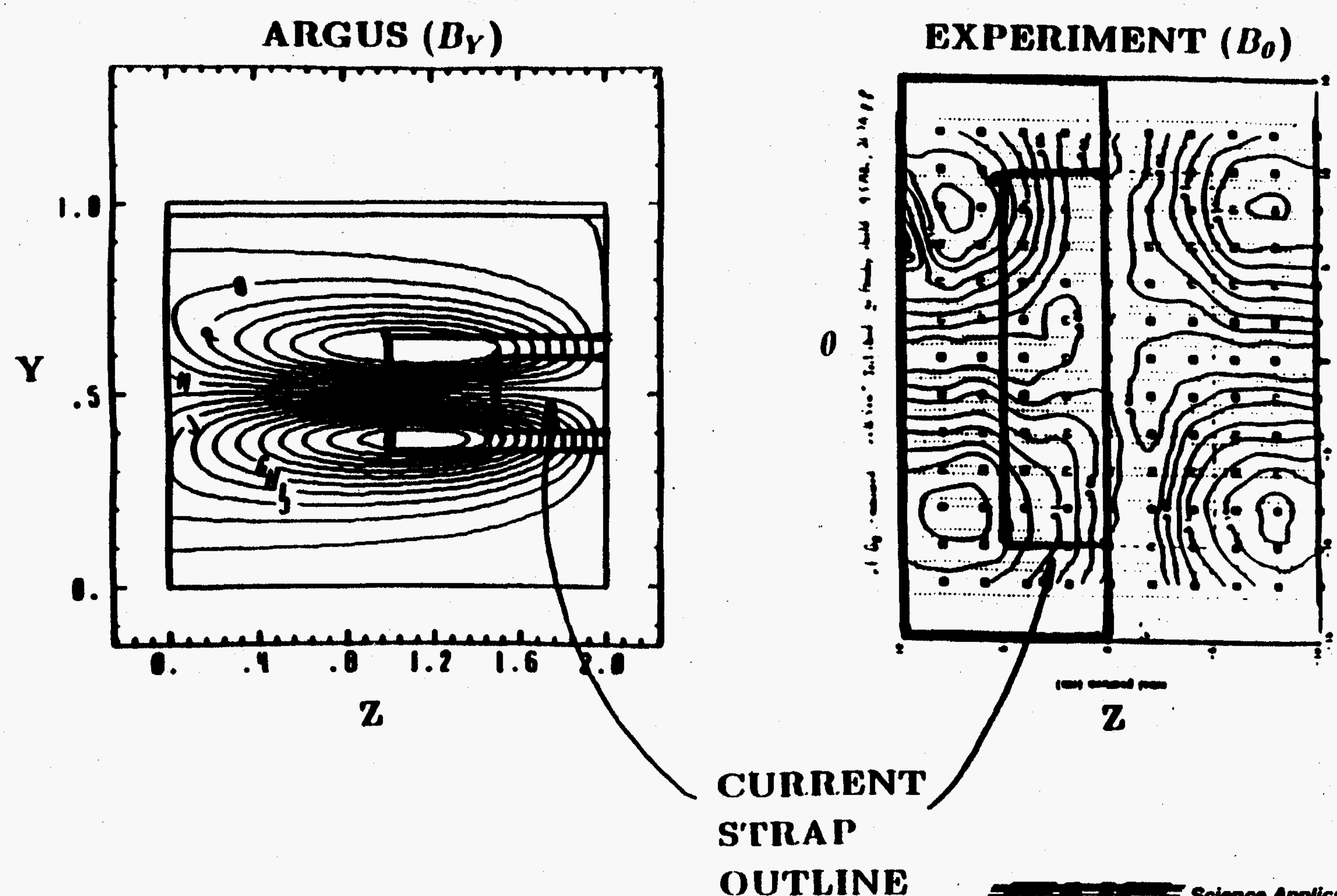
FIELD CONTOURS ON PLANE 4CM ABOVE STRAP



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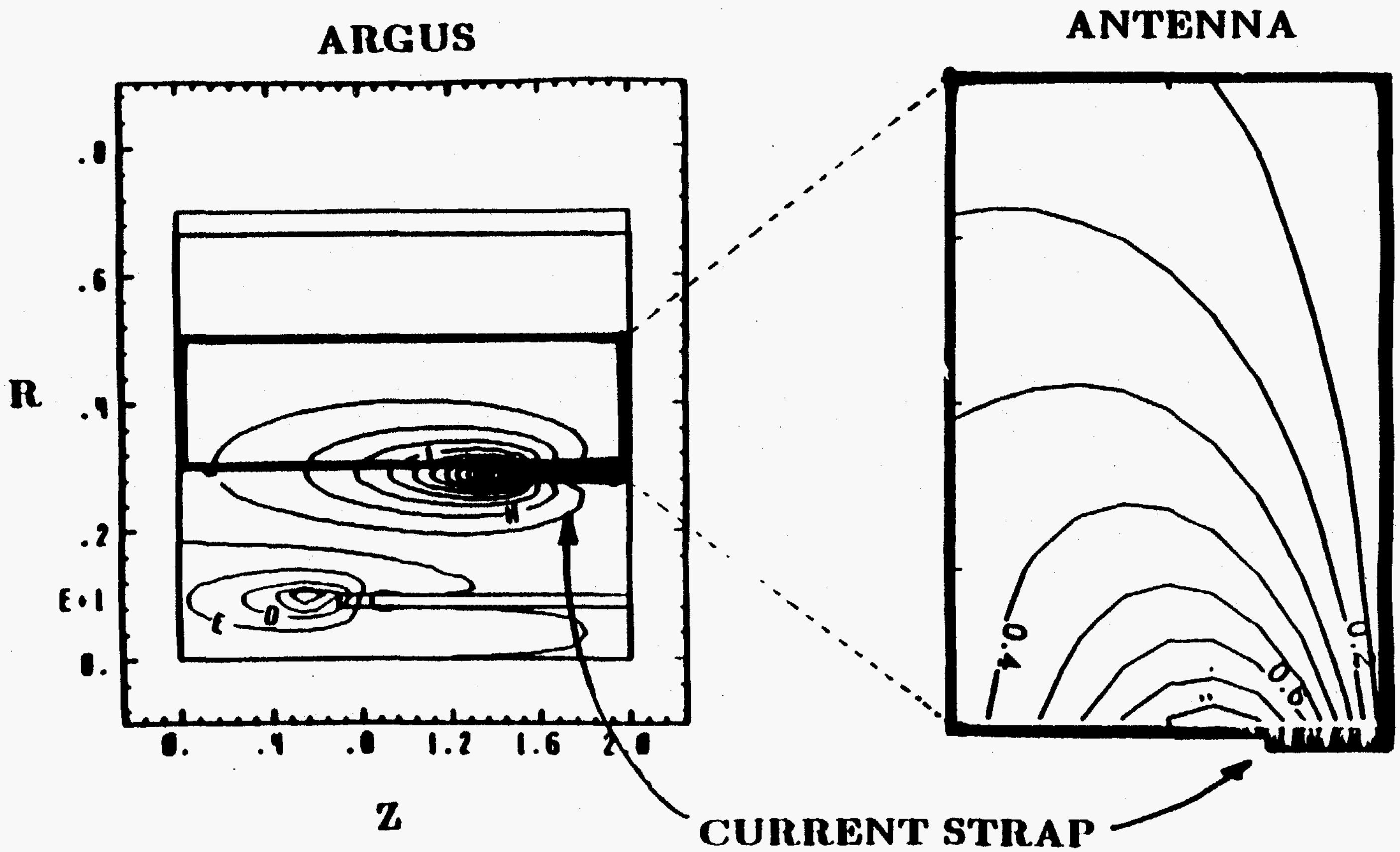
B_R CONTOURS ON CUT-PLANE AT MID-STRAP ($\theta = 0°$)



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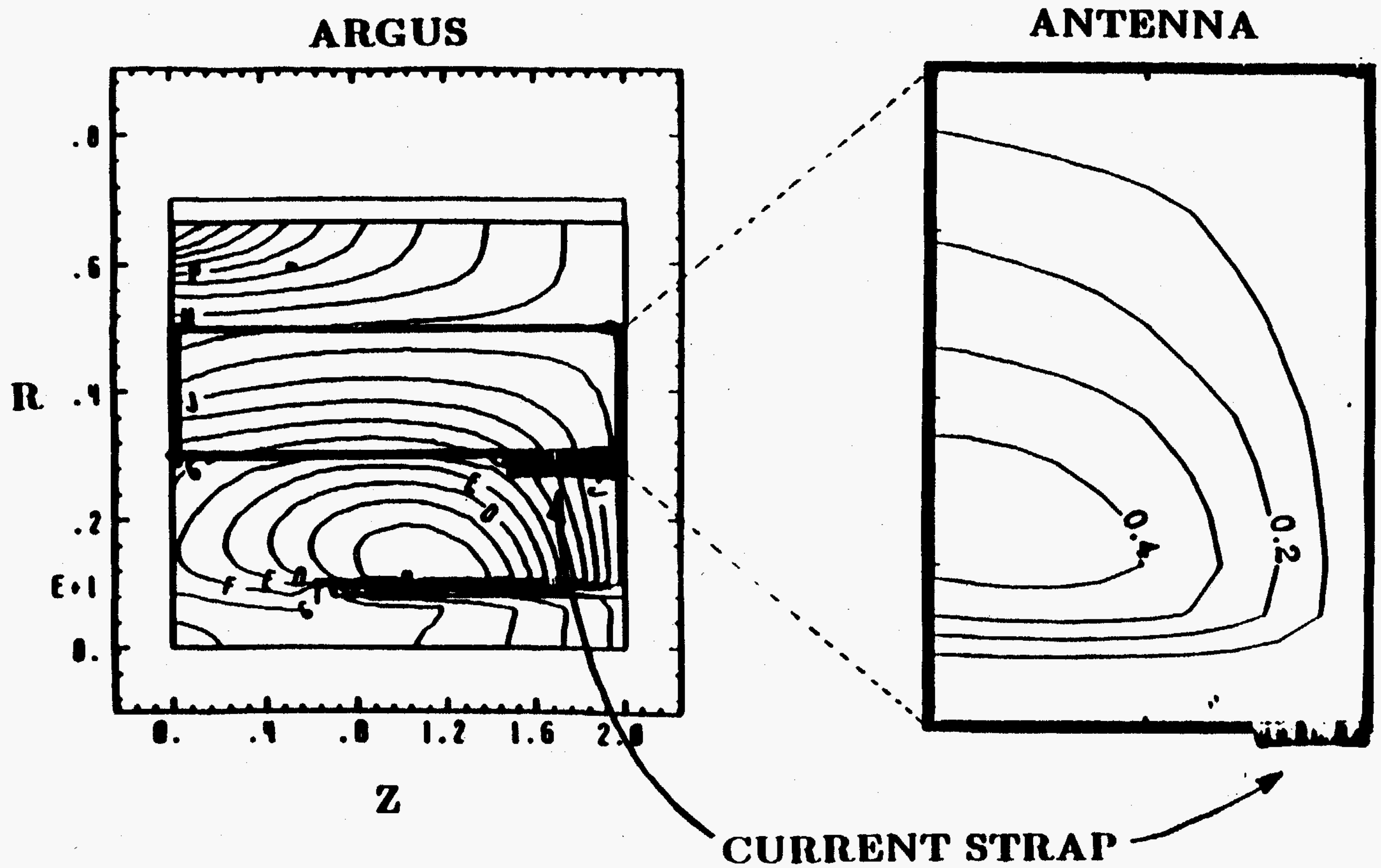
B_θ CONTOURS ON CUT-PLANE AT MID-STRAP ($\theta = 0°$)



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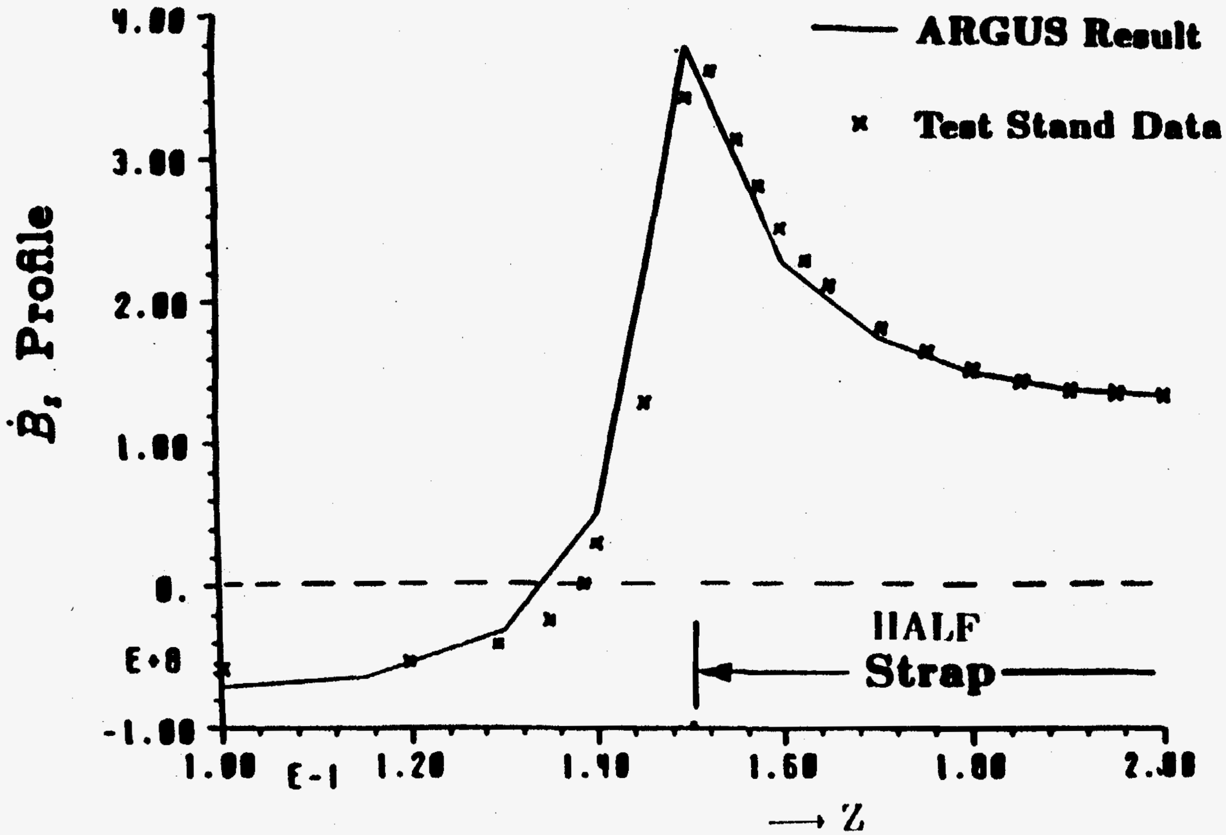
Comparison Between ARGUS and Experiment



- THE AGREEMENT IS EXCELLENT FOR THE SELF-CONSISTENT CURRENT PROFILE

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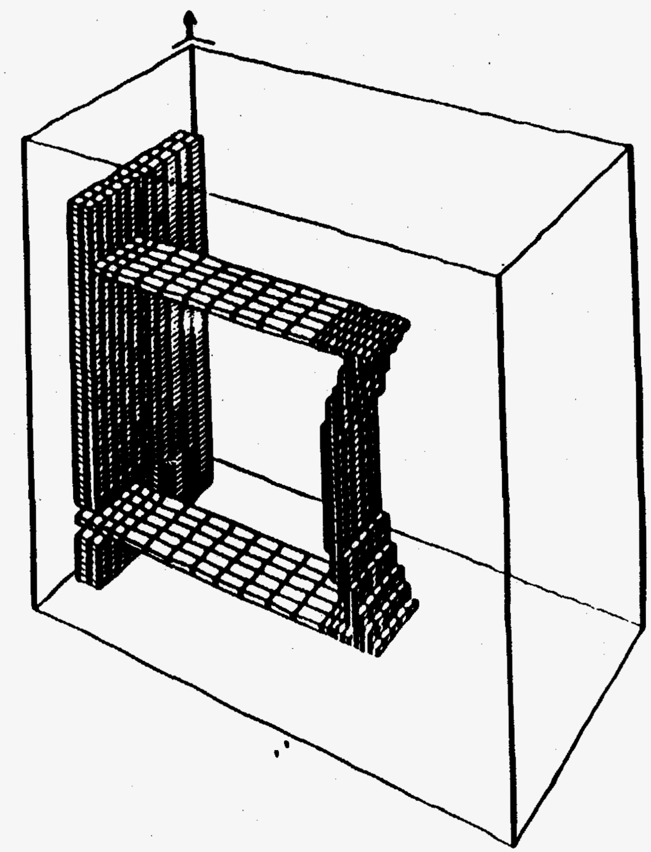
BARE STRAP ON TEST-STAND

- 2-D ANTENNA CODE (McVEY) USES PRESCRIBED STRAP CURRENT PROFILE TO OBTAIN AGREEMENT WITH EXPERIMENT. THREE UNIFORM CURRENT STRAPS CARRYING RESPECTIVELY 35% - 30% - 35% OF THE TOTAL CURRENT ARE SPECIFIED.

- ARGUS SIMULATION YIELDS THE SELF-CONSISTENT STRAP CURRENT PROFILE THAT CLOSELY AGREES WITH MEASURED DATA.



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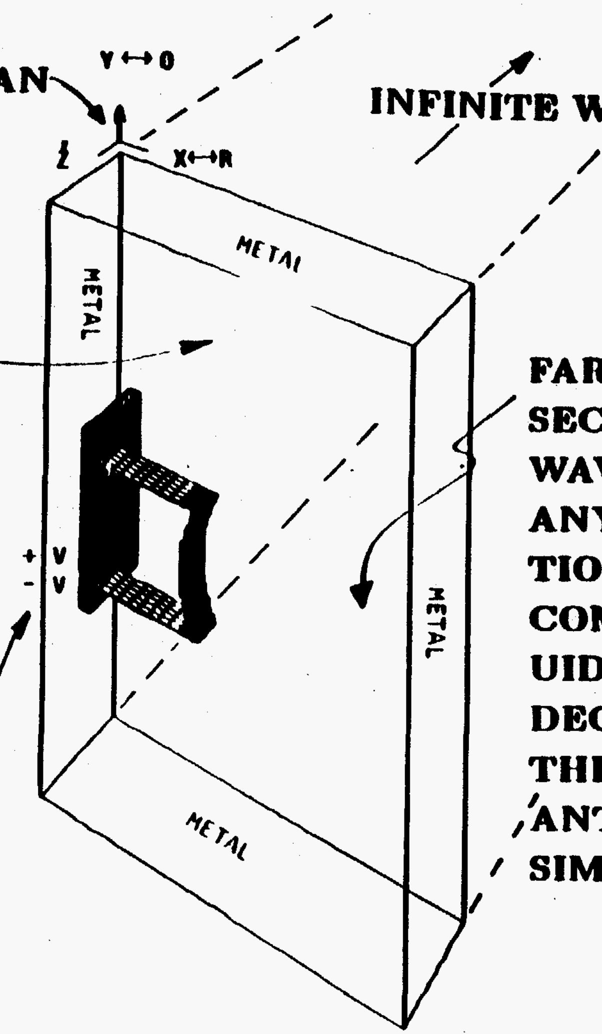
GEOMETRY AND BOUNDARY CONDITIONS

CARTESIAN

INFINITE WAVEGUIDE



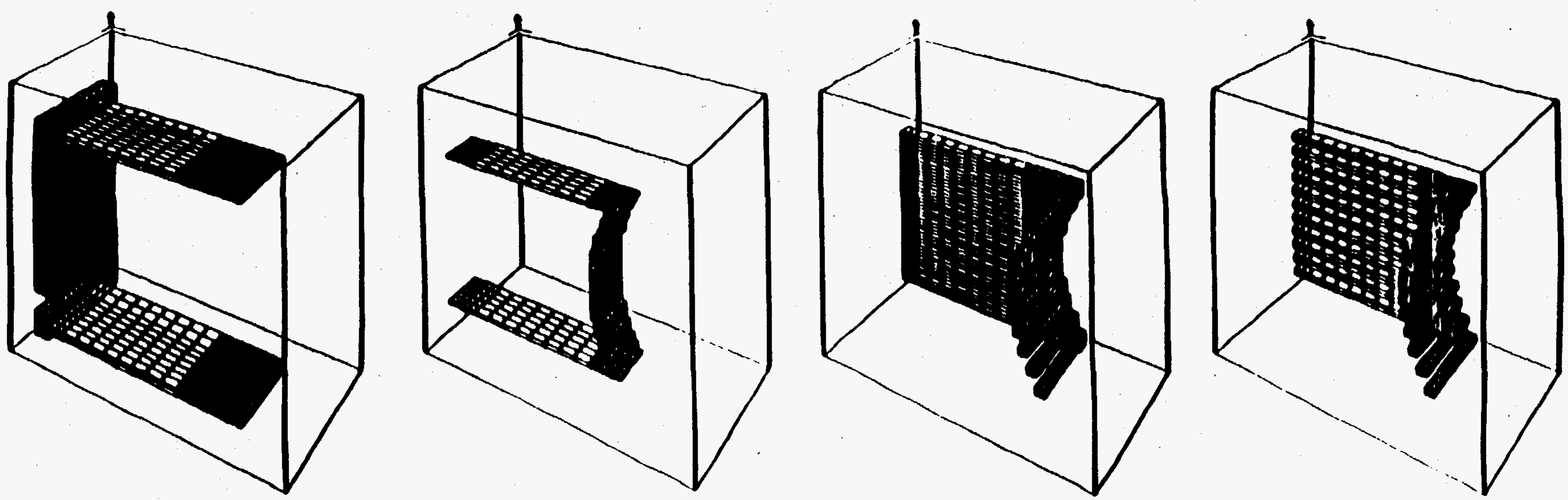
NEAR PLANE IS A SYMMETRY PLANE WHICH REDUCES THE SIMULATION REGION BY HALF.

STRAP IS DRIVEN BY 4.5 MHZ POTENTIAL AT LEAD.

FAR PLANE IS THE CROSS-SECTION OF AN INFINITE WAVEGUIDE SUCH THAT ANY IMPINGING RADIATION IS EXPRESSED AS THE COMPLETE SET OF WAVEGUIDE MODES. THIS MODE DECOMPOSITION ALLOWS THE RADIATION FROM THE ANTENNA TO EXIT THE SIMULATION REGION.

ANTENNA COMPONENTS

- ARGUS INPUT DECK ALLOWS COMPLEX STRUCTURES TO BE INTRODUCED, DELETED OR INTERCHANGED WITH RELATIVE EASE.



BACKPLANE WITH END CAPS

CURRENT STRAP

FARADAY SHIELDS

SOLID SIDE SHIELDS

SLOTTED SIDE SHIELDS

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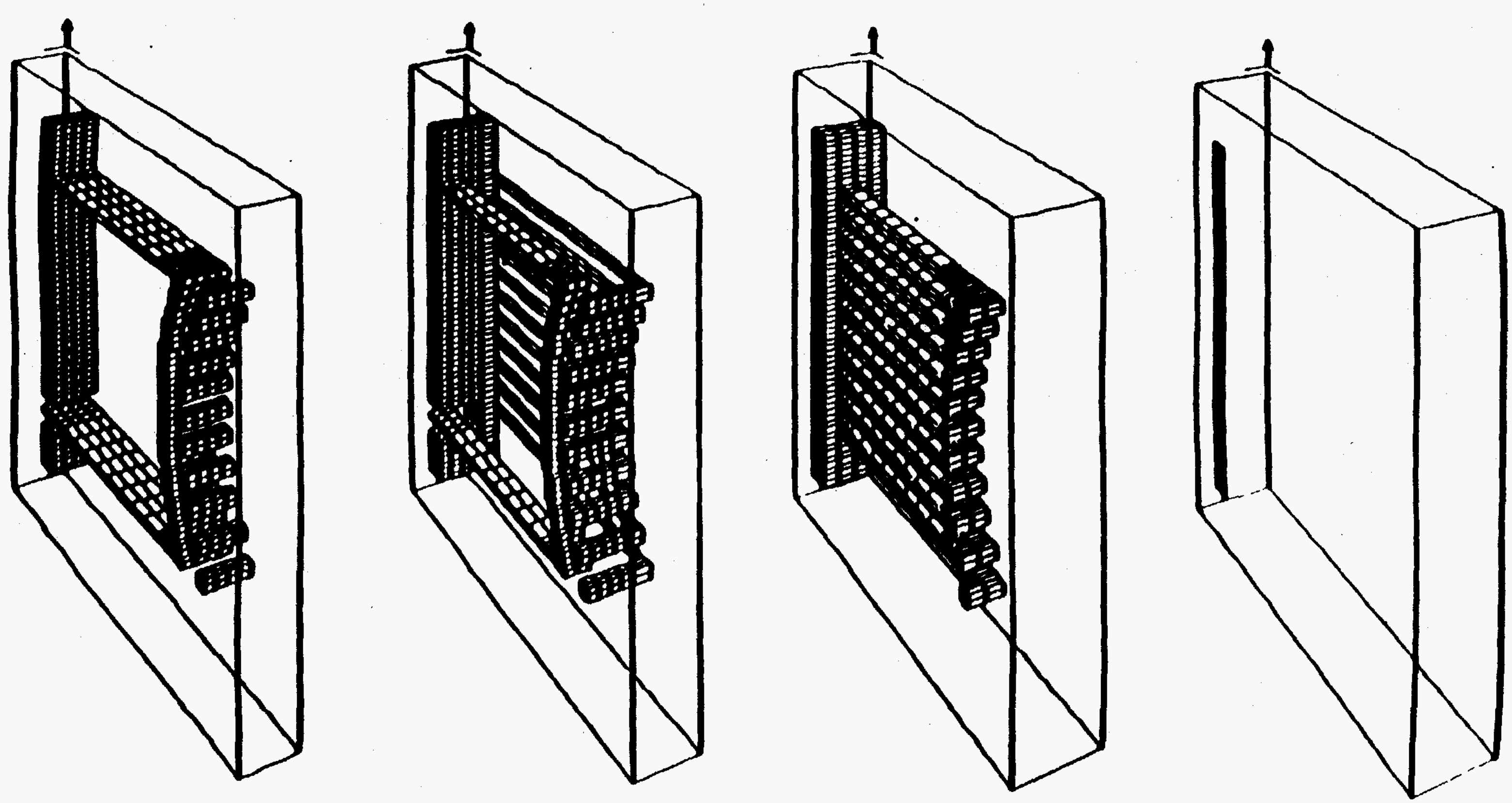
- DOMAIN DECOMPOSITION OF LARGE PROBLEM INTO 4 BLOCKS
- DIMENSION OF EACH BLOCK = $6 \times 53 \times 93$



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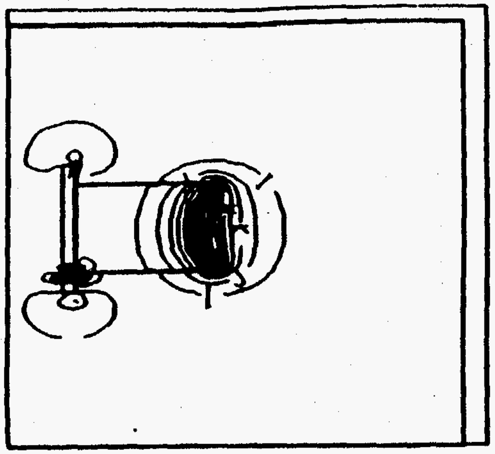
REVIEW OF
SAIC - UNIVERSITY WISCONSIN PROJECT

- **ORIGINAL GOALS**
  - CAPTURE U. WISCONSIN MODEL ANTENNA GEOMETRY IN AS DETAILED A MANNER AS POSSIBLE
  - SIMULATE OPERATION OF ANTENNA AT GIVEN FREQUENCY IN VACUUM
  - COMPARE WITH EXPERIMENTAL MEASUREMENTS
  - COMPARE WITH 2-D "ANTENNA" CODE
  - USE 3-D SIMULATION TO OBTAIN ANTENNA DATA WHICH IS HARD TO MEASURE EXPERIMENTALLY

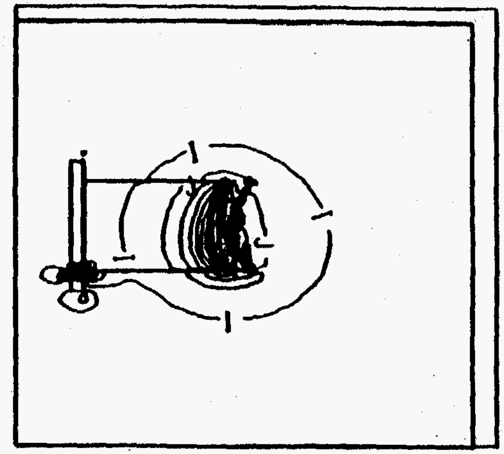
APPENDIX B

WITH | WITHOUT

B_X

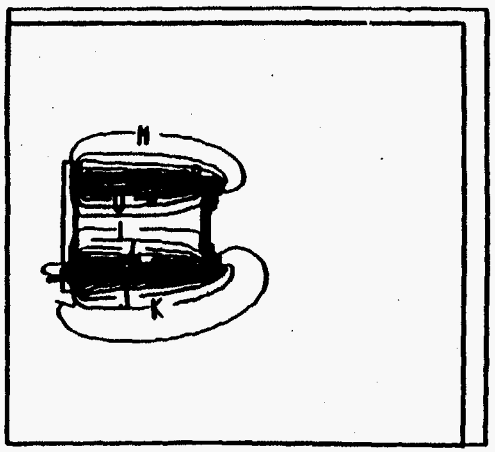


Contour Levels
A: -2.9749e+07
B: -2.5587e+07
C: -2.1425e+07
D: -1.7263e+07
E: -1.3101e+07
F: -8.9393e+06
G: -4.7774e+06
H: -6.1557e+05
I: .5463e+06
J: .7082e+06
K: 1.1870e+07
L: 1.6032e+07
M: 2.0194e+07
N: 2.4356e+07
O: 2.8517e+07
P: 3.2679e+07
Q: 3.6841e+07
R: 4.1003e+07
S: 4.5165e+07
T: 4.9327e+07

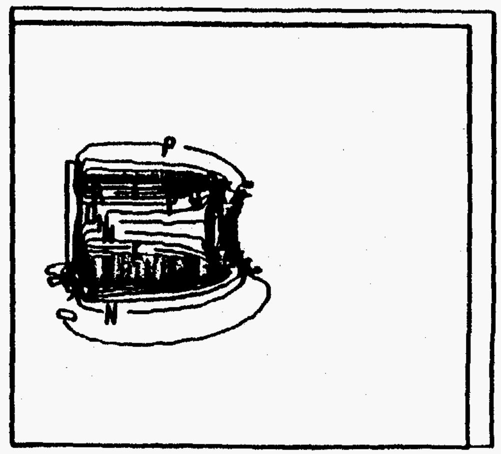


Contour Levels
A: -4.8017e+07
B: -4.1826e+07
C: -3.5634e+07
D: -2.9443e+07
E: -2.3252e+07
F: -1.7060e+07
G: -1.0869e+07
H: -4.6774e+06
I: 1.5140e+06
J: 7.7054e+06
K: 1.3897e+07
L: 2.0088e+07
M: 2.6280e+07
N: 3.2471e+07
O: 3.8662e+07
P: 4.4854e+07
Q: 5.1045e+07
R: 5.7237e+07
S: 6.3428e+07
T: 6.9619e+07

B_Y



Contour Levels
A: -6.5642e+07
B: -5.9864e+07
C: -5.4086e+07
D: -4.8307e+07
E: -4.2529e+07
F: -3.6751e+07
G: -3.0972e+07
H: -2.5194e+07
I: -1.9416e+07
J: -1.3637e+07
K: -7.8590e+06
L: -2.0807e+06
M: 3.6976e+06
N: 9.4759e+06
O: 1.5254e+07
P: 2.1033e+07
Q: 2.6811e+07
R: 3.2589e+07
S: 3.8367e+07
T: 4.4146e+07



Contour Levels
A: -9.6615e+07
B: -8.9070e+07
C: -8.3126e+07
D: -7.6381e+07
E: -6.9637e+07
F: -6.2892e+07
G: -5.6147e+07
H: -4.9403e+07
I: -4.2658e+07
J: -3.5913e+07
K: -2.9169e+07
L: -2.2424e+07
M: -1.5680e+07
N: -8.9350e+06
O: -2.1903e+06
P: 4.5543e+06
Q: 1.1299e+07
R: 1.8044e+07
S: 2.4788e+07
T: 3.1533e+07

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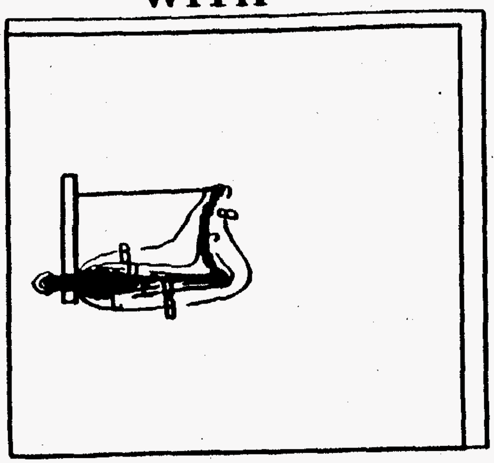
EFFECT OF FARADAY SHIELD (SLOTTED SIDESHIELDS)

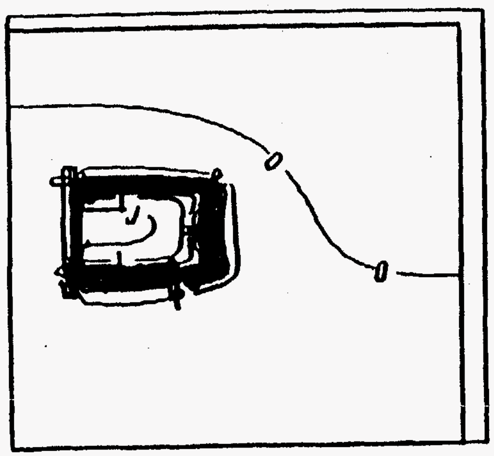
WITH

E_Z



Contour Levels	
A:	-1.1544e-03
B:	2.5373e-02
C:	5.1900e-02
D:	7.8427e-02
E:	1.0495e-01
F:	1.3148e-01
G:	1.5801e-01
H:	1.8454e-01
I:	2.1106e-01
J:	2.3759e-01
K:	2.6412e-01
L:	2.9064e-01
M:	3.1717e-01
N:	3.4370e-01
O:	3.7023e-01
P:	3.9675e-01
Q:	4.2328e-01
R:	4.4981e-01
S:	4.7634e-01
T:	5.0286e-01

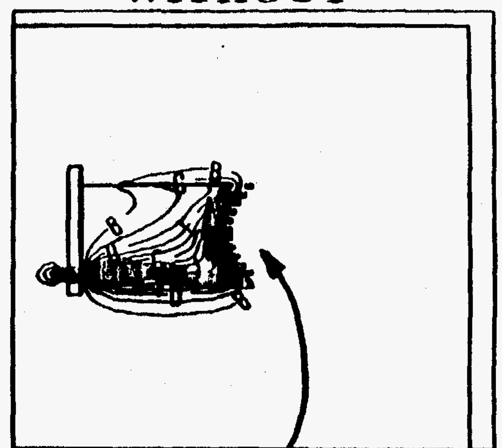
B_Z



Contour Levels	
A:	-1.5433e+08
B:	-1.4316e+08
C:	-1.3198e+08
D:	-1.2081e+08
E:	-1.0963e+08
F:	-9.8457e+07
G:	-8.7282e+07
H:	-7.6107e+07
I:	-6.4932e+07
J:	-5.3758e+07
K:	-4.2583e+07
L:	-3.1408e+07
M:	-2.0233e+07
N:	-9.0578e+06
O:	2.1171e+06
P:	1.3292e+07
Q:	2.4467e+07
R:	3.5642e+07
S:	4.6817e+07
T:	5.7992e+07

WITHOUT

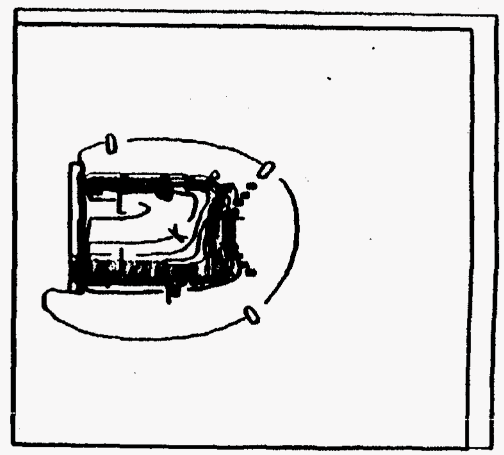
E_Z



SHORTING OUT OF E_Z

Contour Levels	
A:	-1.8346e-03
B:	2.4645e-02
C:	5.1124e-02
D:	7.7604e-02
E:	1.0408e-01
F:	1.3056e-01
G:	1.5704e-01
H:	1.8352e-01
I:	2.1000e-01
J:	2.3648e-01
K:	2.6296e-01
L:	2.8944e-01
M:	3.1592e-01
N:	3.4240e-01
O:	3.6888e-01
P:	3.9536e-01
Q:	4.2184e-01
R:	4.4832e-01
S:	4.7480e-01
T:	5.0128e-01

B_Z



Contour Levels	
A:	-2.0659e+08
B:	-1.9150e+08
C:	-1.7641e+08
D:	-1.6132e+08
E:	-1.4623e+08
F:	-1.3115e+08
G:	-1.1606e+08
H:	-1.0097e+08
I:	-8.5881e+07
J:	-7.0793e+07
K:	-5.5705e+07
L:	-4.0617e+07
M:	-2.5529e+07
N:	-1.0441e+07
O:	4.6468e+06
P:	1.9735e+07
Q:	3.4823e+07
R:	4.9911e+07
S:	6.4999e+07
T:	8.0087e+07

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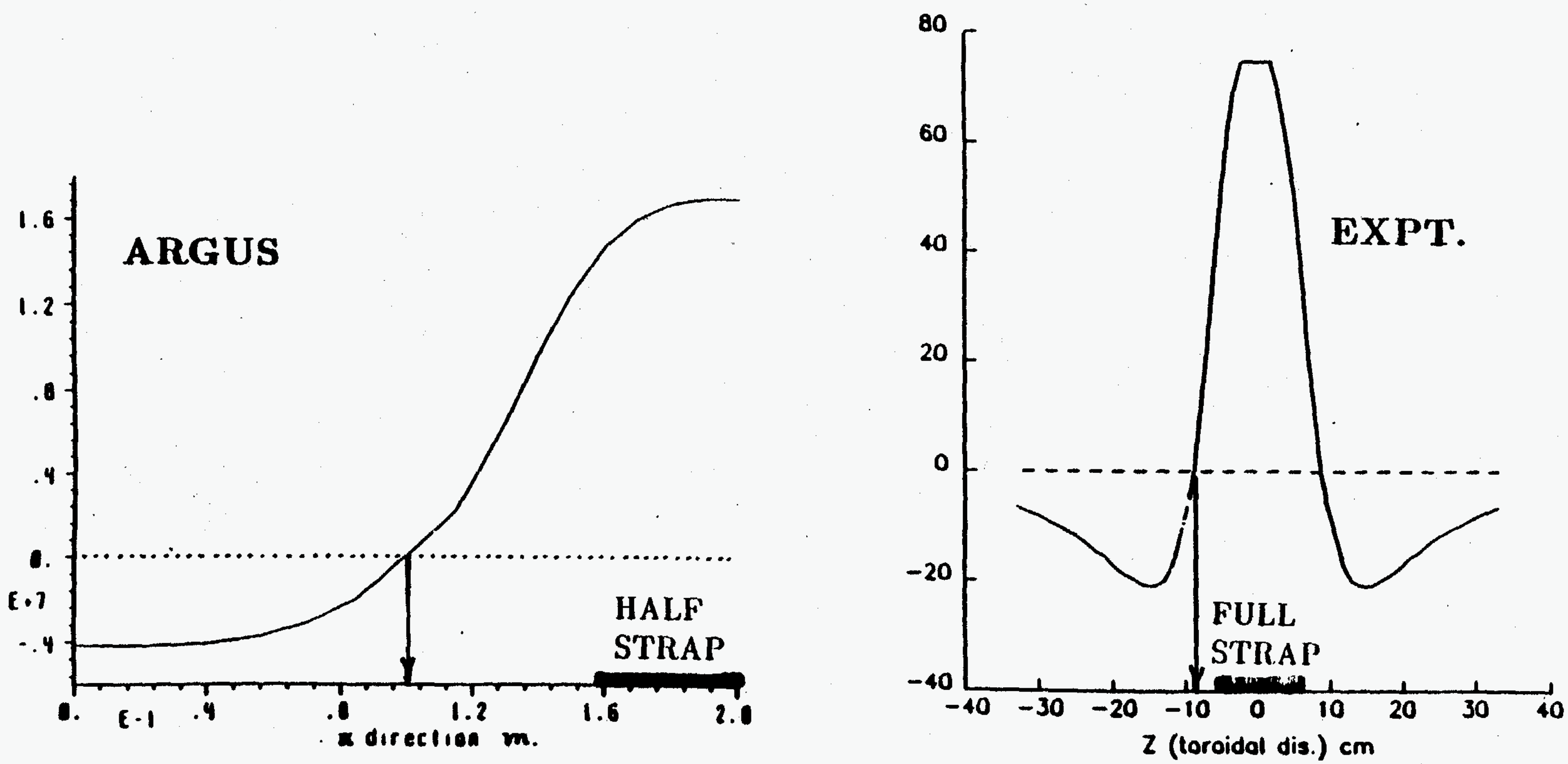
COMPARISON BETWEEN ARGUS AND EXPERIMENT
(STRAP WITH FARADAY SHIELD)



B_Z SPATIAL PROFILE ALONG TOROIDAL DIRECTION AT 4CM ABOVE STRAP

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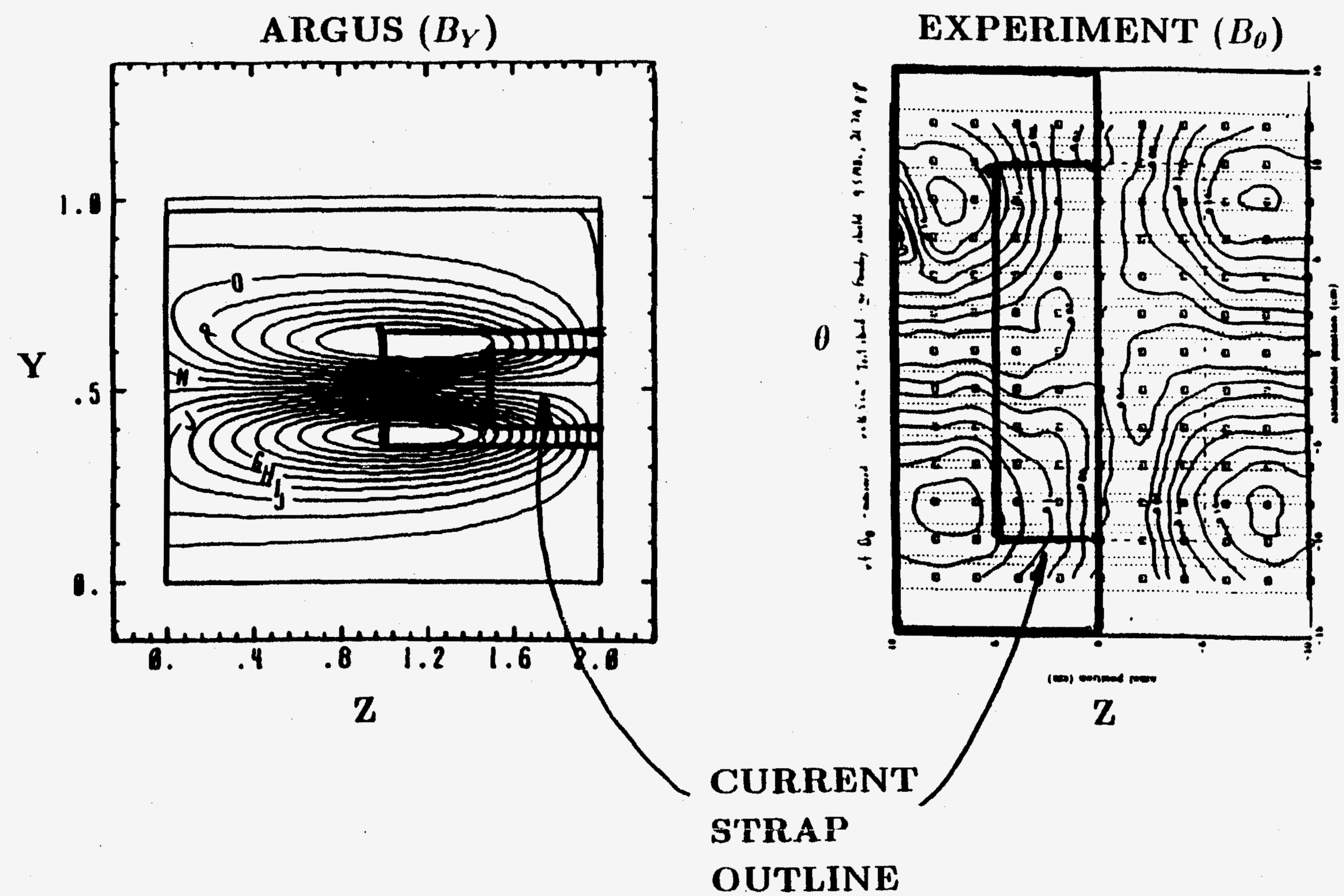
FIELD CONTOURS ON PLANE 4CM ABOVE STRAP



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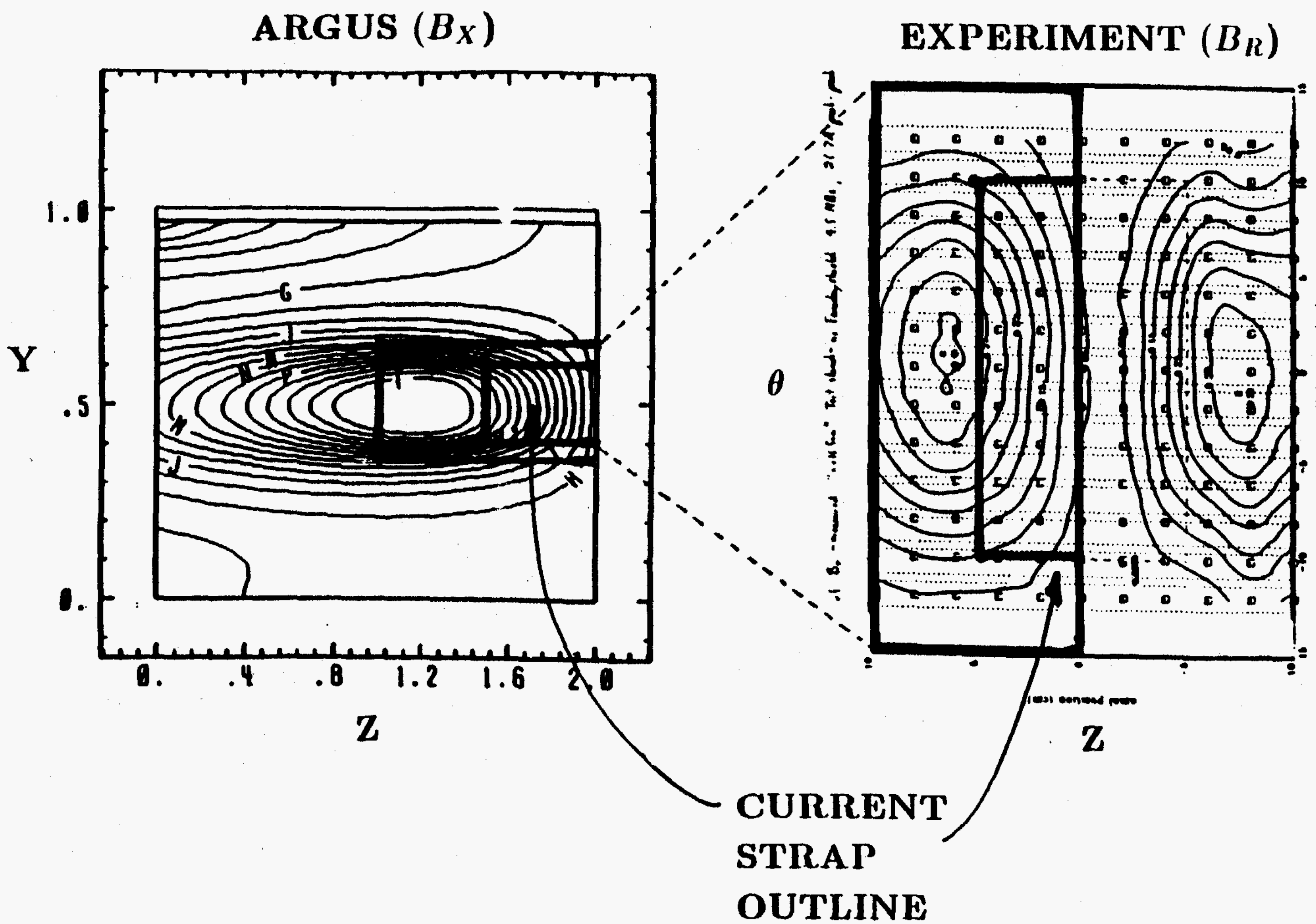
FIELD CONTOURS ON PLANE 4CM ABOVE STRAP



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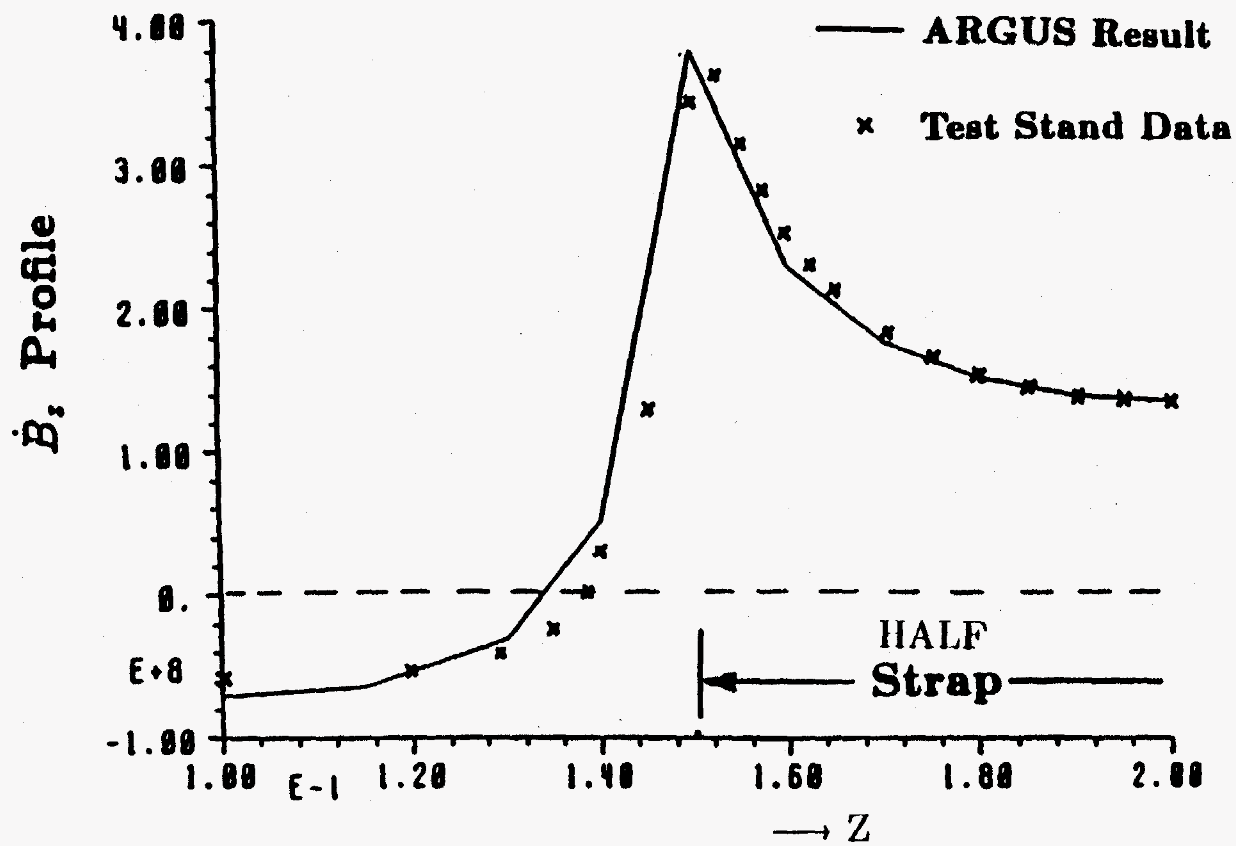
Comparison Between ARGUS and Experiment



- THE AGREEMENT IS EXCELLENT FOR THE SELF-CONSISTENT CURRENT PROFILE

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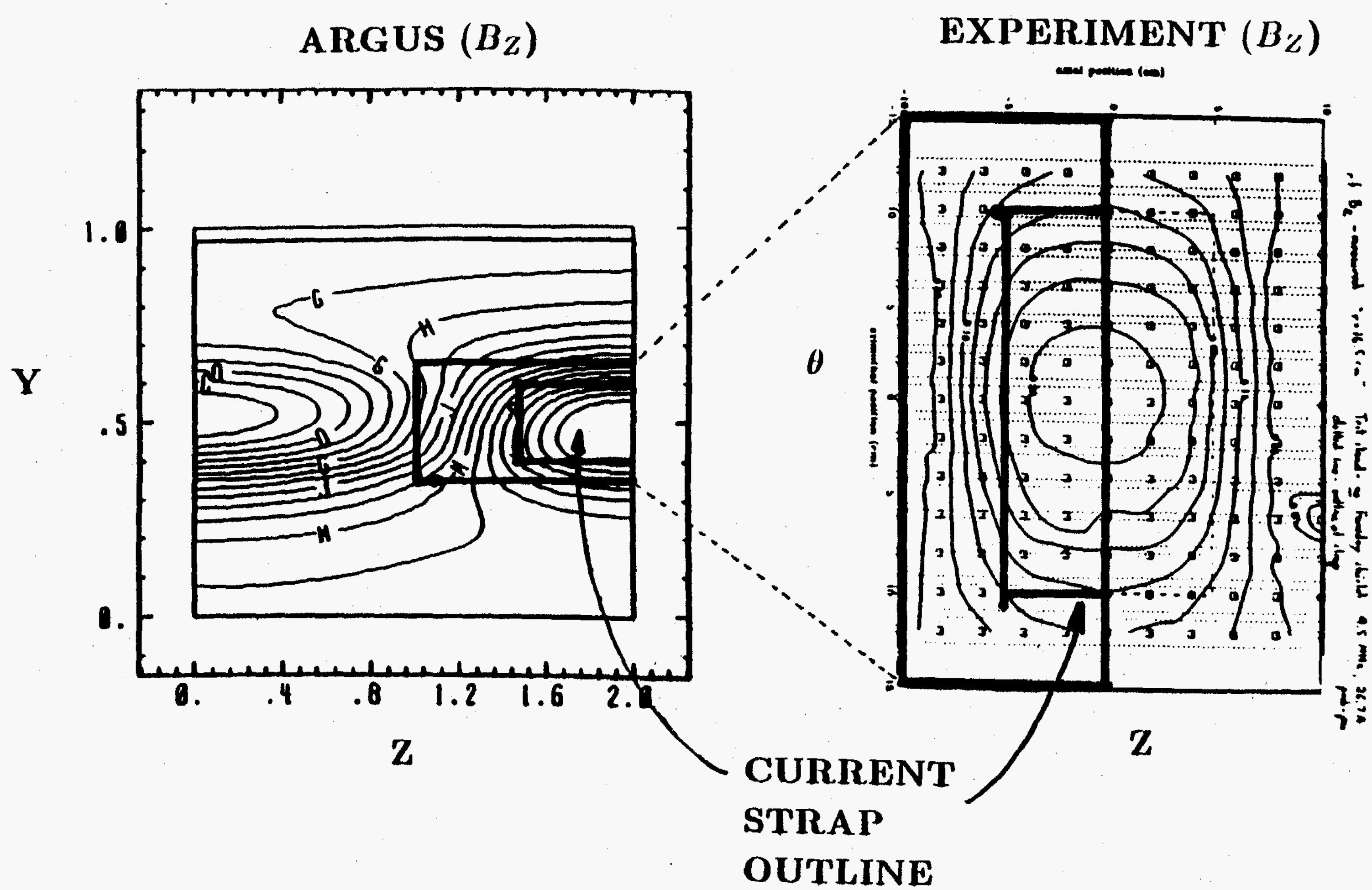
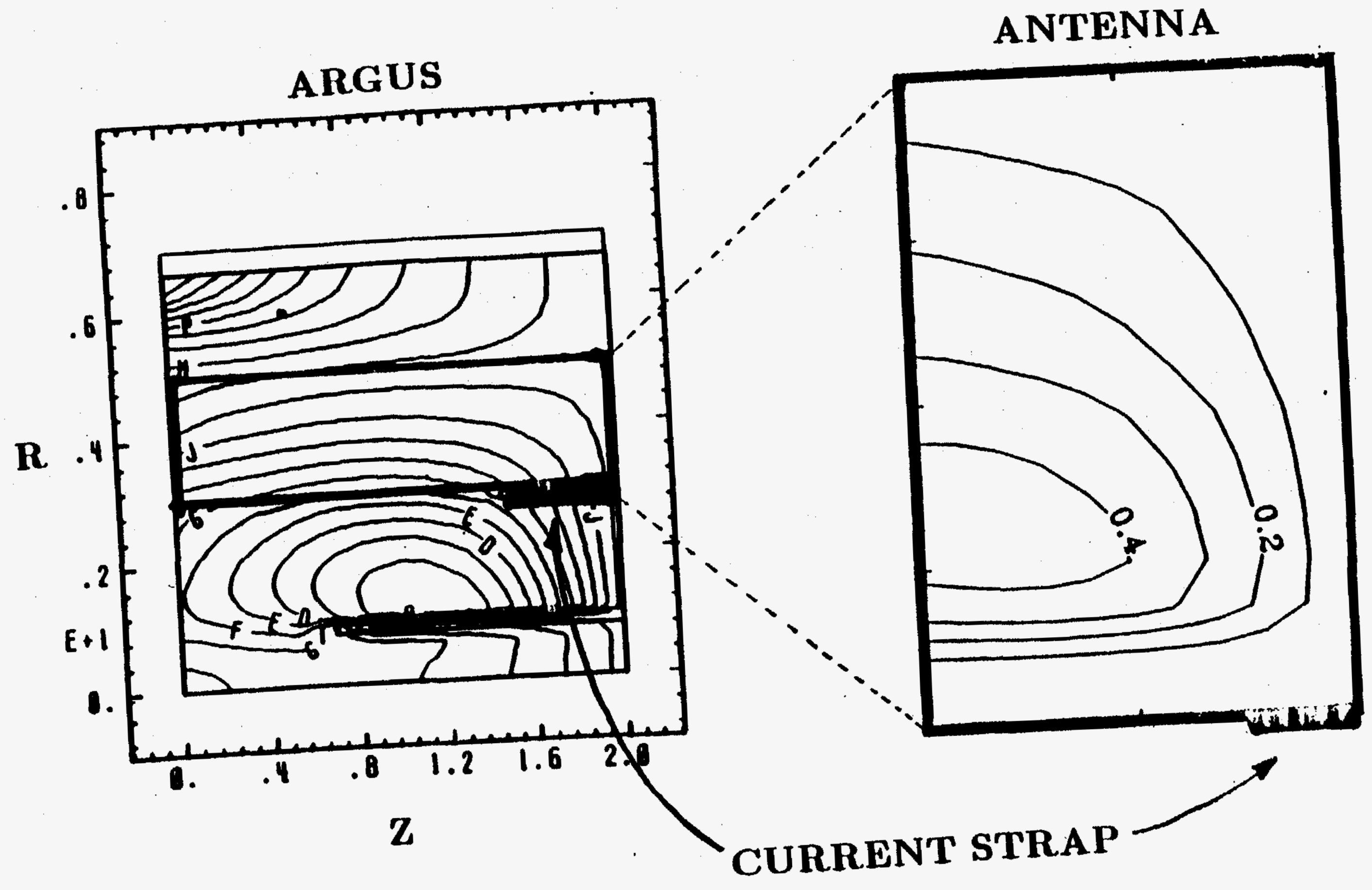
FIELD CONTOURS ON PLANE 4CM ABOVE STRAP



B_θ CONTOURS ON CUT-PLANE AT MID-STRAP ($\theta = 0°$)



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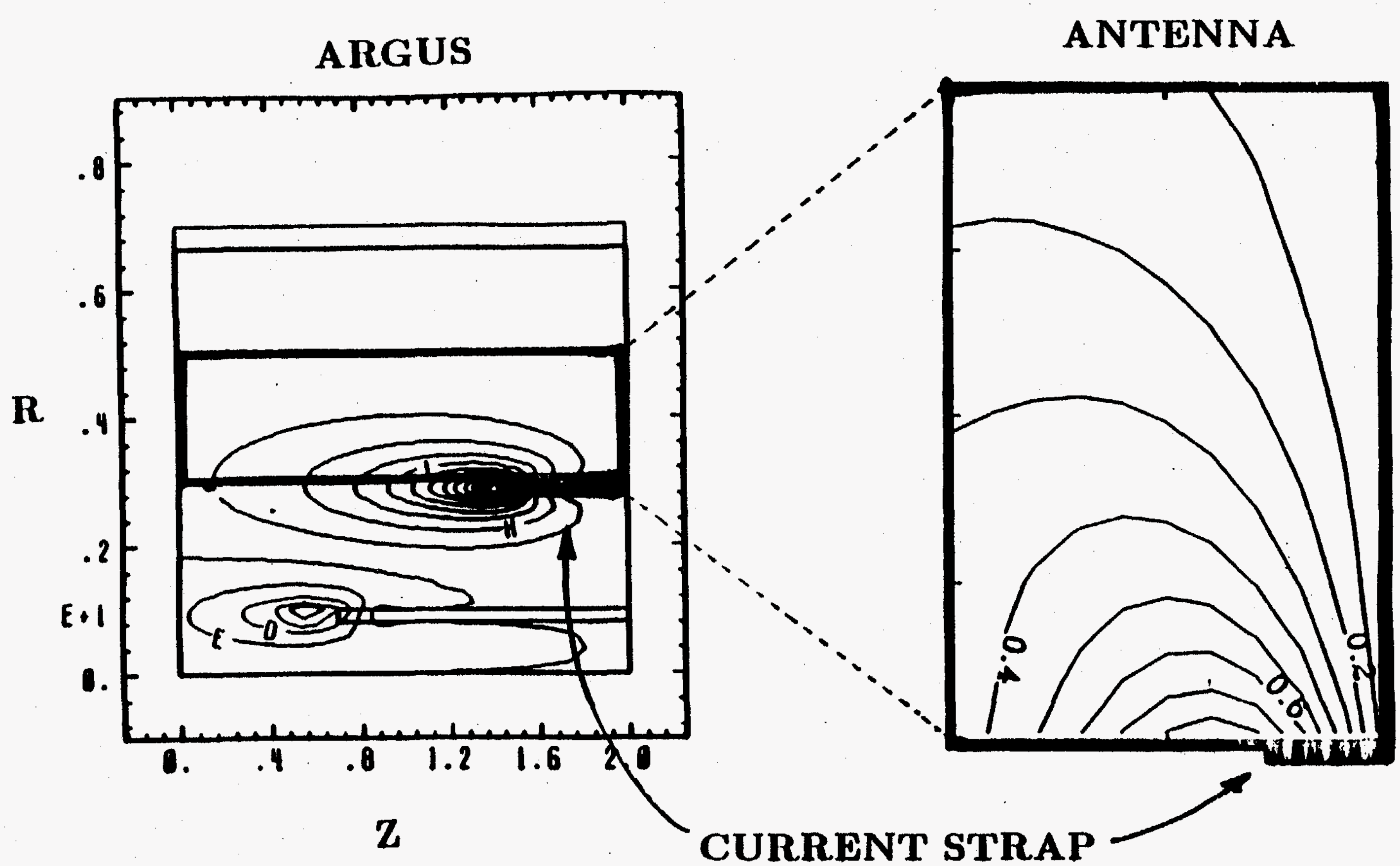
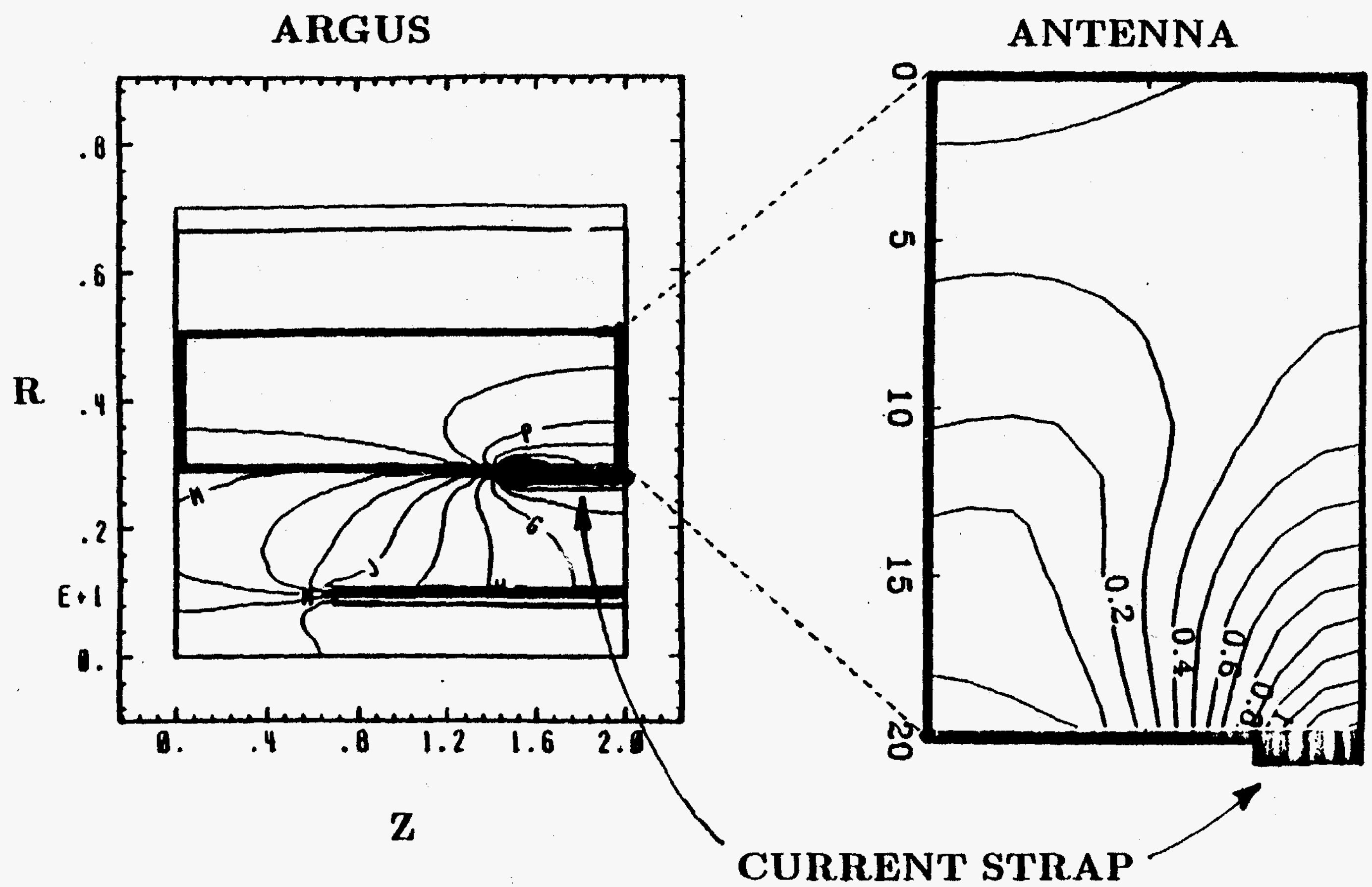
B_R CONTOURS ON CUT-PLANE AT MID-STRAP ($\theta = 0°$)



Science Applications International Corporation

B_Z CONTOURS ON CUT-PLANE AT MID-STRAP ($\theta = 0°$)



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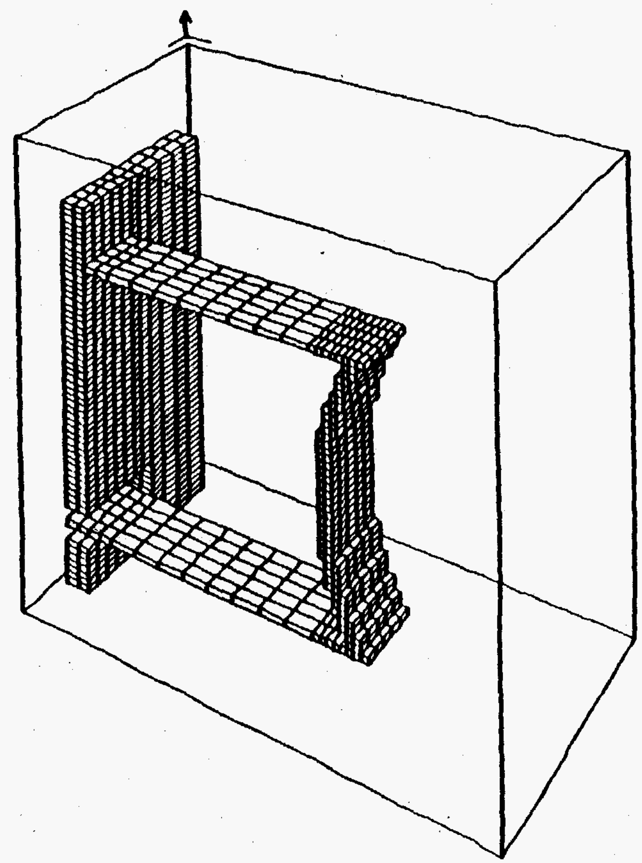
BARE STRAP ON TEST-STAND

- 2-D ANTENNA CODE (McVEY) USES PRESCRIBED STRAP CURRENT PROFILE TO OBTAIN AGREEMENT WITH EXPERIMENT. THREE UNIFORM CURRENT STRAPS CARRYING RESPECTIVELY 35% - 30% - 35% OF THE TOTAL CURRENT ARE SPECIFIED.

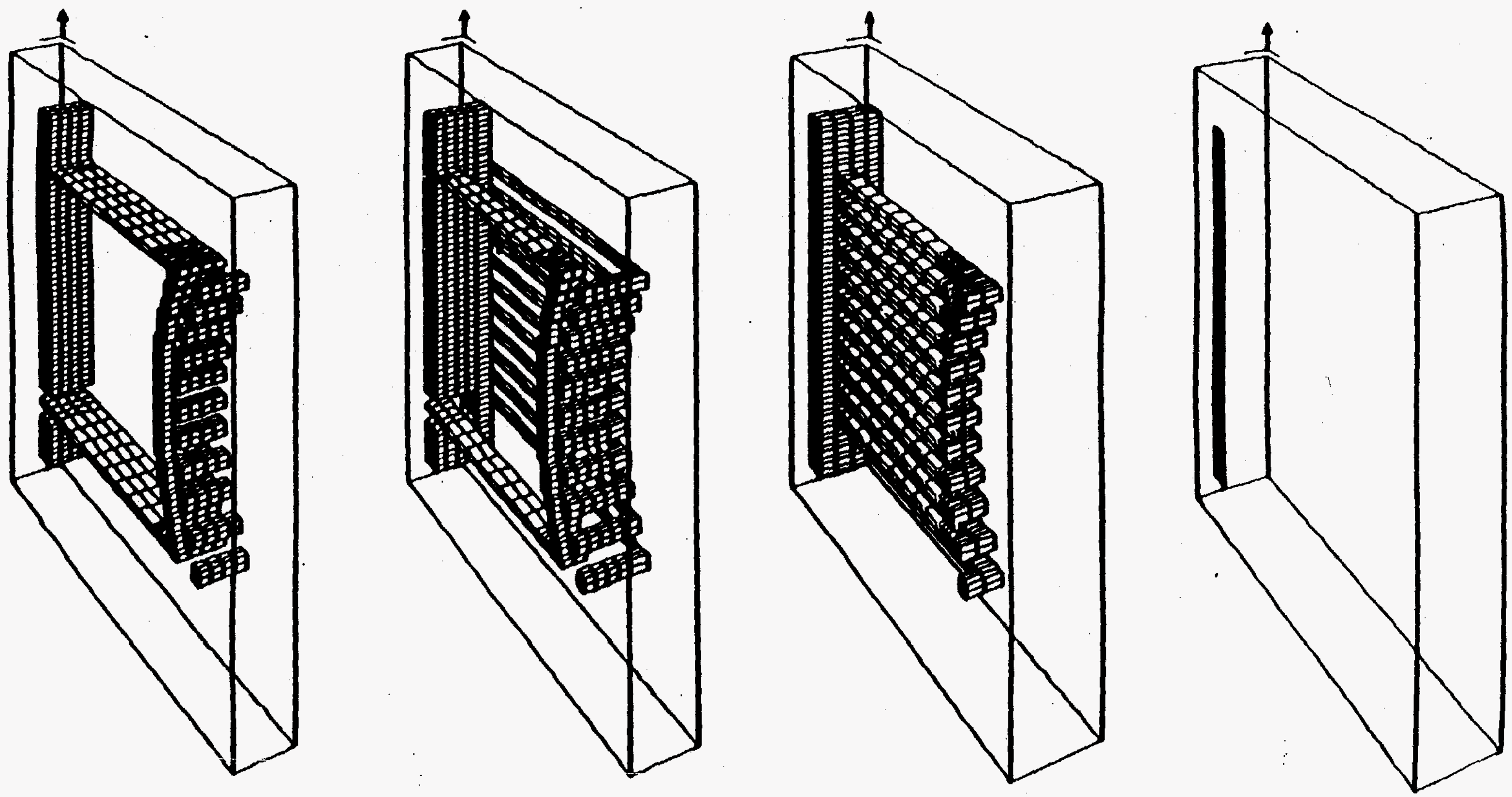
- ARGUS SIMULATION YIELDS THE SELF-CONSISTENT STRAP CURRENT PROFILE THAT CLOSELY AGREES WITH MEASURED DATA.



SAIC Science Applications International Corporation

- DOMAIN DECOMPOSITION OF LARGE PROBLEM INTO 4 BLOCKS

- DIMENSION OF EACH BLOCK = $6 \times 53 \times 93$



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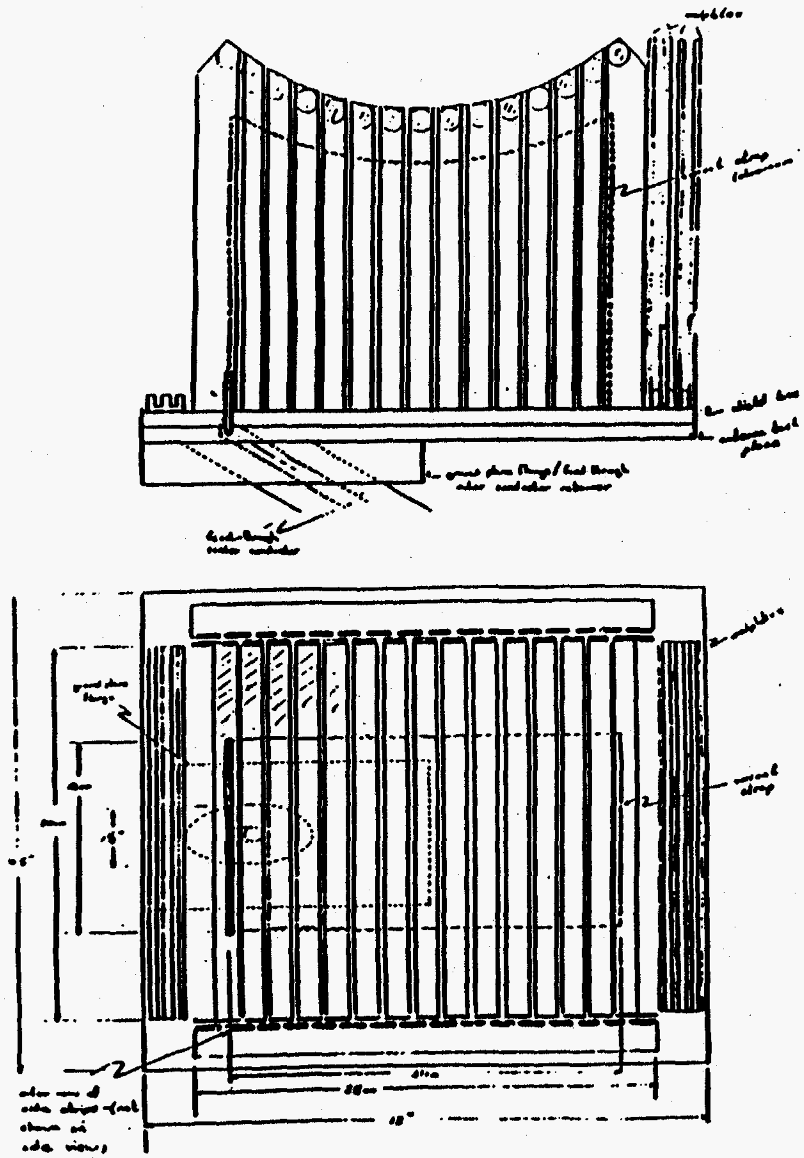
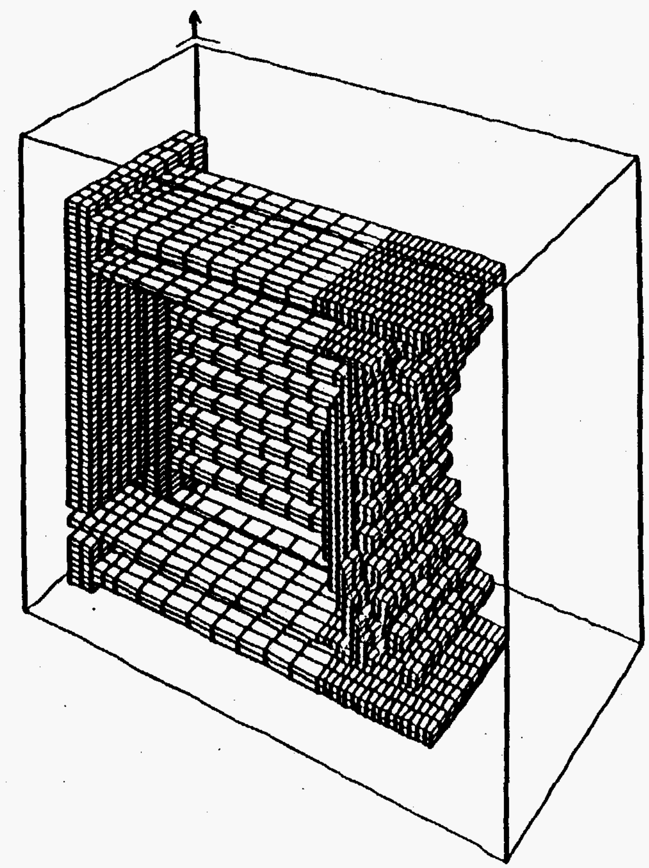
PHAEDRUS-B ANTENNA CONFIGURATION



⇒

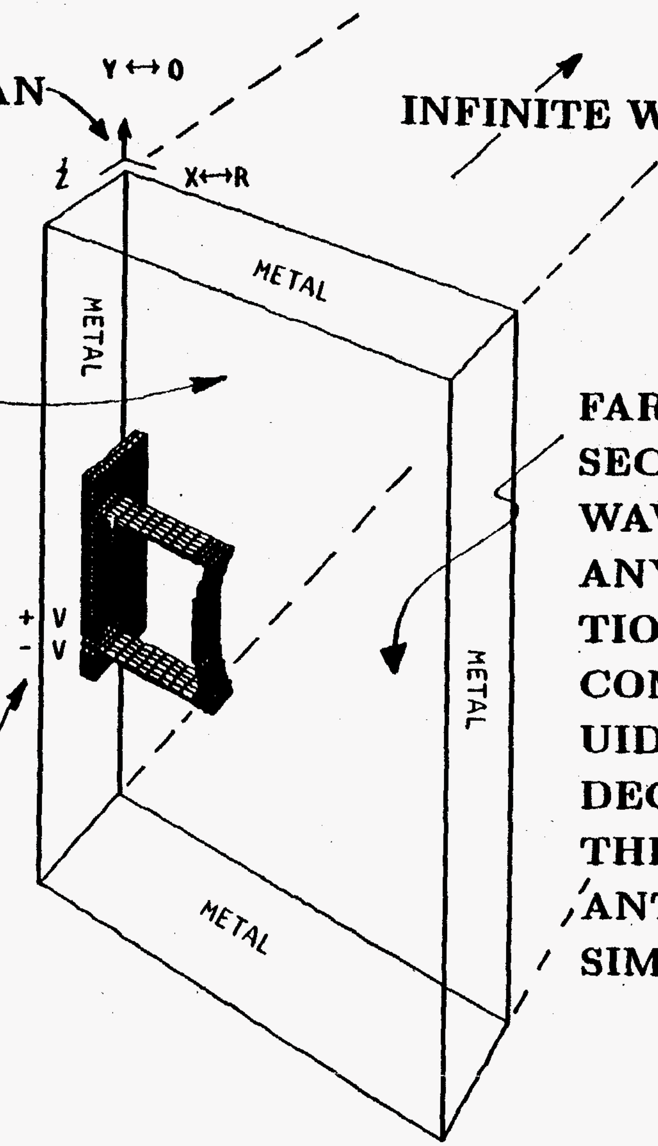
ARGUS MODEL



GEOMETRY AND BOUNDARY CONDITIONS

CARTESIAN

INFINITE WAVEGUIDE



NEAR PLANE IS A SYMMETRY PLANE WHICH REDUCES THE SIMULATION REGION BY HALF.

FAR PLANE IS THE CROSS-SECTION OF AN INFINITE WAVEGUIDE SUCH THAT ANY IMPINGING RADIATION IS EXPRESSED AS THE COMPLETE SET OF WAVEGUIDE MODES. THIS MODE DECOMPOSITION ALLOWS THE RADIATION FROM THE ANTENNA TO EXIT THE SIMULATION REGION.

STRAP IS DRIVEN BY 4.5 MHZ POTENTIAL AT LEAD.

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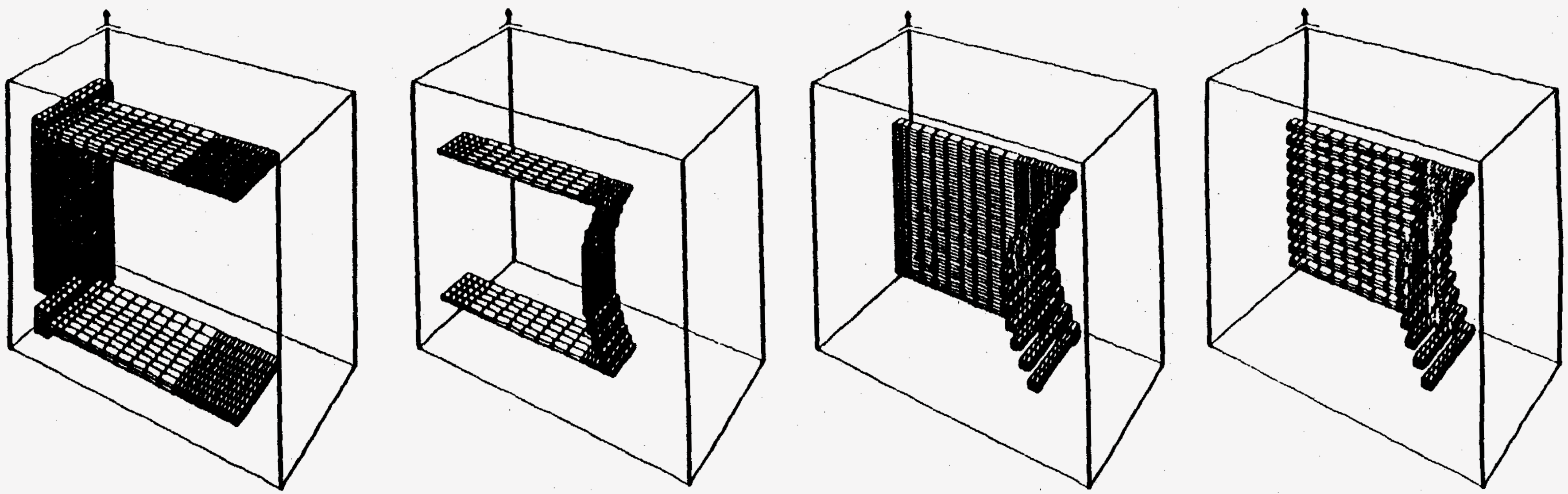
ANTENNA COMPONENTS

- ARGUS INPUT DECK ALLOWS COMPLEX STRUCTURES TO BE INTRODUCED, DELETED OR INTERCHANGED WITH RELATIVE EASE.



BACKPLANE WITH END CAPS

CURRENT STRAP

FARADAY SHIELDS

SOLID SIDE SHIELDS

SLOTTED SIDE SHIELDS

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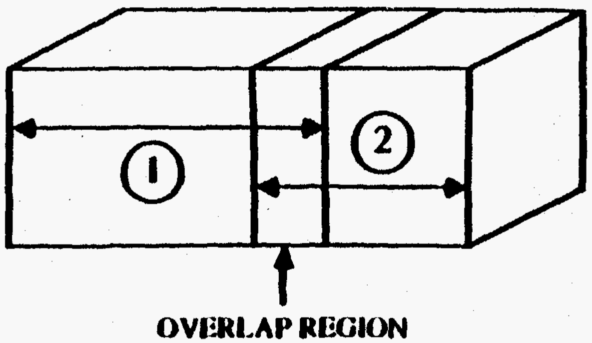
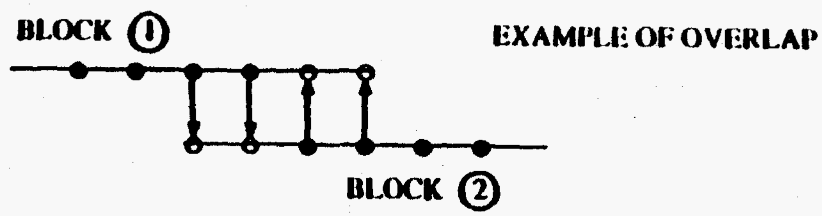
- LARGE PROBLEMS ARE HANDLED THROUGH THE USE OF A BLOCK STRUCTURE IN LOGICAL SPACE

"DOMAIN DECOMPOSITION"





DATA MANAGER HANDLES BLOCK RESOURCES AND SHARING OF INFORMATON AT INTERFACES

- ALGORITHM SELECTION HAS BEEN DONE TO DEFINE TECHNIQUES WHICH PERMIT GLOBAL SOLUTIONS IN THE PHYSICAL SPACE BY SEQUENCE INDEPENDENT OPERATIONS IN EACH BLOCK FOLLOWED BY SHARING OF DATA AT INTERFACES.
  - COMPATABILITY WITH PARALLEL COMPUTER ARCHITECTURES

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- **TIME-DOMAIN ELECTROMAGNETIC FIELD SOLVER**

$$\frac{\partial \vec{B}}{\partial t} = -\vec{\nabla} \times \vec{E}$$

$$\frac{\partial \vec{D}}{\partial t} = \vec{\nabla} \times \vec{H} - \vec{J} - \overleftrightarrow{\sigma} \cdot \vec{E}$$

where $\vec{D} = \varepsilon \vec{E}$, $\vec{B} = \mu \vec{H}$,

and $\vec{\nabla} \cdot \vec{D} = \rho$, $\vec{\nabla} \cdot \vec{B} = 0$ are treated as constraint equations.

METHOD: **EXPLICIT LEAPFROG INTEGRATION WITH DISTRIBUTED POISSON CORRECTION**

Science Applications International Corporation

- **THREE DIMENSIONAL SIMULATION MODEL WITH MODULAR BACKBONE ARCHITECTURE**
  - **SYSTEM MODULES SHARED BY ALL PHYSICS PACKAGES**

    INPUT
    OUTPUT
    DATA MANAGEMENT
    MEMORY MANAGEMENT
    RUN TIME INTERACTION
    DIAGNOSTICS

  - **PHYSICS PACKAGES**

    ELECTROSTATIC SOLVERS
    TIME-DOMAIN ELECTROMAGNETIC SOLVER
    FREQUENCY-DOMAIN ELECTROMAGNETIC SOLVER
    ELECTROMAGNETIC PARTICLE-IN-CELL SOLVER
    HYDRODYNAMIC SOLVER
    INTEGRATED SIMULATIONS

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THE ARGUS SIMULATION CODE

- RESPONSE TO NEED FOR 3-DIMENSIONAL MODELING INVOLVING ELECTROMAGNETIC FIELDS AND PARTICLE MOTION, IN COMPLEX GEOMETRICAL CONFIGURATIONS.
  - INSIGHT FOR RESEARCH ORIENTED PROBLEMS
  - DESIGN FOR DEVICE ENGINEERING
- IMPROVED PERFORMANCE OF COMPUTERS IN SPEED AND MEMORY MAKES BOTH APPLICATIONS PRACTICAL.

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OBJECTIVE: TO MODEL IN 3-D THE VACUUM NEAR FIELDS OF AN ICRF ANTENNA CONFIGURATION IN USE ON CURRENT AND PLANNED FUSION EXPERIMENTS.

METHOD: ARGUS - 3-D PLASMA SIMULATION CODE.

RESULT: FOR THE UNIVERSITY OF WISCONSIN PHAEDRUS-B ANTENNA, ARGUS RESULTS AGREE CLOSELY WITH EXPERIMENTAL DATA.

CONCLUSION: WORK DEMONSTRATES THE POTENTIAL OF FULL 3-D SIMULATION AND WARRANTS FURTHER DEVELOPMENT OF THIS CAPABILITY FOR ICRF ANTENNA DESIGN (E.G., INCLUDE PLASMA EFFECTS).

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APPENDIX E

WILLIAM GROSSMANN

Virginia Polytechnic Institute and State University: B.S. (1958)
Virginia Polytechnic Institute and State University: M.S. (1961)
Virginia Polytechnic Institute and State University: Ph.D. (1964)

Dr. William Grossmann is presently Chief Operations Scientist for the Applied Physics Operation, Science Applications International Corporation. He also holds the positions of Research Professor of Plasma Sciences at New York University's Courant Institute of Mathematical Sciences (CIMS) and Adjunct Professor of Applied Science in the Department of Applied Science. Prior to joining SAIC, Dr. Grossmann was the Associate Director, Magneto Fluid Dynamics Division, CIMS, where his duties included the direction of scientific work, initiation of new research areas, securing and managing contract and grant research. While at NYU, he was elected to the position of Chairman, Spring College on Plasma Physics, International Center for Theoretical Physics, Trieste, Italy. Significant previous positions held by Dr. Grossmann include Senior Scientist, Max-Planck-Institut fur Plasma Physik, Garching, West Germany (1969 - 1974), Assistant Professor of Applied Mathematics, Richmond College of the City University of New York (1967 - 1969), and Aerospace Technologist, National Aeronautics and Space Administration, Langley Research Center (1958 - 1965).

Dr. Grossmann received his undergraduate and graduate degrees in aeronautical and aerospace engineering from Virginia Polytechnic Institute and State University, and upon receiving a NASA award for his Ph.D. dissertation, spent a postdoctoral year in applied mathematics at NYU's Courant Institute. He also received the Sigma Xi Research Award from VPI & SU in 1964.

Dr. Grossmann has been a consultant to Bell Aerosystems Company, JAYCOR, Princeton Plasma Physics Laboratory, lecturer to the University of Padua's Institute of Electronics Fusion Laboratory, visiting staff member of the Los Alamos National Laboratory, visiting senior fellow of the University of Maryland's Center for Theoretical Physics, and member of the advisory board of the University of Texas' Institute for Fusion Studies. He was twice elected to the office of secretary-treasurer for the American Physical Society Division of Plasma Physics and was named a fellow of the society in 1983.

Dr. Grossmann's work experience includes experimental and theoretical aerodynamics, plasma physics and fusion research at national and foreign laboratories, private industry and in the university. He has published widely in these fields and is presently organizing a series of books on MHD and plasma physics as a senior editor for Cambridge University Press. While at the Langley NASA Laboratory, Dr. Grossmann developed an MPD arc jet which later became the basis for research in MPD space propulsion at NASA. At the Max-Planck-Institut, he was co-discoverer and developer of the concept of electromagnetic wave energy absorption in the continuous spectrum of Alfven waves in a fusion plasma; present day rf heating experiments of fusion plasmas based on this discovery are actively being carried out. More recently, his interests have turned to large scale computing and simulation and he is leading an SAIC effort in the 3-D analysis and simulation of radio frequency heating antennas for fusion devices.

Dr. Grossmann has participated in many technology and science studies and surveys. He was chairman of the science subpanel established by DOE's Office of Program Assessment to assess the status and progress of the Office of Fusion Energy's Research and Development Program. Dr. Grossmann has also carried out a study under DARPA funding to assess the role large scale supercomputing will play in enhancing productivity and manufacturing technology in American industry. .

Curriculum Vitae

WILLIAM GROSSMANN

Science Applications International Corporation
1710 Goodridge Drive
McLean, Virginia 22102
(703) 556-7323

EDUCATION:

B.S., Aeronautical Engineering, Virginia Polytechnic Institute and State University, June 1958.

M.S., Aeronautical Engineering, Virginia Polytechnic Institute and State University, June 1961.

Ph.D., Aerospace Engineering, Virginia Polytechnic Institute and State University, June 1964.

Post-Doctoral Studies, Applied Mathematics, Courant Institute of Mathematical Sciences, New York University, 1964 -1965.

PROFESSIONAL EXPERIENCE:

1987 - Present	Chief Operations Scientist, Applied Physics Operation, Science Applications International Corporation, McLean, Virginia.
1983 - Present	Adjunct Professor of Applied Science, Department of Applied Science New York University.
1977 - Present	Research Professor of Plasma Sciences Courant Institute of Mathematical Science New York University.
1977 - 1987	Associate Director, Magneto-Fluid Dynamics Division, Courant Institute of Mathematical Sciences, New York University.
1974 - 1977	Assistant Director, Magneto-Fluid Dynamics Division, Courant Institute of Mathematical Sciences, New York University.
1969 - 1974	Senior Scientist, Max-Planck-Institut fur Plasma Physik, Garching, West Germany.
1967 - 1969	Assistant Professor of Applied Mathematics, Richmond College of City University of New York.
1964 - 1967	Associate Research Scientist, Magneto-Fluid Dynamics Division Courant Institute of Mathematical Sciences, New York University.
1958 - 1964	Aerospace Technologist, National Aeronautics and Space Administration Langley Research Center.
1964	Instructor in Aeronautical Engineering, University of Virginia Engineering Extension Service, Langley Field, Virginia .
1959	Instructor in Aeronautical Engineering, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

CONSULTING EXPERIENCE:

1967 -1969	Consultant, Bell Aerosystems Company Buffalo, New York.
1973 - Present	Visiting Staff Member, Los Alamos National Laboratory Los Alamos, New Mexico.
1971 - 1973	Consultant and Lecturer, University of Padua, Institute of Electronics, Ionized Gas Laboratory, Padua, Italy.
1974 - 1975	Visiting Senior Fellow, University of Maryland Center for Theoretical Physics.
1979 - 1987	Senior Consultant ,Science Applications International Corporation (SAIC), La Jolla, California, and McLean, Virginia.
1982 - 1987	Consultant, JAYCOR, La Jolla, California.
1984 - present	Director of Science and Technology, William Dunk Partners, New York, New York.
1982 - 1983	Consultant, Princeton Plasma Physics Laboratory, Princeton University, Princeton, New Jersey.
1977 - 1979	Member of Alternate Fusion Concept Review Panel, Appointed by Department of Energy, Office of Fusion Energy.
1979 - 1981	Member of DOE Energy Research Advisory Board, Sub-Panel for Research and Development, Appointed by Secretary of Energy.
1983 - 1987	Elected Chairman, Spring College on Plasma Physics, International Center for Theoretical Physics, Trieste, Italy.
1983 to 1986	Elected to Advisory Board of Institute for Fusion Studies, University of Texas Austin, Texas. Appointed Vice-Chairman (1984).

ACADEMIC AND PROFESSIONAL HONORS:

1958	Monteith Award, Virginia Polytechnic Institute and State University
1958	Sigma Gamma Tau, Honorary Aeronautical Society
1959 - 1962	National Defense Fellowship, U.S. Department H.E.W.
1964	SIGMA XI Research Award

PROFESSIONAL SOCIETIES:

American Physical Society, Elected to Fellowship, November 1983, Secretary-Treasurer Division of Plasma Physics, 1981 - 1984.

PUBLICATIONS AND PRESENTATIONS:

1. "Characteristics of Complete Missile Configurations at Hypersonic Speeds," (with R.W. Truitt), at the May 1958 Meeting of Virginia Academy of Sciences, Norfolk, Virginia..

2. "Heat-Transfer Measurements on a Hemisphere Cylinder at M = 3.5 Using a Cooling Technique," (with L.O. Hayman, Jr.) NASA Technical Report, October 1959.

3. "Existence of a Voltage Plateau for a Discharge Crossed with a Magnetic Field at Elevated Pressures," (with R.V. Hess), Annual Meeting of the Division of Plasma Physics of the APS, Seattle, Washington, August 1962 (Bull. Am. Phys. Soc. 7 (7), August 1962). (Abstract only.)

4. "Some Aspects of Magnetohydrodynamic Flows," in the Proceedings of the May 1963 Meeting of the Virginia Academy of Sciences, Norfolk, Virginia. (Abstract only.)

5. "Experiments and Theory for Hall Currents of Steady Discharges in Crossed Electric and Magnetic Fields," (with P. Brockman, R.V. Hess) in Proceedings of the 6th International Conference on Ionization Phenomena in Gases, Seine, France, July 1963.

6. "Non-equilibrium Ionization in Steady Discharges Crossed with Magnetic Fields for High Pressure MHD Studies: I. Experiments," (with R.V. Hess, F.W. Bowen, N.W. Jalufka), Annual Meeting of the Division of Plasma Physics of the APS, Chicago, Illinois, November 1963 (Bull. Am. Phys. Soc. 8 (7), October 1963. (Abstract only.)

7. "Non-equilibrium Ionization in Steady Discharges Crossed with Magnetic Fields for High Pressure MHD Studies: II. Theory," (with H.A. Hassan, R.V. Hess), Annual Meeting of the Division of Plasma Physics of the APS, Chicago, Illinois, November 1963 (Bull. Am. Phys. Soc. 8 (7), October 1963). (Abstract only.)

8. "Experiments with a Co-axial Hall Current Plasma Accelerator," (with H.A. Hassan, R.V. Hess). Paper No.64-700, presented at the 4th Electric Propulsion Conference, Philadelphia, PA., August 1964.

9. "Experiments and Analysis for Co-axial Hall Current Accelerators and the Role of Ionization Effects," (with H.A. Hassan, R.V. Hess) in Proceedings of the 6th Symposium on Engineering Aspects of Magnetohydrodynamics, Pittsburg, PA., April 1985.

10 "Experiments with a Co-axial Hall Current Accelerator," (with R.V. Hess, H.A. Hassan), AIAA Journal, 3 (6), 1034-1039 (1965).

11. "Particle Loss in a Three Dimensional Cusp," Annual Meeting of the Division of Plasma Physics of the APS, Nashville, TN, December 1966 (Bull. Am. Phys. Soc. 11 (6), December 1966). (Abstract only.)

12. "The Computation of Particle Losses from Cusped and Theta Pinch Devices (with R.L. Morse). Paper 2R-3, Annual Meeting of the Division of Plasma Physics of the APS, Nashville, TN., December 1966 (Bull. Am. Phys. Soc. 11 (6), December 1966). (Abstract only.)

13. "Particle Losses in a Three Dimensional Cusp," Physics of Fluids 9, 2478 (1966).

14. "Study of Co-axial Hall Current Plasma Accelerator at Moderate Pressures," (with H.A. Hassan, R.V. Hess), NASA TN D-3286, October 1966.

15. "Two-Dimensional Equilibrium for High Beta Mirror Devices Including Particle Loss," (with J. Friedberg), Physics of Fluids 11, 2476 (1968).

16. "Numerical Calculation of Screw Pinch Stability," in Proceedings of the 4th European Conference on Controlled Fusion and Plasma Physics, Rome, Italy, 1970. (Abstract only.)

17. "Review of High Beta Plasma Stability," Ibid. (Abstract only.)

18. "Compressibility Effects in Diffuse Plasma Profiles," (with J. Tataronis), Annual Meeting of the Division of Plasma Physics of the APS, Madison, Wisconsin, November 1971 (Bull. Am. Phys. Soc. 16 (11), 1293, November 1971). (Abstract only.)

19. "Theta Pinch Experiments with Trapped Anti-Parallel Magnetic Fields," (with A. Eberhagen), Annual Meeting of the Division of Plasma Physics of the APS, Madison, Wisconsin, November 1971 (Bull. Am. Phys. Soc. 16 (11), 1256, November 1971). (Abstract only.)

20. "Theta Pinch Experiments with Trapped Anti-Parallel Magnetic Fields," (with A. Eberhagen), Z. Physik 248, 130-149, (1971).

21. "On the Spectrum of Ideal MHD," (with J. Tataronis), Paper B5, in Proceedings of the 2nd International Topical Conference on Pulsed High Density Plasmas, Garching, IPP Report 1/127, July 1972. (Bull. APS, 17 (9), 847).

22. "The Excitation of Waves and Resonances in High Beta Plasmas," (with J. Tataronis), Paper B6, ibid. (Bull. APS, 847).

23. "Experimental Investigations of the Belt Pinch," (et al.), Paper Fl, ibid, 853.

24. "MHD Stability Considerations of the Belt Pinch," Paper F8, ibid., 854.

25. "Summary of the Second Topical Conference on Pulsed High Beta Plasmas," Kern Energie, 20 (1), A3, September 1972.

26. "Spatial Landau Damping in Ideal MHD - I Theory," (with J. Tataronis), Annual Meeting of the Division of Plasma Physics of the APS, Monterey, CA., November 1972 (Bull. Am. Phys. Soc. 17 (11), 1051, November 1972). (Abstract only.)

27. "Spatial Landau Damping in Ideal MHD - II Laboratory Applications," (with J. Tataronis), ibid. (Abstract only.)

28. "An Analysis of High Beta Plasmas," Lecture Notes at Univ. of Padua, Italy, Universita di Padova, Istituto di Ellectrotecnica e di Elettronica, UPEE-72102, December 1972.

29. "Damping of Alfven and Magnetoacoustic Waves at High Beta," (with M. Kaufmann, J. Neuhauser), Nucl. Fusion 2, 462-464 (1973).

30. "Decay of MHD Waves by Phase Mixing - I: The Sheet Pinch in Plane Geometry," (with J. Tataronis), Z. Physik 261, 203-216 (1973).

31. "Decay of MHD Waves by Phase Mixing - II: The Theta Pinch in Cylindrical Geometry," (with J. Tataronis), Z. Physik 261, 271-236 (1973).

32. "Spatial Landau Damping of Alfven Waves in Bounded Plasmas," (with J. Tataronis), in Proceedings of the First International Congress on Waves and Instabilities in Plasmas, Innsbruck, March 1973. (Abstract only.)

33. "Plasma Heating by Helical Alfven Waves," (with M. Kaufmann, J. Neuhauser), in Proceedings of the 3rd International Conference on Toroidal Plasma Confinement, Paper E3, Max Planck Institut fur Plasma Physik, Garching, W. Germany, March 1973.

34. "Stability of Reverse Field Pinch Configurations," (with S. Ortolani), Paper F8, ibid.

35. "MHD Stability of Helical Modes in a Cylindrical Tokamak Plasma," (with S. Ortolani), Max Planck Institut fur Plasmaphysik Report, IPP-1/132, April 1973.

36. "MHD Modal Analysis of Tokamak-Like Profiles with Various Current Density Profiles," (with S. Ortolani), in Proceedings of the 6th European Conference on Controlled Fusion and Plasma Physics, 83-86, Moscow, July 1973.

37. "MHD Stability of Rotating Helical Perturbations in a Straight Variable Current Density Plasma Column,"(with S. Ortolani), Annual Meeting of Plasma Physics Division of the APS, Philadelphia, PA., November 1973 (Bull. Am. Phys. Soc. 18 (10), 1358, October 1973). (Abstract only.)

38. "Resonant Absorption in Ideal MHD," (with J. Tataronis), Annual Meeting of the Division of Plasma Physics of the APS, Philadelphia, PA., November 1973 (Bull. Am. Phys. Soc. 18 (10), 1358, November 1973). (Abstract only.)

39. "Conference Report: Waves and Instabilities in Plasmas," Nucl. Fusion 13, 623-627 (1973).

40. "RF Heating of a Guiding Center Plasma in the Continuous Spectrum" (with J. Tataronis), in Proceedings of the 2nd Topical Conference on RF Plasma Heating, Paper A6, Texas Tech. University, Lubbock, Texas, 1974.

41. "Stability of Kink Modes in High Beta Tokamaks," (with J.P. Friedberg, F. Haas, J.P. Goedbloed), in Proceedings of the 5th International Conference on Plasma Physics and Controlled Nuclear Fusion Research, Tokyo, 1974. IAEA-CN-33/A13-4, Vienna, 1974.

42. "High Beta Toroidal Belt Pinch Stability," in Proceedings of the Annual Project Sherwood Theoretical Meeting, Berkeley, CA., April 1974.

43. "MHD Instabilities as an Initial Value Problem," (with R. Bateman, W. Schneider), Max-Planck-Institut fur Plasmaphysik Report IPP-1/145, April 1974.

44. "MHD Instabilities as an Initial Value Problem," (with R. Bateman, W. Schneider), Nucl. Fusion 14, 669 (1974).

45. "Comparison of the Ideal MHD and Guiding Center Models of a Plasma (with J. Choe, J.A. Tataronis), Annual meeting of the Division of Plasma Physics of the APS, Albuquerque, NM., November 1974 (Bull. Am. Phys. Soc. 19, 970, October 1974). (Abstract only.)

46. "Toroidal Kink Mode Stability of a Finite Beta, Arbitrary Cross Section Tokamak Plasma," (with J.P. Freidberg), ibid.

47. "A Quantitative Calculation of Alfven Wave Absorption in Fusion Plasma Experiments," (with J.A. Tataronis), in Proceedings of the 2nd International Congress on Waves and Instabilities in Plasma, Innsbruck, Austria, March 1975.

48. "On the Formulation of Transit Time Magnetic Pumping in Guiding Center Theory," (with J.A. Tataronis), ibid.

49. "Magnetohydrodynamic Stability of a Sharp boundary Model of a Tokamak," (with J.P. Freidberg), Phys. Fluids 18, 1494 (1975).

50. "Joule Heating of Theta Pinches," in Proceedings of the High Beta Workshop, Los Alamos, NM., July 1975, U.S. ERDA-76/108, 481.

51. "An Overview of Belt Pinch Plasma Research," ibid., 604.

52. "Stability of the Strongly Non-Circular High Beta Tokamak," (with J.A. Tataronis, H. Weitzner), in Proceedings of the Annual Project Sherwood Theoretical Meeting, Washington, D.C. April 1975.

53. "The Effect of Dissipation on Resonant Alfven Wave Absorption," (with J.A. Tataronis, J. Kappraff), ibid.

54. "Stability of High Beta Tokamaks with Arbitrary Elongated Cross Sections," (with J.A. Tataronis, H. Weitzner), in Proceedings of the 3rd Topical Conference on Pulsed High Beta Plasmas, Pergamon Press, 563, 1976.

55. "Alfven Wave Heating of Fusion Plasma," (with J. Kappraff, J.A. Tataronis), in Proceedings of the 7th European Conference on Controlled Fusion and Plasma Physics, Lausanne, Switzerland, September 1975.

56. "MHD Stability of the Doublet," (with J.A. Tataronis, H. Weitzner), Annual Meeting of the Division of Plasma Physics of the APS. (Bull. of Amer. Phys. Soc. 20 (10), 279, October 1975). (Abstract only.)

57. "Unsteady End-Loss From a Straight Theta Pinch," with H. Weitzner), ibid. 1358.

58. "Stability of a High Beta, 1 = 3 Stellarator," (with J.P. Freidberg), Phys. Fluids 19, 1599 (1976).

59. "On Alfven Wave Heating and Transit Time Magnetic Pumping in the Guiding Center Model of a Plasma," (with J.A. Tataronis), Nucl. Fusion 16, 667 (1976).

60. "Studies of Theta Pinch rf Heating Near Magnetoacoustic Frequencies," (with J. Choe, C.E. Seyler), Annual Meeting of the Division of Plasma Physics of the APS, San Francisco, CA., November 1976 (Bull. Am. Phys. Soc. 21 (9), 1109, October 1976). (Abstract only.)

61. "Effects of Current Density Profile on MHD Stability of High Beta Tokamak with Large Elongation," (with J.A. Tataronis), ibid.

62. "A Comparison of MHD and Guiding Center Plasma Models," (with J. Choe, J.A. Tataronis), Plasma Physics 19, 117 (1977).

63. "On Supplementary Heating of Fusion Plasmas by Means of Alfven Waves," (with J.A. Tataronis), New York University, Courant Institute Report MF-84, 1977.

64. "Magnetohydrodynamic Stability of Highly Elongated Axisymmetric Equilibria," (with J.A. Tataronis, H. Weitzner), Phys. Fluids 20, 239 (1977).

65. "Experimental and Theoretical Studies of Belt Pinches and High Beta Tokamaks," (with C.K. Chu, et al.) in Proceedings of the 6th Conference on Plasma Physics and Controlled Fusion Research, Berchtesgaden, Germany, 1976. IAEA-CN-35/E8, Vienna, 1977.

66. "End Loss Reduction in Linear Devices by Means of Oscillating Multiple Mirrors," (with M. Wakatani), Nagoya University, Institute of Plasma Physics Research Report IPRI-285, April 1977.

67. "Waves and Flows in Linear Theta Pinches," (with C.E. Seyler, H. Weitzner), in Proceedings of the 3rd International Conference on Waves and Instabilities in Plasmas, Paris, June 1977.

68. "Effect of Plasma Rotation and Hall Current on Linear Tearing Modes in Reverse Field Pinches," (with J. Kappraff, P. Rosenau), in Proceedings of the Annual Sherwood Theoretical Meeting, San Diego, CA., May 1977.

69. "Field Reversed Multiple Mirror End Stoppering of Linear Devices," (with C.E. Seyler, L. Steinhauer), Annual Meeting of the Division of Plasma Physics of the APS, Atlanta, GA., November 1977 (Bull. Am. Phys. Soc. 22 (9), 1189, October 1977). (Abstract only.)

70. "Plasma Confinement in the Field Reversed Multiple Mirror (FRMM)," (with L. Steinhauer, C.S. Seyler), Annual Meeting of the Division of Plasma Physics of the APS, Atlanta, GA., November 1977 (Bull. am. Phys. Soc. 22 (9), 1190, October 1977). (Abstract only.)

71. "Stability considerations of Field Reversed Multiple Mirrors (FRMM)," (with M. Kress, C. Seyler, L. Steinhauer), Annual Meeting of the Division of Plasma Physics of the APS, Atlanta, GA., November 1977 (Bull. Am. Phys. Soc. 22 (9), 1190, October 1977). (Abstract only.)

72. "On Tearing Modes in the Presence of Flow and Hall Current," (with J. Kappraff, P. Rosenau), Annual Meeting of the Division of Plasma Physics of the APS, Atlanta, GA., November 1977 (Bull. Am. Phys. Soc. 22 (9), 1190, October 1977). (Abstract only.)

73. "End Stoppering by the Reversed Field Multiple-Mirror Concept," (with C.S. Seyler, L.C. Steinhauer), in Comments on Modern Physics: Part E, March 1978.

74. "Stability Properties of an Anisotropic Guiding Center Plasma and Relation to Suydam Function," (with J. Choe, R.C. Davidson), in Proceedings of the Annual Sherwood Theoretical Meeting, San Diego, CA., May 1977.

75. "The Reversed-Field Multiple Mirror Fusion Concept," (with L.C. Steinhauer and C.S. Seyler), in Proceedings of the Fusion Technology Meeting, Santa Fe, NM, May 1978.

76. "Progress in Heating of Fusion Plasmas with Alfven Waves," (with J.A. Tataronis, et al.), in Proceedings of the 7th Conference on Plasma Physics and Controlled Fusion Research, (IAEA-CN 37Q-3), Innsbruck, Austria, August 1978.

77. "High-Beta MHD Theory," (with H. Grad, J.P. Freidberg, et al.), in Proceedings of the 7th Conference on Plasma Physics and Controlled Fusion Research, (IAEA-CN 37/L-3-1), Innsbruck, Austria, August 1978.

78. "High Order Methods for Nonlinear Time Dependent MHD," (with E. Turkel), in Proceedings of the Annual Sherwood Theoretical Meeting, Gatlinburg, TN., April 26-28, 1978.

79. "Macroscopic Transport Model for a Reversed Field Mirror Machine," (with H. Grad, D.C. Stevens, E. Turkel, S. Wollman), ibid.

80. "Numerical Simulation of Reversed Field Buildup in a Mirror Machine," (with D.C. Stevens, E. Turkel, S. Wollman, H. Grad), ibid.

81. "High Order Methods for Nonlinear Time Dependent MHD," (with E. Turkel), in Proceedings of the Numerical Computation and Plasma Simulation Conference, Monterey, CA., 1978.

82. "Stability of Topolotron to Global Kink Modes," (with J. Saltzman, J. Freidberg), Annual Meeting of the Division of Plasma Physics of the APS, Colorado Springs, CO., November 1978 (Bull. Am. Phys. Soc. 23 (7), 828, September 1978). (Abstract only.)

83. "Stability Investigations of the Imploding Linus Plasma," (with J. Kappraff, M. Kress), Annual Meeting of the Division of Plasma Physics of the APS, Colorado Springs, CO., November 1978 (Bull. Am. Phys. Soc. 23 (7), 823, September 1978). (Abstract only.)

84. "Stability of a Sharp Boundary Model of Spheromak," (with J.P. Freidberg), Annual Meeting of the Division of Plasma Physics of the APS, Colorado Springs, Co., November 1978 (Bull. Am. Phys. Soc. 23 (7), 872, September 1978). (Abstract only.)

85. "Reversed Field Mirror Simulations," (with D.C. Stevens, E. Turkel, S. Wollman, H. Grad), Annual Meeting of the Division of Plasma Physics of the APS, Colorado Springs, CO., November 1978 (Bull. Am. Phys. Soc. 23 (7), 842, September 1978). (Abstract only.)

86. "Adiabatic Compression of 3-D Plasma Magnetic Field Configuration," (with J. Saltzman), in the Proceedings of the 2nd International Conference on Megagauss Physics and Related Topics, held in Washington, D.C., May 30-June 1, 1979, Megagauss Physics and Technology, Plenum Press, New York 1980.

87. "Simulation of Adiabatic Compression in Reversed Field Plasmas," (with E. Hameiri), in Proceedings of the Annual Sherwood Theoretical Meeting, Mount Pocono, PA., April 1979.

88. "Adiabatic Compression of Rotating Reversed Field Plasmas," (with E. Hameiri, J. Saltzman), Annual Meeting of the Division of Plasma Physics of the APS, Boston, MA., November 1979 (Bull. Am. Phys. Soc. 24 (8), 955, October 1979). (Abstract only.)

89. "A 2-D Transport Code for the Reversed Field Theta Pinch," (with R.N. Byrne, J. Saltzman), Annual Meeting of the Division of Plasma Physics of the APS, Boston,

Massachusetts, November 1979 (Bull. Am. Phys. Soc. 24 (8), 1081, October 1979). (Abstract only.)

90. "Two-Dimensional Compression in General Compact Tori," (with E. Hameiri), in the Proceedings of the U.S.-Japan Joint Symposium on Compact Toruses and Energetic Particle Injection, Princeton University, Princeton, New Jersey, December 1979.

91. "Variational Formulation and Adiabatic Compression of Rotating Plasmas," (with E. Hameiri, D.C. Stevens), in Proceedings of the Annual Sherwood Theoretical Meetings, Tucson, Arizona, April 1980.

92. "Evolution of a Long Compact Torus," (with R.N. Byrne), in Proceedings of the Annual Sherwood Theoretical Meeting, Tucson, Arizona, April 1980.

93. "Formation and Evolution of Spheromak and General Compact Toroids," (with E. Hameiri, D.C. Stevens, J.L. Schwarzmeier, H. Weitzner, et al.) in the Proceedings of the IAEA 8th International Conference on Plasma Physics and Controlled Nuclear Fusion Research, (IAEA-CN-38/R-1), Brussels, Belgium, July 1980.

94. "Hall Current Effects on Tearing Modes in Rotating Reverse Field Plasmas," (with J. Kapproff, M. Kress), New York University, Courant Institute Report MF-96, March 1980.

95. "Adiabatic Compression of Rotating Plasmas," (with E. Hameiri, D.C. Stevens). Paper presented at the 9th Conference on Numerical Simulation of Plasmas, Evanston, Illinois, June 1980.

96. "Stability of Field Reversed Configurations," (with H. Weitzner), Annual Meeting of the Division of Plasma Physics of the APS, San Diego, CA., November 1980 (Bull. Am. Phys. Soc. 25 (8), 920, October 1980). (Abstract only.)

97. "Spheromak Scaling with Compression," (with S. Greenberg), Annual Meeting of the Division of Plasma Physics of the APS, San Diego, CA., November 1980). (Abstract only.)

98. "Two-Dimensional FRX Model," (with R.N. Byrne), Annual Meeting of the Division of Plasma Physics of the APS, San Diego, CA., November 1980 (Bull. Am. Phys. Soc. 25 (8), 1026, October 1980. (Abstract only.)

99. "The Moving-Ring Field-Reversed Mirror Prototype Reactor," (with A.C. Smith, Jr., G.A. Carlson, H.H. Fleischmann, T. Kammash, K.R. Schultz, and D.M. Woodall), in Proceedings of the 3rd Symposium on Physics and Technology of Compact Toroids in the Magnetic Fusion Energy Program, Los Alamos National Laboratory, Los Alamos, NM, December 1980.

100. "Two-D Transport Model for FRC Plasmas," (with R.N. Byrne), ibid.

101. "Hall Current Effects on Tearing Modes in Rotating Reverse Field Plasmas," (with J. Kappraff, M. Kress), J. Plasma Physics 25, part 1, 111-131, (1981).

102. "Physics of Burning Plasmas in Compact Toroids," (with R.N. Byrne), in the Proceedings of the Annual Sherwood Theoretical Meeting, Austin, Texas, April 1981.

103. "Stability Studies of Compact Toroids," (with E. Hameiri, H. Weitzner), ibid.

104. "Equilibrium Development Calculation for Compact Toroids with Compression and Diffusion," Invited paper 2D6-7 in the Proceedings of the 1981 IEEE International Conference on Plasma Science, May 18-20, 1981, Santa Fe, NM. (Abstract only.)

105. "D-D Tokamak Reactor Modelling," (with D.C. Baxter, et al.), in the Proceedings of the 1982 IEEE International Conference on Plasma Science, Paper 3B4, May 18-20, 1981, Sante Fe, New Mexico.

106. "The Moving-Ring Field Reversed Mirror Prototype Reactor," (with A.C. Smith, Jr., et al.), Paper 5P8, ibid.

107. "The Effect of Random Fluctuations on Shear Alfven Waves," Annual Meeting of Division of Plasma Physics, APS, New York City, October 1981 (Bull. Am. Phys. Soc. 26 (7), 914, September 1981). (Abstract only.)

108. "The Moving-Ring Field Reversed Reactor, Annual Report, 1979-1980," (with A.C. Smith Jr. et al.), Pacific Gas and Electric Company Report 81FUS-2, August 1981.

109. "Stochastic Fluctuations in Ideal MHD Plasmas," (with J. Teichmann), in Proceedings of 10th International Conference on Plasma Physics. Goteborg, Sweden, June 9-15, 1982.

110. "Magnetohydrodynamic and Double-Adiabatic Stability of Compact Toroid Plasmas," (with E. Hameiri, H. Weitzner), Phys. Fluids 26 (2), February 1983.

111. "Resonant Absorption at the Lower Hybrid Frequency," (with H. Weitzner), in Proceedings of the Annual Sherwood Theoretical Meeting, March 21-23, 1983, Arlington, Virginia.

112. "Computation of Field Reversed Theta Pinch Equilibrium," (with D.C. Stevens and E. Hameiri), ibid.

113. "Lower Hybrid Resonance Absorption," (with H. Weitzner and L. Ibanez), Annual Meeting of Division of Plasma Physics, APS, October 1983. (Abstract Only.)

114. "A Reformulation of Lower Hybrid Wave Propagation and Absorption," (with H. Weitzner), Phys. Fluids 27, 1966 (1984).

115. "Lower Hybrid Wave Propagation in a Stochastic Plasma Background," (with R. Spigler), Proceedings of the Annual Sherwood Theoretical Meeting, April 11-13, 1984, Lake Tahoe, Nevada.

116. "A Stochastic MHD Analysis of Tearing Modes," (with J. Teichmann), Proceedings of the International Conference on Plasma Physics, Ecole Polytechnique Frederal de Lausanne, Switzerland, June 27-July 3, 1984.

117. "Mathematical Problems in Wave Propagation and rf Heating of Plasma," Invited Lecture at the International Workshop on Mathematical Aspects of Fluid and Plasma Dynamics, University of Trieste, Trieste, Italy, May 30-June 2, Published in Proceedings of the Workshop.

118. "Lower Hybrid Wave Scattering by Random Density Fluctuations in Inhomogeneous Plasmas" (with Renato Spigler), Annual Meeting of the Division of Plasma Physics of the APS, Boston, Mass., November 1984. (Bull. Am. Phys. Soc. 29 (8), 1225, October 1984, Abstract only.)

119. "Linear Stability of Realistic RFP Plasma Equilibria" (with S. Ortolani and R. Paccagnella), ibid., 1357.

120. "The Dynamo Effect in RFP's" (with Eliezer Hameiri), ibid., 1357.

121. "Propagazione Ondosa alla Risonanaza Ibrida Inferiore, Attraverso uno Sfondo di Plasma Stocastico" (with Renato Spigler), LXX Cong. SIF, Ott. 1984, Genove (Lunedi-Sezione 6, 155).

122. "Adiabatic Compression and Interchange Stability of Rotating Compact Toroid Plasmas," Phys. Fluids 28 (2), February 1985 (with E. Hameiri and D.C. Stevens.)

123. "Lower Hybrid Wave Scattering by Random Density Fluctuations In Inhomogeneous Plasmas" (with Renato Spigler), in the Proceedings of the International conference on Stochasticity and turbulence in Plasmas, Paper B-1, March 26-29, 1985, University of California, Santa Barbara, Calif.

124. "A Stochastic Model for Lower Hybrid Wave Scattering by Density Fluctuations," Phys. Fluids 28 (6), Jun 1985, 1783 (with R. Spigler).

125. "Heating of Solar Coronal Loops by Resonant Absorption of Alfven Waves," Annual Meeting of Division of Plasma Physics, A.P.S., San Diego, Calif., Nov. 4-8, 1985. (Bull. Am. Phys. Soc., 30, (9), 1470, October 1985.) (Abstract only, with R.A. Smith.)

126. "Lower Hybrid Wave Propagation in Inhomogeneous Plasmas with Random Density Fluctuations," ibid (Bull. Am. Phys. Soc., 30, (9), 1562, October 1985). (Abstract only, with R. Spigler.)

127. "3-D Simulation of Lower Hybrid Wave Launching," Annual Meeting of Division of Plasma Physics, A.P.S., Baltimore, Maryland, 1986. (Bull. Am. Phys. Soc., 31, (9), 1422, October 1986) (Abstract only, with A. Drobot and L. Seftor.)

128. "Transmission and Reflection of Lower Hybrid Waves in Fluctuating Inhomogeneous Plasmas," ibid (Bull. Am. Phys. Soc., 31, (9), 1577, October 1986) (Abstract only, with R. Spigler.)

129. "Scattering di onde ibride inferiori da parte di fluttuazioni aleatorie di densita in plasmi disomogenei," S.I.F., LXXI Congresso Nationale Trieste, 3-8 October 1986 (Abstract only, with R. Spigler.)

130. "Conceptual Design of a Moving-Ring Reactor," Fusion Technology 9, 136, January 1986 (with A.C. Smith, et al.)

131. "Heating of Solar Coronal Loops by Resonant Absorption of Alfven Waves," Ap. J., 332, 1, part 1, September 1988.

132. "Thermal Catastrophe in the Plasma Sheet Boundary Layer," Geophys. Res. Lett. 13, 1380-1383 (1986) (with R.A. Smith, C.K. Goertz)

133. "3-D Modeling, Simulation, and Evaluation of ICRH Antennas," (with A. Drobot, K. Ko, A. Mankofsky, J. Tataronis) Proceedings of the U.S.-Japan Workshop on Plasma Modeling with MHD and Particle Modeling, Napa, CA, September 25-26, 1987.

134."Three Dimensional Studies of Lower Hybrid Wave Launching," (with A. Drobot, L. Seftor), proceedings of the Annual Sherwood Theory Conference, April 6-8, 1984, San Diego, CA.

135. "3-D Numerical Modeling of ICRF Antenna in Phaedrus-B" Proceeding of 30th Annual Meeting of the American Physical Society Division of Plasma Physics, Hollywood (Bull, Am. Phys. Soc., 33 (9), 1982, October 1988, abstract only) (K. Ko, A. Drobot, R. Majeski, T. Tanaka, N. Hershkowitz).

136. "Vacuum Field Measurements of ICRF Antenna Configurations," ibid, 1983 (with K. Ko. R. Majeski, T. Tanaka, T. Intrator, D. Roberts, N. Hershkowitz).

137. "Linear Stability of the Dense Z-Pinch," ibid, 1409 (with W. Ellis).

138. "Simulation of Dense Z-Pinch Plasmas," (with A. Mankofsky) Proceedings of the Annual Sherwood Theory Conference, April 3-5, 1989, San Antonio, TX.

139. "3-D Modeling, Simulation and Evaluation of ICRF Antennas," (with K. Ko, A. Drobot, R. Majeski, T. Tanaka, N. Hershkowitz) ibid.

140. "3-D Numerical Modeling of ICRF Antenna in Phaedrus-B," (with K. Ko, A. Drobot, R. Majeski, T. Tanaka, N. Hershkowitz) Proceedings of the 16th European Conference on Controlled Fusion and Plasma Physics, paper P4 F19, Venice, Italy, March 13-17, 1989.

141. "On the Relationship Between Neutron Yield and Plasma Current in the Dense Z-Pinch," (with W. Ellis) submitted to Physics of Fluids, June 1988.

142. "A Review of Propulsion Applications at the Pulsed Detonation Engine Concept," (with S. Eidelman, I. Lottati) paper AIAA 89-2446, presented at AIAA/ASME/SAE/ASEE 25th Joint Propulsion Conference, Monterey, CA, July 10-12, 1989, submitted to AIAA Journal.

KWOK CHUEN KO

San Jose State University: B.A. (1972)
University of Southern California: Ph.D. (1978)

Dr. Ko is a research physicist in the Plasma Physics Division at Science Applications International Corporation. His prior experience at the MIT RF theory and computation groups includes linear and nonlinear wave propagation in nonuniform media as well as radio-frequency heating of fusion plasmas. Since joining SAIC, he has carried out theoretical and numerical studies of a variety of problems. These range from nonlinear wave excitations in space plasmas with emphasis on parametric decays to microwave breakdown of air and to particle simulation of plasma erosion opening switches. Currently, he is involved in a design study for a 100MW gyroklystron by providing key numerical and theory support.

Curriculum Vitae

KWOK CHUEN KO

Science Applications International Corporation
1710 Goodridge Drive
McLean, Virginia 22102
(703) 734-4077

EDUCATION:

Ph.D., Electrical Engineering, University of Southern California, 1978
M.S., Electrical Engineering, University of Southern California, 1974
M.A., Physics, University of Southern California, 1974
B.S., Physics, San Jose State University, 1972

EXPERIENCE:

1981-Present Research Physicist, Science Applications International Corporation.

1978-1981 Postdoctoral Fellow, MIT.

1973-1978 Research Assistant, USC.

1972-1973 Teaching Assistant, USC.

PUBLICATIONS:

1. "Excitation and Linear Mode Conversion of Lower Hybrid Resonance Cones in an inhomogeneous Plasma," with H. Kuehl, *Phys. Fluids* **18**, 1816 (1976).

2. "Korteweg-de Vries Soliton in a Slowly Varying Medium," with H. Kuehl, *Phys. Rev. Lett* **40**, 233 (1978).

3. "Cylindrical and Spherical Korteweg-de Vries Solitary Waves," with H. Kuehl, *Phys. Fluids* **23**, 1343 (1979).

4. "Theory of Mode Conversion in Weakly Inhomogeneous Plasmas," with V. Fuchs and A. Bers, *Phys. Fluids* **24**, 1251 (1981).

5. "Nonlinear Coupling of Lower Hybrid Waves at the Edge of Tokamak Plasmas," with V. Krapchev, K. Theilhaber and A. Bers, *Phys. Rev. Lett.* **46**, 1398 (1981).

6. "Lower Hybrid Wave Absorption by Mode Conversion Near Ion Cyclotron Harmonics," with A. Bers and V. Fuchs, MIT Report PFC/RR-81-8.

7. "Nonlinear Steady-State Coupling of Lower Hybrid Waves," with V. Krapchev, MIT Report PFC/RR-81-9.

8. "The Coupling Approximation of Local Dispersion Relations," with V. Fuchs and A. Bers, MIT Report PFC/RR-81-10.

9. "ELF Communication by Electrojet Current Modulation," with C. Chang, V. Tripathi, K. Papadopoulos, J. Fedder, P. Palmadesso and S. Ossakow, SAI Report No. 82-550-WA.

10. "Review of Ionospheric VLF and ELF Generation," with K. Papadopoulos, A. Reiman and V. Tripathi, *Proceedings of International Symposium on Active Experiments in Space*, Alpbach, Austria (1983).

11. "Efficient Parametric Decay in Dissipative Media," with K. Papadopoulos and V. Tripathi, *Phys. Rev. Lett.* **51**, 463 (1983).

12. "Numerical Simulation of High Power R.F. Sources," with A. Drobot, L. Seftor, H. Hanerfeld and W. Herrmannsfeldt, *IEEE Transactions on Nuclear Science* NS-30, No. 4 (August 1983).

13. "Collective Plasma Effects on Beam Energy Injection from Rockets," with K. Papadopoulos, SAI Progress Report (1982).

14. "Mode Competition in the Gyro-Peniotron Oscillator," with P. Vitello, *IEEE Transactions on Plasma Science* PS-13, No. 6 (December 1985).

15. "ELF Generation in the Lower Ionosphere via Collisional Parametric Decay," *JGR* 91, A9 (1986).

CURRICULUM VITA
THE COLLEGE OF STATEN ISLAND

1. NAME: Michael E. Kress COLLEGE: College of Staten Island

2. RECOMMENDATION FOR: Reappointment

TITLE: Associate Professor DEPARTMENT: Computer Science

EFFECTIVE DATE: September 1, 1988 TERMINATION: August 31, 1989

SALARY: (Subject to financial ability)

3. HIGHER EDUCATION

A. Degrees

INSTITUTION	DATE ATTENDED	DEGREE	DATE CONFERRED
New York University Courant Institute of Mathematical Sciences	1/83-6/85	Ph.D. Computational Fluid Dynamics	6/85
New York University Courant Institute of Mathematical Sciences	9/80-1/83	M.S. Mathematics and Computer Sciences	1/83
Richmond College City University of New York	9/71-6/75	M.A. Environmental Science	6/75
Richmond College City University of New York	9/67-6/69	B.S. Mathematics with minors in Physics and Comp. Science	6/69
Staten Island Community College City University of New York	9/65-6/67	A.S. Mathematics	6/67

B. ADDITIONAL HIGHER EDUCATION

INSTITUTION	DATE ATTENDED	DEGREE	DATE CONFERRED
New York University Courant Institute of Mathematical Sciences	9/69-6/71	30 crs. towards M.S.	

C. PROFESSIONAL COURSES

1. "Ecological Modeling Using Microcomputers", Colorado State University, Ft. Collins CO, January 1988.

2. "Advanced Users Seminar for Multitasking on the Cray 2", Lawrence Livermore National Labratory, Livermore CA, January 1986.

3."Cray 1 Users Seminar", National Magnetic Energy Fusion Energy Computer Center, Lawrence Livermore National Labratory, Livermore CA, January 1979.

4. EXPERIENCE (OTHER THAN CUNY)

B.OTHER

INSTITUTION	DATES	TITLE & TYPE OF WORK	FT or PT
New York University Courant Institute of Mathematics	2/88-Pres.	Computational Phys. Research Consultant	PT
Aneutronic Lab. Inc. Princeton, NJ	11/87-2/88	Computational Phys. Research Consultant	PT
Science Applications International Inc. McLean, VA	6/87-7/87	Computational Phys. Research Consultant	FT
New York University Courant Institute of Mathematics	2/87-6/87	Research Associate Research Consultant Transonic Flow Project	PT
New York University Courant Institute of Mathematical Science	12/85-1/87	Research Associate Research Consultant Magneto Fluid Dynamics	PT
New York University Courant Institute of Mathematical Science	1981-8/85	Research Assistant Research, Magneto Fluid Dynamics (MFD)	FT
New York University Courant Institute of Mathematical Science	1978-1981	Research Associate Research, MFD	FT
Richmond College City University of New York	1968-1969	Research Assistant, Coord. Computer Center ,Pure and Applied Science	PT

5. ACADEMIC AND PROFESSIONAL HONORS

1. PSC-CUNY Research Grant 1988-89, Nonlinear Phase Magneto-tail Reconnection ($5,000 for student support).

2. Research Grant, PIC Simulation of Migma-Plasma, U.S. Air Force 2/1988 ($65,000 for 9 months).

3. Research Grant of Cray Supercomputer Resources from Department of Energy 1988 (52 hours for 1 year).

4. Research Rlease Time Grant, College of Staten Island 1987.

5. Dean's Award College of Staten Island, March, 1986.

6. NASA fellowship 6/83-9/83 and 6/84-9/84.

7. Achievement Award Civic Congress Of Staten Island, 1975.

8. Richmond College, B.S. Cum Laude, Dean's List 1968, 1969.

9. Staten Island Community College, Dean's List 1967.

6. REFEREED PUBLICATIONS

B. REFEREED ARTICLES

1. "Semi-Implicit Reduced Magnetohydrodynamics", Journal of Computational Physics, accepted for publication July 1988, Academic Press Inc., (with Riedel).

2. "Plasma Transport by Relaxation of Localized Perturbations", The Physics of Fluids Vol. 31 no. 8 , August 1988, American Institute of Physics, (with. Blank et al.) pp 2165-2170.

3. "An Accelerated Iterative Method for Simulating Plasma Diffusion", Journal of Computational Physics, Vol. 76, May 1988, Academic Press Inc., pp 201-237.

4. "Anomalous Transport and the Coupling of Plasma Diffusion", Physical Review Letters, February 1987, Am. Phys. Soc. (with M. Hossain et al.), pp 487-490.

5. "Simulation of Boltzmann Process: An Energy Space Model", Am. J. Phys. 50 (2) February 1982, American Association of Physics Teachers, pp 120-124.

6. "Hall Current Effects on Tearing Modes in Rotating Reverse Field Plasma", J. Plasma Physics, Vol. 25, Part 1, 1981, Cambridge University Press, pp. 111-131.

C. REFEREED PROCEEDINGS

1. "L.N.G. Transportation, Storage, Relative Risks and Alternatives", in Proceedings of Staten Island Institute Arts and Science, Vol. 28 (11) Fall 1984, S.I. Institute of Arts and Sciences, pp. 48-54.

6.5 PUBLICATIONS IN PROGRESS

1. "The Factor of Efficiency in the Use of Energy Resources", Teachers Of Science and Mathematics (submitted 9/87) (with J. Fishman).

2. "Marine Ecosystem Simulation of New York Harbor and The Bight, Center for Environmental Studies, CSI (with J. Oppenheimer and W. Silvert).

3. "Random Digit Dialing for Control Selection in an Urban Epiedemiologica. Survey", Saten Island Air Pollution and Respiratory Disease Study, (with D. Gerstle and J. Oppenheimner).

4. "Particle Simulation of Migma Reactor", (with Alfred Levine)

5. Helical Coil Driven Saw Teeth in a Tokamak", (with K. Riedel).

7. OTHER PUBLICATIONS:

A. NON-REFEREED ARTICLES, BOOKS, & PROCEEDINGS

1. "Modeling with the Technology of Supercomputers and Global Models Using Micro-Computers in Secondary Schools", Proceedings of The Global Futures Forum II Technology and Global Development, College of Staten Island, 1988, (with G. Lee).

2. "Start-Up 128", Ahoy! No. 31 May 1987, Ion International Inc.(with M. DeVilla and P. Maoriello).

3. "Customized Operating Systems",Ahoy! No. 28 April 1986, Ion International Inc., pp. 71-72.(with M. Devilla and P. Maoriello).

4. "Liquified Natural Gas, A Potential For An Abundant Energy Supply Or A Potential For Danger", monograph, (Joseph Fishman) Mathematics Eduction Trust of The National Council Of Teachers Of Mathematics, May 1986.(Contributed section.)

8. OTHER PROFESSIONAL ACTIVITIES:

A. Technical Reports

1. Research Grant, "PIC Simulation of Migma- Plasma", US Air Force, submitted 12/87.

2. Research Grant, "Plasma Simulations", DOE 1/88 for Supercomputer Resources for CSI.

3. Research Grant Proposal " Nonlinear Phase of Magnetotail Reconnection", submitted to PSC-CUNY 1987.

4. Research Grant Proposal "Applications of 3D Alternating Dimension Plasma Simulation", submitted to Department of Energy ($115,380), July 1987.

5. Research Grant Proposal "Numerical Simulation of Non-Linear Phase of Magnetotail Reconnection", submitted to Office of Naval Research ($150,000), March 1987.

6. Research Grant Proposal "Numerical Simulation of Non-Linear Phase of Magnetotail Reconnection", submitted to Office of Naval Research ($192,950), December 1985.

7. "Optimal Iterative Methods for Simulating Plasma Reconnection", NYU Courant Institute, Ph.D. Thesis, 1985 (with H. Grad).

8. "Hall Current Effects on Tearing Modes In Rotating Reverse Field Plasma", M-96, Courant Institute Report, NYU, March 1980.

9. "The Dynamic Speed-Density Relation for Vehicular Traffic", at Richmond College, CUNY, 1975 (with A. Levine and L. Winkler), Masters Thesis.

C. CONSULTANCIES

1. Science Applications Incorporated Company, Dr. William Grossman, (August 1988 to present).

2. Courant Institute, N.Y.U., Dr. Kurt Riedel, (Feb. 1988 to present).

3. Aeneutronic Labratories Inc., Princeton, NJ, Dr. B. Maglich (Nov 1987 to Feb. 1988).

4. Science Applications International Inc., McLean VA , Dr. Adam Drobot (June 1987 and July 1987)

5. The Staten Island Air Pollution and Respiratory Disease Study, College of Staten Island, Environmental Science Department, (October 1986 to Present).

6. Courant Institute, N.Y.U., Paul Garabedian, (February 1987 to June 1987).

7. Magneto Fluid Dynamics Division, N.Y.U. , Harold Grad, (December 1985 to January 1987).

8. Civic Congress of Staten Island, Liquified Natural Risk Analysis, Charles Burger, (September 1973 to January January 1976).

9. BLAST, Staten Island, Liquified Natural Gas Atmospheric Transport and Risk Analysis Report at FPC Hearings on Rossville, S.I. Facility (1973 to 1976).

D. PAPERS PRESENTED

1. "Particle Simulation of Migma-Plasma", Technical Review of Feasibility of Aneutronic Power Sources, AE Lab., Pricneton NJ, August 1988, (with A. Levine).

2. "Helical Coil Driven Sawteeth", The Proceedings of the Annual Sherwood Theorectical Meeting, Gatlinburg, Tenn. April 1988, (with K. Riedel).

3. "Relating Resistive and Adiabatic Alternating Dimension Codes, The Proceedings of the Annual Sherwood Theorectical Meeting, Gatlinburg, Tenn. April 1988, (with A. Blank).

4. "Fokker-Planck Simulation of Migma Reactor", The Proceedings of the Annual Sherwood Theorectical Meeting, Gatlinburg, Tenn. April 1988, (with C. Powell).

5. "Simulation of Migma-Plasma", Technical Review of Feasibility of Aneutronic Power Sources, AE Lab., Pricneton NJ, Nov. 1987, (with C. Powell).

6. "Adiabatic and Resistive Reconnection", Annual Meeting of DDP of the APS, November, 1987 (Bull Am. Ph. Soc. 32(9), San Diego, CL, 1987)

7. "Relaxation of an Ablated Pellet Cloud Using the Grad Transport Model", The Proceedings of the Annual Sherwood Theorectical Meeting, San Diego, Calf. April 1987.

8. "Reconnection in the Adiabatic Limit", The Proceedings the Annual Sherwood Theorectical Meeting, San Diego, Calf. April 1987.

9. "Scattering of Lower Hybrid Waves in Two Dimensions", The Proceedings of the Annual Sherwood Theorectical Meeting, San Diego, Calf. April 1987.

10. "Utilization of Multitasking for Accelerated Iterarative Simulation Techniques", Los Alamos National Labratory, Los Alamos, N.M., January 1987.

11. "Relaxation Times for Localized Perturbations in Tokamak Plasma", Annual Meeting of DPP of the APS, Baltimore, Nov. 1986.(Bull. Am. Phys. Soc. 31(9),1986.)

12. "The Effects of 3-D Geometry on Plasma Transport in Tokmak Plasma", Annual Meeting of DPP of the APS, Baltimore, Nov. 1986.(Bull. Am. Phys. Soc. 31(9),1986.)

13 "Environmental Modeling Using the Technology of Super Computers and World Modeling Using Micro-Computers", Global Futures Forum II, College of Staten Island, October 1986.

14. "3D Alternating Dimension Energy Dissipation Simulation in Tokamak", in the Proceedings of the Annual Sherwood Theoretical Meeting, New York, N.Y., April 1986 (with Harold Grad).

15. "3D Transport Simulation II: Applications", in the Proceedings of The Annual Sherwood Theoretical Meeting, New York, N. Y., April 1986 (with H. Grad, M. Hossain and A. Bayliss).

16. "Advanced User Seminar for Multitasking on the Cray 2", National Magnetic Fusion Energy Computer Center, Lawrence Livermore Laboratories, January 1986.

17. "Accelerated Iterative Solutions to Mixed Partial Differential Equations", Invited speaker Naval Research Laboratory, Washington, D.C., Nov. 1, 1985.

18. "Magnetic Reconnection of a Resistive Plasma in the Adiabetic Limit", in the Proceedings of the Annual Sherwood Theoretical Meeting, Madison, Wisconsin, April 15, 1985.

19. "Magnetic Reconnection in a Resistive Plasma in the Adiabetic Limit", Magneto Fluid Dynamics Division Seminar at Courant Institute, NYU, March 6, 1985.

20. "Optimal 1 1/2 D Algorithms for Simulating a Resistive Doublet in the Adiabetic Limit", Annual Meeting of the Division of Plasma Physics of the APS, Boston, Massachusetts, November, 1984. (Bull. Am. Phys. Soc. 29 (8), October, 1984) (with H. Grad.)

21. "Adiabatic Limits in An Oscillating Doublet Continued with Special Emphasis on Numerical Solution of Generalized Differential Equation Using Optimized Backing Techniques", in the Proceedings of the Annual Sherwood Theoretical Meeting, Lake Tahoe, Nevada, April 1984, (with H. Grad).

22. "Optimal Iterative Back Average Algorithms for Solving Generalized Differential Equations", Numerical Analysis Seminar, Courant Institute, NYU, Feb. 15, 1984. - Presentation.

23. "Adiabatic Limits in An Oscillating Doublet", Annual Meeting of the Division of Plasma Physics of the APS, Los Angeles, California, Nov., 1983 (Bull Am., Phys. 28 (8) October 1983 (with H. Grad). - Paper Presentation

24. "Low Frequency Heating of a Resistive Doublet, Continued", in the Proceedings of Annual Sherwood Theoretical Meeting, Arlington, Virginia, March 1983, (with H. Grad). - Paper Presentation

25. "Ohmic Heating of a Resistive Doublet", Annual Meeting of the Division of Plasma Physics of the APS, New Orleans, Louisiana, November, 1982. (Bull. Am. Phys. Soc. 27 (8), October, 1982 (with H. Grad). - Paper Presentation

ERIC J. HOROWITZ

Yeshiva University, New York City: B.A. (1982)
University of California at Davis: M.S. (1984)
University of California at Davis: Ph.D. (1987)

Dr. Horowitz is a theoretical physicist with experience in magnetically confined plasmas and charged particle beams. In particular, he has done large-scale computational modeling of plasma and beam systems characterized by non-linear partial differential equations with disperate spacial and temporal scales. These systems required developing new algorithms which effectively used the most modern and powerful computers available.

At Science Applications International Corporation, Dr. Horowitz is currently working on simulating the neutralization and propagation of particle beams propagating in vacuum and through plasmas.

Before joining SAIC, Dr. Horowitz was a computational physicist at the National Magnetic Fusion Energy Computer Center from 1982 to 1987 where he worked on the global stability of field-reversed configuration magnetic confinement devices.

Dr. Horowitz is the author of numerous articles in scientific journals.

Curriculum Vitae

ERIC JACK HOROWITZ

Science Applications International Corporation
1710 Goodridge Drive
McLean, VA 22102
(703) 734-4090

EDUCATION:

B.A., Physics, Yeshiva College, Yeshiva University, 1982
M.S., Engineering/Applied Science, University of California, Davis and Livermore, 1984
Ph.D., College of Engineering, University of California, Davis and Livermore, 1987

EXPERIENCE:

1987-Present Computational Physicist with Science Applications International Corporation, Plasma Technology Division. Simulating particle beam neutralization processes and propagation.

1987-Present Computational Physicist with the Charged Particle Beam Group at the Laboratory for Plasma Research at the University of Maryland. Simulating high brightness charged particle beam production and propagation.

1982-1987 Computational Physicist, Lawrence Livermore National Laboratory, National Magnetic Fusion Energy Computer Center (NMFECC). Thesis research in the area of computational physics involving code development and application to problems related to magnetically confined plasmas. Extensive experience using the Cray Time Sharing System (CTSS).

Summer 1981 Quality Assurance Engineer, Litton Industries, Control Data and Guidance Division. Collected and analyzed data on failure rates of guidance systems subjected to environmental stress.

Summer 1980 Quality Assurance Engineer, Litton Industries, Data Systems Division. Verified and recorded diagnostic tests for an integrated computer-controlled communications systems.

Summer 1979 Environmental Test Technician, Litton Industries, Data Systems Division. Tested durability of various electronic components to inertial shock, temperature shock and vibration. Also tested computer guidance systems for susceptibility to and emission of electromagnetic radiation.

INVITED TALKS:

1. "QN3D: A PIC Code for the CRAY-2," E.J. Horowitz, *12th Conference on the Numerical Simulation of Plasmas*, San Francisco, CA (September 1987).
2. "Optimization Techniques for Particle Codes on the CRAY-2," E.J. Horowitz, *NMFECC Intermediate to Advanced Users Class*, Lawrence Livermore National Laboratory (January 29, 1986).
3. "Vectorization and Multitasking," E.J. Horowitz, *U.S. D.O.E. Supercomputer Honors Program*, Lawrence Livermore National Laboratory (August 13, 1986).
4. "Development of a 3-D Electromagnetic Plasma Particle Simulation Code that is Fully Parallelized for the Cray-2," E.J. Horowitz and D.V. Anderson, *Plasma Simulation Seminar*, University of California at Berkeley (1985).
5. "Computer Models for Kinetic Equations of Magnetically Confined Plasmas," J. Killeen, G.D. Kerbel, M.G. McCoy, A.A. Mirin, E.J. Horowitz, and D.E. Shumaker, *1987 International Conference on Plasma Physics*, Kiev, USSR (1987).
6. "Solving Laplace's Equations on the Computer," D.E. Shumaker, E.J. Horowitz, and D.V. Anderson, *U.S. D.O.E. Supercomputer Honors Program*, Lawrence Livermore National Laboratory (June 23, 1987).

PUBLICATIONS:

1. "Parallel Computing and Multitasking," D.V. Anderson, E.J. Horowitz, A.E. Koniges, and M.G. McCoy, *Computer Phys. Commun.* **43**, 69 (1986).
2. "Comparison of a Particle Code Run on the Cray X-MP and the Cray-2," E.J. Horowitz, *NMFECC Buffer* **9**, 9, 1 (1985).
3. "Particle Codes and the Cray-2," E.J. Horowitz, *Supercomputer* **16**, 30 (1986).
4. "Vectorizing the Interpolation Routines of Particle-in-Cell Codes," E.J. Horowitz, *J. Comp. Phys.* **68**, 56 (1987).
5. "Computer Models for Kinetic Equations of Magnetically Confined Plasmas," J. Killeen, G.D. Kerbel, M.G. McCoy, A.A. Mirin, E.J. Horowitz, and D.E. Shumaker, *1987 International Conference on Plasma Physics*, Kiev, USSR (1987).
6. "QN3D: A Three-Dimensional Quasi-Neutral Hybrid Particle-in-Cell Code with Applications to the Tilt Mode Instability in Field Reversed Configurations," E.J. Horowitz, D.E. Shumaker, and D.V. Anderson, *J. Comp. Phys.*, in press.
7. "Approach of a Gas Focusing System to Steady State," E.J. Horowitz, D. Chernin, and M. Reiser, *Phys. Fluids*, in press.

PAPERS PRESENTED:

1. "A Fully Implicit Solver for 3-D Particle Simulation Codes," D.V. Anderson, E.J. Horowitz, A.E. Koniges, and D.E. Shumaker, *Sherwood Theory Conference* **2C-18**, New York (1986).

2. "Solution of Vector Field Equations by Pre-Conditioned Conjugate Gradient Methods on Three-Dimensional Domains," D.V. Anderson, E.J. Horowitz, A.E. Koniges, and D.E. Shumaker, *Bull. Am. Phys. Soc.* **30** (1985).

3. "Fully Implicit Solutions of Maxwell's Equations in Three Dimensions by Preconditioned Conjugate Gradient Methods with an Application to Reversed Field Configurations," D.V. Anderson, E.J. Horowitz, A.E. Koniges, and D.E. Shumaker, *Proc. 13th European Conference on Controlled Fusion and Plasma Heating*, Schliersee, FRG (April 1986).

4. "A Fully Vectorized 3-D Particle Code for the Cray-2 Multiprocessor," E.J. Horowitz, D.V. Anderson, and D.E. Shumaker, *Bull. Am. Phys. Soc.* **30** (1985).

5. "Fokker-Planck Studies of a DD Tandem Mirror Reactor," E.J. Horowitz, A.A. Mirin, G.W. Shuy, and D. Dobrott, *UCRL-89556*.

6. "Modelling the Rigid Rotor Problem with a 3-Dimensional Particle-in-Cell Code," E.J. Horowitz and D.E. Shumaker, *Bull. Am. Phys. Soc.* **31** (1986).

7. "Normal Mode Simulation as a Test for a 3-Dimensional Particle-in-Cell Code," E.J. Horowitz and D.E. Shumaker, *Sherwood Theory Conference* **2C-19** (1986).

8. "A 3-D PIC Code to Model the Tilt Mode in FRCs," E.J. Horowtiz and D.E. Shumaker, *Sherwood Theory Conference* (1987).

9. "A 3-D Hybrid PIC Code to Model the Tilt Mode in FRCs," E.J. Horowitz and D.E. Shumaker, *8th Compact Torid Symposium*, College Park, MD (1987).

10. "Low-Energy Transport of High-Brightness H-Beams," M. Reiser, C.R. Chang, D. Chernin and E. Horowitz, *Symposium on Innovative Science and Technology*, Los Angeles, CA (1988).

11. "Simulation of the Tilt Mode in the FRC," D.E. Shumaker, A.A. Mirin, and E.J. Horowitz, *Bull. Am. Phys. Soc.* **32** (1987).

ALAN MANKOFSKY

New York University: B.A. (1976)
Cornell University: M.S. (1979)
Cornell University: Ph.D. (1982)

Dr. Mankofsky is a computational plasma physicist with in-depth experience in the numerical modeling of various plasma and beam-plasma configurations and electromagnetic devices. His background also includes theoretical work and close collaboration with experimentalists. He is currently involved in the design, development, and application of multidimensional numerical simulations in the areas of particle beam and microwave propagation, plasma dynamics, diode and device physics, laser isotope separation, accelerator design, and space plasmas. He is also a member of various corporate and governmental committees and working groups involved in long-range strategic planning for scientific computer facilities and data communications networks.

Prior to joining SAIC's Plasma Technology Division, Dr. Mankofsky was a Graduate Research Assistant in the Laboratory of Plasma Studies at Cornell University, where he specialized in the development of large-scale plasma simulation codes under the direction of Professors R.N. Sudan and J. Denavit. His work at Cornell included multidimensional particle and hybrid models as applied to several problems in both magnetic and inertial confinement fusion. In 1975, he was employed by A-Division, Lawrence Livermore National Laboratory, where he participated in the development of multidimensional MHD simulation models.

Dr. Mankofsky is an author or co-author of numerous publications, reports, and presentations in the area of numerical simulation of plasmas, intense particle beams and rings, and electromagnetic devices. He is a member of Phi Beta Kappa, Sigma Pi Sigma, Pi Mu Epsilon, the Society for Industrial and Applied Mathematics, and the Divisions of Plasma Physics and Fluid Dynamics of the American Physical Society.

Curriculum Vitae

ALAN MANKOFSKY

Science Applications International Corporation
1710 Goodridge Drive
McLean, Virginia 22102
(703) 734-5596

EDUCATION:

B.A., Physics, *summa cum laude*, New York University, 1976
M.S., Applied Physics, Cornell University, 1979
Ph.D., Applied Physics, Cornell University, 1982

Thesis: "Numerical Simulation of Ion Rings and Ion Beam Propagation"

PROFESSIONAL EXPERIENCE:

1982-Present Senior Scientist/Computational Physicist, Plasma Technology Division, Science Applications International Corporation, McLean, VA. Conducting numerical and theoretical investigations into various problems of current interest in plasma physics and electromagnetics, including particle beam and microwave propagation, plasma dynamics, diode and device physics, laser isotope separation, accelerator design, and space plasmas. Co-author of the ARGUS simulation code. Also participating in corporate and governmental long-range planning activities for scientific computing facilities and data communications networks.

1976-1982 Graduate Research Assistant, Laboratory of Plasma Studies, Cornell University, Ithaca, NY. Responsible for development of the RINGA particle code and the CIDER hybrid code; applied these codes to various problems in magnetic and inertial confinement fusion (R.N. Sudan, thesis advisor; J. Denavit, thesis consultant). Also managed computer facilities for the Laboratory.

1975-1976 Computer System Manager, Physics Department, New York University, New York, NY. Responsible for management, operation and maintenance of HP-3000 computer system.

1975 Computational Plasma Physicist, A-Division, Lawrence Livermore National Laboratory, Livermore, CA. Development of new physics routines and packages for the multidimensional MHD code ANIMAL.

PROFESSIONAL ORGANIZATIONS:

Division of Plasma Physics, American Physical Society

Division of Fluid Dynamics, American Physical Society

Society for Industrial and Applied Mathematics

HONORS AND AWARDS:

New York University Dean's List (1972-1976)
National Merit Scholar (1972-1976)
New York State Regents Scholar (1972-1976)
New York University Brown Scholar's Award in Physics (1975)
New York University Founder's Day Award (1976)
Phi Beta Kappa (1976)
Sigma Pi Sigma (1976)
Pi Mu Epsilon (1976)

PUBLICATIONS AND PRESENTATIONS:

1. "Numerical Simulation of Strong Ion Rings: Injection and Trapping, and Equilibrium with Confined Plasma," with R.N. Sudan and A. Friedman, *Bull. Am. Phys. Soc.* **22**, 1069 (1977).

2. "Cornell Intense Ion Beam Program," with P.L. Dreike, C.B. Eichenberger, A. Friedman, M.A. Greenspan, D.A. Hammer, S. Humphries, R.V.E. Lovelace, J.E. Maenchen, E. Ott, R.N. Sudan, and L.G. Wiley, *Proc. 2nd Intl. Topical Conf. on High Power Electron and Ion Beam Research and Technology*, Ithaca, NY (1977).

3. "Numerical Study of Strong Ion Ring Trapping Efficiency," with A. Freidman and R.N. Sudan, *Proc. Sherwood Theory Conf.*, Gatlinburg, TN (1978).

4. "Ion Ring Simulation Using a Generalization of the RINGA Code," with A. Friedman, R.N. Sudan, and J. Denavit, *Proc. 8th Conf. on Numerical Simulation of Plasmas*, Monterey, CA (1978).

5. "Ion Ring Simulation Including Confined Plasma and Toroidal Field," with R.N. Sudan and J. Denavit, *Bull. Am. Phys. Soc.* **23**, 842 (1978).

6. "Injection and Trapping of Ion Rings," with P.L. Dreike, A. Friedman, M. Greenspan, D.A. Hammer, S. Humphries, Jr., and R.N. Sudan, *Proc. 7th Intl. Conf. on Plasma Phys. and Controlled Nuc. Fus. Res.*, Innsbruck, Austria (1978).

7. "The RINGA Code (and offspring)," *Proc. Computational Mirror Workshop*, Lawrence Livermore National Laboratory, Livermore, CA (1979).

8. "Numerical Simulation of Plasma Confinement and Heating by Field Reversed Ion Rings," with R.N. Sudan and J. Denavit, *Proc. Sherwood Theory Conf.*, Mt. Pocono, PA (1979).

9. "Equilibria and Interchange Stability on Ion Ring - Plasma Systems Using the RINGA Code," with R.N. Sudan and J. Denavit, *Bull. Am. Phys. Soc.* **24**, 955 (1979).

10. "Interchange Stability of Plasma Confined by Field-Reversed Ion Rings," with L. Sparks, R.N. Sudan, and J. Denavit, *Proc. Sherwood Theory Conf.*, Tucson, AZ (1980).

11. "The Evolution of RINGA from Particle to Hybrid Code," with R.N. Sudan and J. Denavit, *Proc. 9th Conf. on Numerical Simulation of Plasmas*, Evanston, IL (1980).

12. "Hybrid Simulation of Ion Beams and Rings," with R.N. Sudan and J. Denavit, *Bull. Am. Phys. Soc.* **25**, 1009 (1980).

13. "Reflection of Long-Pulse Diamagnetic Proton Layers in a Ramped Magnetic Field," with J. Greenly, D.A. Hammer, P.M. Lyster, H. Sheldon, and R.N. Sudan, *Bull. Am. Phys. Soc.* **25**, 1008 (1980).

14. "Ballooning and Interchange Stability of an Ion Ring Confined Plasma," with L. Sparks, R.N. Sudan, J. Denavit, and J.M. Finn, *Bull. Am. Phys. Soc.* **25**, 953 (1980).

15. "Hybrid Simulation of Ion Beams and Rings in Background Plasma," with R.N. Sudan and J. Denavit, *Proc. Sherwood Theory Conf.*, Austin, TX (1981).

16. "Numerical Simulation of Injection and Resistive Trapping of Ion Rings," with A. Friedman and R.N. Sudan, *Plasma Physics* **23**, 521 (1981).

17. "Applications of Intense Pulsed Ion Beams to Magnetically Confined Fusion," with K.O. Busby, P.L. Dreike, J.B. Greenly, D.A. Hammer, B.R. Kusse, P.M. Lyster, Y. Nakagawa, and R.N. Sudan, *Proc. 4th Intl. Topical Conf. on High Power Electron and Ion Beam Research and Technology*, Palaiseau, France (1981).

18. "Hybrid Simulation of Ion Beams and Rings," with R.N. Sudan and J. Denavit, *Bull. Am. Phys. Soc.* **26** 1014 (1981).

19. "Research Progress in Intense Ion Beam Production for Inertial Confinement Fusion at Cornell University," with H. Bluhm, J. Greenly, D. Hammer, B. Kusse, J. Maenchen, J. Neri, R. Pal, T. Renk, G. Rondeau, and R.N. Sudan, *Proc. 9th Intl. Conf. on Plasma Phys. and Controlled Nuc. Fus. Res.*, Baltimore, MD (1982).

20. "Hybrid Simulation of Ion Beam Transport in Plasma Channels," with R.N. Sudan and J. Denavit, *Bull. Am. Phys. Soc.* **27**, 1008 (1982).

21. "Hybrid Simulation of Ion Beams," *Proc. 10th Conf. on Numerical Simulation of Plasmas*, San Diego, CA (1983).

22. "Hybrid Simulation of Field Reversed Systems," with P.M. Lyster and R.N. Sudan, *Proc. Sherwood Theory Conf.*, Arlington, VA (1983).

23. "Numerical Simulation of Charged Particle Beams," with L. Seftor and A.T. Drobot, *Proc. 5th Intl. Conf. on High-Power Particle Beams*, San Francisco, CA (1983).

24. "Progress in Intense Ion Beam Research for Inertial Confinement Fusion at Cornell University," with D.A. Hammer, B.R. Kusse, J. Maenchen, J. Neri, T.J. Renk, and R.N. Sudan, *Proc. 5th Intl. Conf. on High-Power Particle Beams*, San Francisco, CA (1983).

25. "ARGUS – A General Three-Dimensional Plasma Simulation Model," with L. Seftor, A.A. Mondelli, and A.T. Drobot, *Bull. Am. Phys. Soc.* **28**, 1124 (1983).

26. "ARGUS: A Three-Dimensional Plasma Simulation Model," with L. Seftor, C.L. Chang, A.A. Mondelli, and A.T. Drobot, *Proc. IEEE Intl. Conf. on Plasma Science*, St. Louis, MO (1984).

27. "Numerical Simulation of Ion Beam Propagation in Z-Pinch Plasma Channels," with R.N. Sudan, *Nucl. Fusion* **24**, 827 (1984).

28. "ARGUS – A Three-Dimensional Plasma Simulation Model", with L. Seftor, C.L. Chang, A.A. Mondelli, and A.T. Drobot, *Bull. Am. Phys. Soc.* **29**, 1209 (1984).

29. "Simulation of the Injection of a Cold Dense Ion Beam in a Hot Magnetized Plasma," with A.T.Y. Lui, C.C. Goodrich, and K Papadopoulos, *Proc. 2nd Intl. School for Space Simulation*, Kapaa, Kauai, Hawaii (1985).

30. "Early Time Interaction of Lithium Ions with the Solar Wind in the AMPTE Mission," with A.T.Y. Lui, C.C. Goodrich, and K. Papadopoulos, *Proc. Spring 1985 AGU Meeting*, Baltimore, MD (1985).

31. "ARGUS: A Three-Dimensional Hybrid Simulation Model," with J.L. Seftor, C.L. Chang, A.A. Mondelli, and A.T. Drobot, *Proc. 11th Intl. Conf. on Numerical Simulation of Plasmas*, Montreal, Quebec, Canada (1985).

32. "Cold-Testing of Microwave Structures Using the ARGUS Hybrid Simulation Code," with J.L. Seftor, A.T. Drobot, and A.A. Mondelli, *Proc. 11th Intl. Conf. on Numerical Simulation of Plasmas*, Montreal, Quebec, Canada (1985).

33. "Numerical Simulation of AMPTE Ion Releases in the Solar Wind," with C.C. Goodrich, K. Papadopoulos, and A.T.Y. Lui, *Proc. IAGA Conf.*, Prague, Czechoslovakia (1985).

34. "Broadband Electrostatic Noise and Ion Beam Dynamics in the Magnetotail," with A.T.Y. Lui, H.L. Rowland, and K. Papadopoulos, *Proc. AGU Chapman Conf. on Magnetotail Physics*, Laurel, MD (1985).

35. "Numerical Simulation of Particle Releases in the Magnetosphere," with C.C. Goodrich, A.T.Y. Lui, and K. Papadopoulos, *Bull. Am. Phys. Soc.* **30**, 1468 (1985).

36. "Microwave Structure Design - An Application of ARGUS," with A.T. Drobot and L. Seftor, *Bull. Am. Phys. Soc.* **30**, 1463 (1985).

37. "Three-Dimensional PIC Simulations Using ARGUS," with J.L. Seftor, A.T. Drobot, and J. Moura, *Bull. Am. Phys. Soc.* **30**, 1565 (1985).

38. "Numerical Simulation of High Power Microwave Sources," with A.T. Drobot, C.L. Chang, K. Ko, A. Mondelli, L. Seftor, and P. Vitello, *IEEE Trans. Nucl. Sci.* **NS-32**, 2733 (1985).

39. "Wave Phenomena During Artificial Gas Releases in the Magnetosphere," with A.T. Drobot, L. Linson, K. Papadopoulos, and A.T.Y. Lui, *Proc. Natl. Radio Science Meeting*, Boulder, CO (1986).

40. "Modeling of Ion Cloud Expansion in Space," with A.T.Y. Lui, R.A. Smith, A.T. Drobot, L. Linson, K. Papadopoulos, and C.C. Goodrich, *Proc. Natl. Radio Science Meeting*, Boulder, CO (1986).

41. "Early Time Interaction of Lithium Ions with the Solar Wind in the AMPTE Mission," with A.T.Y. Lui, C.C. Goodrich, and K. Papadopoulos, *J. Geophys. Res.* **92**, 1333 (1986).

42. "Realistic Modeling of Physical Devices using Supercomputers," *Proc. Virginia Center for Innovative Technology Invitational Forum on the Supercomputing Decision for Cost-Effective Scientific Computation*, Herndon, VA (1986).

43. "Hybrid Simulations of the AMPTE Lithium Release in the Solar Wind," with C.C. Goodrich and A.T.Y. Lui, *Proc. Fall 1986 AGU Meeting*, San Francisco, CA (1986).

44. "Space Charge Effects on Heavy Ion Beam Transport with Quadrupole Focusing," with C.L. Chang, A.T. Drobot, and J.W-K. Mark, *Bull. Am. Phys. Soc.* **31**, 1397 (1986).

45. "Three-Dimensional Simulations of Magnetically-Insulated Power Flow in Coaxial Geometry," with C.L. Chang, L. Seftor, A.T. Drobot, J. Moura, and S. Brandon, *Bull. Am. Phys. Soc.* **31**, 1399 (1986).

46. "Hybrid Simulations of the AMPTE Lithium Release in the Solar Wind," with C.C. Goodrich and A.T.Y. Lui, *Bull. Am. Phys. Soc.* **31**, 1513 (1986).

47. "Hybrid Simulation of Ion Beams in Background Plasma," with R.N. Sudan and J. Denavit, *J. Comput. Phys.* **70**, 89 (1987).

48. "Counterstreaming Plasma Interactions in the Plasma Sheet," with A.T.Y. Lui, A. Drobot, and K. Papadopoulos, *Proc. 3rd Intl. School for Space Simulation*, Beaulieu, France (1987).

49. "Three-Dimensional PIC Simulations and Mixed Geometry Calculations using ARGUS," with L. Seftor, C.L. Chang, A.A. Mondelli, A.T. Drobot, J. Moura, S.T. Brandon, and D.E. Nielsen, Jr., *Proc. 12th Conf. on the Numerical Simulation of Plasmas*, San Francisco, CA (1987).

50. "A Three-Dimensional Electromagnetic Eigenvalue Solver Compatible with ARGUS," with K. Ko, M. Kress, L. Seftor, A. Drobot, and A.A. Mondelli, *Proc. 12th Conf. on the Numerical Simulation of Plasmas*, San Francisco, CA (1987).

51. "Theory and Simulation of Cross-Field Ion Beam Propagation," with K. Papadopoulos and A.T. Drobot, *Bull. Am. Phys. Soc.* **32**, 1787 (1987).

52. "3D Simulations of Heavy Ion Fusion Beam Compression with Quadrupole Focusing," with C.L. Chang, A.T. Drobot, and J.W-K. Mark, *Bull. Am. Phys. Soc.* **32**, 1867 (1987).

53. "Three-Dimensional Electromagnetic Particle Codes and Applications to Accelerators," in *Linear Accelerator and Beam Optics Codes*, edited by C.R. Eminhizer (American Institute of Physics, New York, 1988).

54. "Numerical Simulation of Non-neutral Plasmas," in *Non-neutral Plasma Physics*, edited by C.W. Roberson and C.F. Driscoll (American Institute of Physics, New York, 1988).

55. "Domain Decomposition and Particle Pushing for Multiprocessing Computers," with J.L. Seftor, C.L. Chang, A.A. Mondelli, A.T. Drobot, J. Moura, W. Aimonetti, S.T. Brandon, D.E. Nielsen, Jr., and K.M. Dyer, *Comput. Phys. Commun.* **48**, 155 (1988).

56. "Long-Range Cross-Field Ion-Beam Propagation in the Diamagnetic Regime," with K. Papadopoulos and A.T. Drobot, *Phys. Rev. Lett.* **61**, 94 (1988).

57. "The ARGUS Simulation Code,", with K. Ko, A. Mondelli, A. Drobot, F. Kantrowitz, I. Tammaru, and J. Christensen, *Proc. 1988 Microwave Power Tube Conf.*, Monterey, CA (1988).

58. "3-D Particle-in-Cell Simulation for Multistage Depressed Collector Design," with J. Petillo, C.L. Chang, A. Drobot, and A. Adler, *Proc. 1988 Microwave Power Tube Conf.*, Monterey, CA (1988).

59. "Extension of Lower Hybrid Drift Instability into the Neutral Sheet of the Earth's Magnetotail," with A.T.Y. Lui, K. Papadopoulos, and A.T. Drobot, *Proc. IEEE Intl. Conf. on Plasma Science*, Seattle, WA (1988).

60. "Simulations in 3D of Heavy Ion Fusion Beam Compression with Quadrupole Focusing," with J.W-K. Mark, S.T. Brandon, C.L. Chang, A.T. Drobot, and D. Nielsen, *Proc. IEEE Intl. Conf. on Plasma Science*, Seattle, WA (1988).

61. "Three-Dimensional Particle-in-Cell Simulations of Beam Transport," with C.L. Chang, K. Ko, A.A. Mondelli, J.J. Petillo, and A.T. Drobot, *Proc. 7th Intl. Conf. on High-Power Particle Beams*, Karlsruhe, Germany (1988).

62. "Simulations of Heavy Ion Fusion Beam Compression with Quadrupole Focusing: Development of 3D Capability," with J.W-K. Mark, A. Friedman, C.L. Chang, and A. Drobot, *Proc. 7th Intl. Conf. on High-Power Particle Beams*, Karlsruhe, Germany (1988).

63. "Development of 3D Simulations for Heavy Ion Fusion Beam Transport and Compression Problems," with J.W-K. Mark, A. Friedman, C.L. Chang, A. Drobot, and A. Faltens, *Proc. Heavy Ion Conf.*, Darmstadt, Germany (1988).

64. "Extension of the LHD Instability into the Neutral Sheet," with K. Papadopoulos, A.T. Drobot, and A.T.Y. Lui, *Bull. Am. Phys. Soc.* **33**, 1893 (1988).

65. "Simulations of Heavy Ion Fusion Accelerator Beams with 3D PIC Codes," with J.W-K. Mark, A. Friedman, D. Nielsen, Jr., T. Fessenden, E. Lee, C.L. Chang, and A.T. Drobot, *Bull. Am. Phys. Soc.* **33**, 1989 (1988).

66. "Advanced Computational Techniques for the Design and Modeling of Electron Devices," with A. Drobot, C.L. Chang, K. Ko, A. Mondelli, J. Petillo, F. Kantrowitz, I. Tammaru, J. Christiansen, K. Eppley, H. Hanerfeld, and W. Herrmannsfeldt, *Proc. Intl. Electron Devices Meeting*, San Francisco, CA (1988).

67. "Application of the ARGUS Code to Accelerator Design Calculations," with A. Mondelli, C. Chang, A. Drobot, K. Ko, and J. Petillo, *Bull. Am. Phys. Soc.* **34**, 224 (1989).

68. "Simulation of Dense Z-Pinch Plasmas," with W. Grossmann, *Proc. 1989 Intl. Sherwood Theory Conf.*, San Antonio, TX (1989).

PUBLICATIONS:

1. "Relaxation Toward States of Minimum Energy in a Compact Torus," S. Riyopoulos, A. Bondenson, and D. Montgomery, Phys. Fluids, 25, 107 (1982).

2. "Low Amplitude, Wave Induced Particle Energy Diffusion in an Inhomogeneous Magnetic Field," S. Riyopoulos, T.M. Antonsen Jr., and E. Ott, Phys. Fluids, 27, 184 (1984).

3. "Enhanced Lower Hybrid Heating Caused by Frequency Modulation," S. Riyopoulos, Phys. Fluids, 28, 1097 (1985).

4. "Nonlinear Landau Damping of Purely Perpendicular Bernstein Modes," S. Riyopoulos, J. Plasma Phys. 196, 444 (1986).

5. "Diffusion Induced by Cyclotron Resonance Heating," S. Riyopoulos, T. Tajima, T. Hatori, and D. Pfirsch, Nuc. Fusion 26, 627 (1986).

6. "Alfven Continuum with Toroidicity," S. Riyopoulos and S. Mahajan, Phys. Fluids 29, 731 (1986).

7. "Simulation Study of Two-Ion Hybrid Heating," S. Riyopoulos and T. Tajima, Phys. Fluids 29, 4161 (1986).

8. "Small Signal Analysis for the Induced Resonance Electron Cyclotron Maser," S. Riyopoulos, C.M. Tang and P. Sprangle, Phys. Rev. A36, 197 (1987).

9. "Effect of Toroidicity During Lower Hybrid Mode Conversion," S. Riyopoulos and S. Mahajan, J. Plasma Phys. (1987).

10. "Tearing Mode Growth in a Regime of Weak Magnetic Shear," S. Riyopoulos and R.D. Hazeltine, accepted for publication, Phys. Fluids (1988).

11. "Operation of he Induced Resonance Electron Cyclotron Maser at Higher Harmonics," S. Riyopoulos, C.M. Tang and P. Sprangle, Phys. Fluids 31, 924 (1988).

12. "The Structure of the Sideband Spectrum in Free Electron Lasers," S. Riyopoulos and C.M. Tang, accepted for publication, Phys. Fluids (1988).

13. "The Sideband Instability Reconsidered," S. Riyopoulos and C.M. Tang, Proc. 8th Intl. FEL Conf., Glasgow, Scotland (1986), p. 226.

14. "Stochastic Electron Diffusion Induced by Sidebands in Free Electron Lasers," S. Riyopoulos and C.M. Tang, accepted for publication, Phys. Fluids (1988).

15. "Electron Detrapping in FELs Caused by Sidebands," S. Riyopoulos and C.M. Tang, Proc. 9th Intl. FEL Conf., Williamsburg, VA (1987).

16. "Reflection Matrix for Resonators in FEL Oscillators," S. Riyopoulos, P. Sprangle, C.M. Tang and A. Ting, Proc. 9th Intl. FEL Conf., Williamsburg, VA (1987).

17. "Resonator Optics for FEL Oscillators," S. Riyopoulos, C.M. Tang and P. Sprangle, in preparation.

ADAM T. DROBOT

As manager of the Applied Physics Operation in SAIC's Technology Research Group, Dr. Drobot is responsible for supervision of approximately fifty research physicists. His main research interests are the development of advanced numerical simulation methods based on particle-in-cell techniques, and the application of these methods to complex physical systems involving the interaction of electromagnetic fields with high density energetic particles. He has contributed recently to work on collective ion acceleration, free electron lasers, and the basic theory and simulation of high power microwave sources such as gyrotrons, magnetrons and klystrons. He is currently involved in problems of power flow in high-power magnetically insulated transmission lines and in intense relativistic diodes.

Dr. Drobot is a frequent contributor to the literature and conference presentations on the above topics and is co-holder of a patent on the Converging Guide Accelerator.

Thorough cooperative efforts with the university community, he has helped supervise graduate students in their doctoral work. These include: A. Friedman with R. Sudan at Cornell, A. Palevsky with G. Bekefi at MIT, T. Hughes with E. Ott at Maryland, and R. Jackson with W.O. Doggett at North Carolina.

Dr. Drobot received the B.S. Degree in engineering physics from Cornell University, Ithaca, N.Y., in 1968 and the Ph.D. degree in physics from the University of Texas at Austin in 1974.

Dr. Drobot is a member of the American Physical Society, Sigma Phi Sigma, and Phi Kappa Phi.

Curriculum Vitae

ADAM THOMAS DROBOT

Science Applications International Corporation
1710 Goodridge Drive
McLean, Virginia 22102
(703) 734-5595

EDUCATION:

B.S. Engineering Physics, Cornell University, Ithaca, N.Y. (1968)
Ph.D. Plasma Physics, University of Texas at Austin (1975)
Dissertation, "Theory and Experiments in the Simulation of Collisionless Plasmas"

PROFESSIONAL EXPERIENCE:

1975 - Present	Research Physicist, Science Applications International Corporation, McLean, Virginia. Working on theory and simulation of radiation and acceleration by relativistic electron and ion beams. Manager of Applied Physics Operation.
1975	Post Doctoral Appointment, Cornell University, Ithaca, New York. Analysis and simulation of strong field reversed ion layers and rings.
1974 - 1975	Computational Physicist, Austin Research Associates, Austin, Texas, working on problems of collective ion acceleration
1973 - 1974	Research Assistant, Fusion Research Center, Dept. of Physics, University of Texas, Austin, Texas. Analysis of turbulent plasmas, streaming instabilities and plasma heating.
1971 - 1973	Junior Physicist, Austin Research Associates, Austin, Texas. Simulation of strong collisionless shocks and plasma instabilities.
1969 - 1971	Research Assistant, Center for Plasma Physics and Thermonuclear Research, University of Texas, Austin, Texas.
1968 - 1969	Teaching Assistant, Dept. of Physics, University of Texas, Austin, Texas.

1966 - 1968	Student Research Assistant, Dept. of Material Sciences, College of Engineering, Cornell University, Ithaca, New York. Design and production of beam steering system for 5 MeV accelerator.
1967 - Summer	Junior Designer, Leesona Moos Corp., Lake Success, New York. Tool and component design for spaceborne applications.
1966 - Summer	Machinist, Westchester Tool & Die, Elmsford, New York.
1965 - Summer	Draftsman and Engineer's Aide, Gibbs & Hill, Inc., New York, New York.

PROFESSIONAL ACTIVITIES:

Member of American Physical Society and American Association for the Advancement of Science.

Member of American Physical Society Committee on Applications of Physics, 1987 - present.

Member of Sandia National Laboratory Inertial Confinement Fusion Internal Review Committee, 1980 - present.

Member of Defense Nuclear Agency Missile Flight Theory Committee, 1979 - present.

Member of Strategic Defense Initiative Directed Energy Synthesis Group, 1986 - 1987.

Member of SAIC Executive Science and Technology Council, 1984 - present.

Member of IEEE Committee on Computer Applications in Nuclear and Plasma Science, 1984 - 1987.

Organizer of Sessions on Computer Applications at IEEE International Plasma Science Conferences, 1980 - present.

Organizer of IEEE Minicourse on Computer Simulation, 1977.

Consultant to Hughes Aircraft Co., Microwave Tube Division, Torrance, California.

HONORS AND AWARDS:

Dean's List, Cornell University School of Engineering, 1968
New York State Regents Scholarship, Cornell University, 1964-1968
Sigma Phi Sigma
Phi Kappa Phi

PATENTS:

A Converging Guide Collective Ion Accelerator
A Gyrotron Travelling Wave Amplifier
Emittron Microwave Source

PUBLICATIONS:

1. "Stability of an Unneutralized Rigidly Rotating Electron Beam," with H. Vernon Wong, M. Lee Sloan, and James R. Thompson, Phys. Fluids, 16, 902 (1973).

2. "Equilibrium and Stability of Mirror-Confined Nonneutral Plasmas," with R.C. Davidson and C.A. Kapetanakos, Phys. Fluids, 16, 2199 (1973).

3. "Collective Ion Acceleration in a Converging Wave Guide," with P. Sprangle and W.M. Manheimer, Phys. Rev. Lett., 36, 1180 (1976).

4. "Stimulated Collective Scattering from a Magnetized Relativistic Electron Beam," Digest 2nd International Conference on Submillimeter Waves and Theory Applications, p. 124, San Juan, Puerto Rico, (1976).

5. "Results of Numerical Simulation of Submillimeter Radiation from Relativistic Electron Beams", Digest 2nd International Conference on Submillimeter Waves and Theory Applications, p. 126, San Juan, Puerto Rico, (1976).

6. "The Linear and Self Consistent Nonlinear Theory of the Cyclotron Maser Instability," with P. Sprangle, Digest 2nd International Conference on Submillimeter Waves and Theory Application, p. 136, San Juan, Puerto Rico, (1976).

7. "A Wave Accelerator for Collective Ion Acceleration," with R. Adler, G. Gammel, H.A. Nation, M.E. Read, R. Williams, and P. Sprangle, Proceedings 2nd International Conference on High Power Electron and Ion Beam Research and Technology, p. 509, Ithaca, N.Y. (1977).

8. "The Electron Cyclotron Maser Instability," with P. Sprangle and V.L. Granatstein, Journel De Physique, Tome 38, p. C6-135 (1977).

9. "The Linear and Self-Consistent Nonlinear Theory of the Electron Cyclotron Maser Instability," with P. Sprangle, IEEE Trans. MTT-25, 528 (1977).

10. "The Electron Cyclotron Maser," with P. Sprangle, K.R. Chu, and V.L. Granatstein, Proceedings 2nd International Conference on High Power Electron and Ion Beam Research and Technology, p. 703, Ithaca, N.Y., (1977).

11. "Coherent Microwave Scattering from Intense Relativistic Electron Beams -- A Powerful, Tunable Source of Millimeter and Sub-millimeter Radiation," with V.L. Granatstein, R.K. Parker, J.A. Pasour, and P. Sprangle, Proceedings 2nd International Conference on High Power Electron and Ion Beam Research and Technology, p. 675, Ithaca, N.Y., (1977).

12. "The NRL Ion Ring Program," with C.A. Kapetanakos, J. Golden, R.A. Mahaffey, S.J. Marsh, and J.A. Pasour, Proceedings 2nd International Conference on High Power Electron and Ion Beam Research and Technology, p. 435, Ithaca, N.Y. (1977).

13. "Generation of Intense Ion Beams and Theory Application to Controlled Fusion Research," with P. Dreike, R.L. Ferch, A. Friedman, S. Humphries, R.V. Lovelace, G. Ludwig, R.N. Sudan, D.L. Book, G. Cooperstein, J. Golden, S.A. Goldstein, C.A. Kapetanakos, Roswell Lee, W. Manheimer, S.J. Marsh, D. Mosner, E. Ott, S.J. Stephanakis, and P.J. Turchi, Plasma Physics and Controlled Nuclear Fusion Research 1976, Vol. III, p. [illegible], IAEA, Vienna, (1977).

14. "Numerical Simulations of Strong Proton Rings," with A. Friedman, R.L. Ferch and R.N. Sudan, Plasma Physics, 19, p. 1101 (1977).

15. "Numerical Simulation of Proton Rings During Static Compression Trapping," with S.J. Marsh, J. Golden, and C.A. Kapatanakos, Phys. Rev. Lett., p. 705 (1977).

16. "A Dielectrically Loaded Converging Guide Accelerator," with P. Sprangle, NRL Memorandum Report 3660, Naval Research Laboratory, Washington, D.C. (1977).

17. "Regulation of the Wave Velocity in the Converging Guide Accelerator (CGA)," with P. Sprangle, Third International Conference on Collective Methods of Acceleration, University of California, Irvine, CA (1978).

18. "Relativistic Electron Beam Interactions for Generation of High Power Millimeter and Submillimeter Waves," with V.L. Granatstein, P. Sprangle, R. Parker, K.R. Chu, L. Seftor, M. Read, and T. Coffey, in Conf. Proc. No. 245, in Millimeter and Submillimeter Wave Propagation and Circuits, AGARD-NATO, p. 39-1 (1978).

19. "Computer Simulation Studies of Strong Proton Rings," with S.J. Marsh, J. Golden, and A. Kapetanakos, Phys. Fluids, 21, 1045 (1978).

20. "Theory and Single Wave Simulation of the Gyrotron Traveling Wave Amplifier Operating at Cyclotron Harmonics," with K.R. Chu, NRL Memorandum Report 3788, Naval Research Laboratory, Washington, D.C. (1978).

21. "Characteristics and Optimum Operating Parameters of a Gyrotron Traveling Wave Amplifier," with K.R. Chu, V.L. Granatstein, and J.L. Seftor, IEEE Microwave Theory and Techniques, Vol. MTT-27, p. 178 (1979).

22. "Stimulated Backscattering from Relativistic Unmagnetized Electron Beams," with P. Sprangle, J. Appl. Phys., in press (1979).

23. "An Investigation of a Magnetron Injection Gun Suitable for Use in Cyclotron Resonance Masers," with J.L. Seftor and K.R. Chu, IEEE Trans. on Electron Devices, Vol. ED-26, No. 10, p. 1609-1616 (October 1979).

24. "NRL Light Ion Beam Research for Inertial Confinement Fusion," with G. Cooperstein, S.A. Goldstein, D. Mosher, R.J. Barker, J.R. Boller, D.G. Colombant, R.A. Meger, W.F. Oliphant, P.F. Ottinger, F.L. Sondel, S.J. Stephanakis, and F.C. Young, Proc. 5th Int'l Workshop on Las... Interaction and Related Plasma Phenomena, Rochester, N.Y., Nov. 5-9, 1979.

25. "Gain, Saturation, and Bandwidth Measurements of the NRL Gyrotron Travelling Wave Amplifier", with L.R. Barnett, K.R. Chu, J. Markbaird, V.L. Granatstein, International Electron Devices Meeting, CAT 79CH1504-OED, p. 164-166, Washington, D.C., Dec. 1979.

26. "Simulation Techniques for Self-Consistent Treatment of Electron Dynamics in High-Power Microwave Tubes," (Invited Paper) International Electron Devices Meeting, CAT 79CH1504-OED, p. 663-665.

27. "Progress at NRL and Cornell in Light-Ion Beam Research for ICF," with G. Cooperstein, S.A. Goldstein, D. Mosher, R.J. Barker, J.R. Boller, D.G. Colombant, R.A. Meger, W.F. Oliphant, P.G. Ottinger, F.L. Sandel, S.J. Sephazakis, F.C. Young, G. Giner, D.A. Hammer, S. Humphries, Jr., J.N. Neri, R. Pal and R.N. Sudan, 8th International Conference on Plasma Physics and Controlled Nuclear Fusion Research, IAEA Brussels, 1-10 July 1980.

28. "Field Reversed Ion Layers," with J. Chen, R.C. Davidson, J. Finn, J. Golden, C.A. Kapetanakos, S.J. Marsh, J.A. Pasour, D. Pershing, H.S. Uhm, P.L. Dreike, M.P. Gaydar, J.B. Greenly, D.A. Hammer, G.D. Rondeau, R.N. Sudan, and L.G. Wiley, 8th International Conference on Plasma Physics and Controlled Nuclear Fusion Research, IAEA Brussels, 1-10 July 1980.

29. "Theory and Simulation of the Gyrotron Traveling Wave Amplifier Operating at Cyclotron Harmonics," with K.R. Chu, H.H. Szu, and P. Sprangle, IEEE Trans. MTT-28, No. 4 (1980)

30. "Spatial and Temporal Coherence of a 35 GHz Gyromonotron Using the TE Circular Mode," with M.E. Read, K.R. Chu, V.L. Granatstein, R.M. Gilgenbach, R. Lucey, Jr., NRL Memorandum Report 4244, Washington, D.C. 20375 and, IEEE Trans. MTT-28, No. 8 (1980).

31. "Computer Simulation Studies of the Tearing Mode Instability in a Field-Reversed Ion Layer," with S.J. Marsh and C.A. Kapetanakos, submitted for publication in Plasma Physics 1980.

32. "Practical Considerations in the Design of a High-Power 1-mm Gyromonotron", with J.D. Silverstein, M.E. Read, and K.R. Chu, IEEE Trans. MTT-28, No. 9 (1980).

33. "Numerical Simulation of Oscillating Magnetrons", with A. Palevsky and G. Bekefi, J. Appl. Phys., 52 (8), pp. 4938-4941 (1981).

34. "Space Charge Effects on the Equilibrium of Guided Electron Flow with Gyromotion", with K. Kim, Int. J. Electron., 51 (4), pp. 351-367 (1981).

35. "High Impedance Ion Diode Experiment on Aurora", with R.A. Meger, F.C. Young, G. Cooperstein, S.A. Goldstein, and D. Mosher, J. Appl. Phys., 52(10), p. 6084-6093 (1981).

36. "Nonlinear Development of the Resistive Filamentation Instability" with T.P. Hughes and E. Ott, Phys. Rev. Lett, 47 (21), p. 1529-1532 (1981).

37. "Design Considerations for a Megawatt CW Gyrotron," with K.J. Kim, M.E. Read, J.M. Baird, K.R. Chu, J.L. Vomvoridis, A. Ganguly, D. Dialetis, and V.L. Granatstein, Int. J. Electron., 51 (4), p. 427-445 (1981).

38. "Light-Ion Inertial-Confinement-Fusion at NRL," with G. Cooperstein, R.J. Barker, D.G. Colombant, S.A. Goldstein, R.A. Meger, D. Mosher, P.F. Ottinger, F.L. Sondel, S.J. Stephonakis, and F.C. Young, 9th International Conference on Plasma Physics and Controlled Nuclear Fusion Research, IAEA Baltimore, USA, 1-8 Sept. 1982, paper IAEA-CN-41/N-2, p. 361-370.

39. "Nonlinear Development of the Resistive Filamentation Instability", with T.P. Hughes and E. Ott, Phys. Fluids, 26 (6) (1983).

40. "Relativistic Electron Trajectories in Free Electron Lasers with an Axial Guide Field," with H.P. Freund, Phys. Fluids, 25 (4), p. 736-739 (1982).

41. "Application of Particle Simulation Codes to Fusion Reactor Engineering," with E.C. Morse, A. Friedman, and B. McNamara, Nuclear Technology/Fusion, 3 (2) p. 287-292 (1983).

42. "Propagation of Intense Relativistic Electron Beams through Drift Tubes with Perturbed Walls," with M. Friedman, V. Serlin, and L. Seftor, Phys. Rev. Lett., 50 (24), p. 1922-1925 (1983).

43. "Stability Theory of Magnetically Insulated Electron Flow," with C.L. Chang, E. Ott, T. Antonsen, Jr., K. Eppley, and P. Wheeler, Proc. 5th International Conference on High Power Particle Beams, San Francisco, CA, Sept. 1983, p. 187-189.

44. "Electron Sheath Dynamics in Magnetically Insulated Diodes," with M.P. Desjarlais, R.N. Sudan, Proc. 5th International Conference on High Power Particle Beams, San Francisco, CA, Sept. 1983, p. 190-193.

45. "Modeling of Diode Emission Processes," with E.L. Kane, D.P. Bacon, Proc. 5th International Conference on High Power Particle Beams, San Francisco, CA, Sept. 1983, p. 194-198.

46. "Numerical Simulation of High Power r.f. Sources," with L. Seftor, K. Ko, H. Hanerfeld, and .B. Herrmansfeldt, IEEE Trans. Nuc. Sci., Vol. NS-30, No. 4, August 1983, p. 3633-3635.

47. "Theory and Numerical Modeling of a Compact Low-Field High-Frequency Gyrotron", IEEE Trans. MTT 32 (4), p. 373-386 (1984).

48. "Theory and Numerical Simulation of a Compact, Low Field, High Frequency Gyrotron," with P. Vitello, and W. Miner, Int. J. of Infr. and MM Waves, 5 (4), p. 507-529 (1984).

49. "Self Modulation of an Intense Relativistic Electron Beam," with M. Friedman, V. Serlin, and L. Seftor, J. Appl. Phys. 56 (9), (1984).

50. "Theory of the Rippled Field Magnetron," with C.L. Chang, E. Ott, and T.M. Antonsen Phys. Fluids 27 (12), (1984).

51. "Instabilities in Magnetically Insulated Gaps with Resistive Electrode Plasmas," with C.L. Chang, T.M. Antonsen, Jr., and E. Ott Phys. Fluids 27, (10) (1984).

52. "Stability of Space-Charge Limited Electron Flow," with T.M. Antonsen, Jr., W.H. Miner, and E. Ott, Phys. Fluids, 27 (5), 1257-1267 (1984).

53. "Theory and Numerical Simulation of a TE Gyroresonant Accelerator," with W.H. Miner and P. Vitello, IEEE Trans. MTT Vol. MTT-32 (10), p. 1293-1301 (October 1984).

54. "Numerical Simulation of High Power Microwave Sources," with C.L. Chang, K.Ko, A. Mankofsky, A. Mondelli, L. Seftor, and P. Vitello, IEEE Trans. Nuc. Sci., Vol. NS-32, No. 5, p.2733-2737, (October 1985).

55. "Results of Simulations of High-Power Klystrons," with K. Eppley, S. Yu, W. Herrmannsfeldt, H. Hanerfeld, D. Nielsen, S. Brandon, and R. Melandez, IEEE Trans. Nuc. Sci. Vol. NS-32 (5) p. 2903-2905 (October 1985).

56. "Two and One-Half Dimensional Particle-in-Cell Simulations of High-Power Klystrons," with S. Yu and P. Wilson, IEEE Trans. Nuc. Sci., Vol. NS-32, (5) p. 2918-2920 (October 1985).

57. "Design of Gyrotron Amplifiers for Driving 1 TeV e-e+ Linear Colliders," with V.L. Granatstein, P. Vitello, K.R. Chu, K. Ko, P.E. Latham, W. Lawson, C.D. Striffler, IEEE Trans. Nuc. Sci. Vol. NS-32 (5) p. 2957-2959 (October 1985).

58. "Frequency Scaling of RF Linacs," with A.A. Mondelli, D.P. Chernin, M. Reiser, and V. Granatstein, IEEE Trans. Nuc. Sci. Vol. NS-32 (5) p. 3157-3159 (October 1985).

59. "Electromagnetic Stability of High-Power Ion Diodes," with C.L. Chang, D.P. Chernin, E. Ott, and T.M. Antonsen, Jr., Phys. Fluids 29, (4) 1258-1267 (1986).

60. "High-Power Modulated Intense Relativistic Electron Sources with Applications to RF Generation and Controlled Thermonuclear Fusion," with M. Friedman, V. Serlin, and A. Mondelli, IEEE Trans. Plas. Sci. Vol. PS-14, No. 3, (June 1986).

61. "Numerical Simulation of a Low-Density Plasma Erosion Opening Switch," with J.M. Grossmann, P.F. Ottinger, J.M. Neri, Phys. Fluids 29 (8) 2724-2735 (1986).

62. "Stochastic Electron Acceleration in Obliquely Propagating Electromagnetic Waves" with C.R. Menyuk, K. Papadopoulos, and H. Karimabadi, Phys. Rev. Lett. 58, p. 2071-2074 (1987).

63. "Generation of High-Power Microwaves, Millimeter and Submillimeter Waves: Introduction and Overview" with B. Levush, in High Power Microwave Sources, V.L. Granatstein, and I. Alexeff, eds., Artech House, Boston, p. 3-36 (1987).

64. "Long Range Cross-Field Ion-Beam Propagation in the Diamagnetic Regime," with K. Papadopoulos, and A. Mankofsky, Phys. Rev. Lett. 61 p. 94-97 (1988).

65. "Electron Acceleration Using Intense Electromagnetic Waves" with C.R. Menyuk, K. Papadopoulos, and H. Karimabadi, (accepted for publication Phys. Fluids 1988).

66. "Quasineutral Beam Propagation in Space" with K. Papadopoulos and A. Mankofsky (accepted for publication Special Issue on Active Experiments, Bruce Tsurutani, Ed., AGU Monograph, 1988).

67. "Domain Decomposition and Particle Pushing for Multiprocessing Computers," with A. Mankofsky, J.L. Seftor, C.C. Chang, K. Ko, A.Mondelli, J. Moura, W. Aimonetti, S.T. Brandon, D.E. Nielsen, Jr., K.M. Dyer in Particle Methods in Fluid Dynamics and Plasma Physics, J.U. Brackbill and J.J. Monaghon eds., North Holland, Amsterdam p.155-166, 1988.

68. "Three-Dimensional Particle-in-Cell Simulations of Beam Transport" with A. Mankofsky, C.L. Chang, K. Ko, and A. Mondelli, Proceedings of the Seventh International Conference on High Power Particle Beams, Karlsrude, Germany, (1988).

Curriculum Vitae

ADAM THOMAS DROBOT

Science Applications International Corporation
1710 Goodridge Drive
McLean, Virginia 22102
(703) 734-5595

EDUCATION:

B.S. Engineering Physics, Cornell University, Ithaca, N.Y. (1968)
Ph.D. Plasma Physics, University of Texas at Austin (1975)
Dissertation, "Theory and Experiments in the Simulation of Collisionless Plasmas"

PROFESSIONAL EXPERIENCE:

1975 - Present	Research Physicist, Science Applications International Corporation, McLean, Virginia. Working on theory and simulation of radiation and acceleration by relativistic electron and ion beams. Manager of Applied Physics Operation.
1975	Post Doctoral Appointment, Cornell University, Ithaca, New York. Analysis and simulation of strong field reversed ion layers and rings.
1974 - 1975	Computational Physicist, Austin Research Associates, Austin, Texas, working on problems of collective ion acceleration
1973 - 1974	Research Assistant, Fusion Research Center, Dept. of Physics, University of Texas, Austin, Texas. Analysis of turbulent plasmas, streaming instabilities and plasma heating.
1971 - 1973	Junior Physicist, Austin Research Associates, Austin, Texas. Simulation of strong collisionless shocks and plasma instabilities.
1969 - 1971	Research Assistant, Center for Plasma Physics and Thermonuclear Research, University of Texas, Austin, Texas.
1968 - 1969	Teaching Assistant, Dept. of Physics, University of Texas, Austin, Texas.Page 2
1966 - 1968	Student Research Assistant, Dept. of Material Sciences, College of Engineerng, Cornell University, Ithaca, New York. Design and production of beam steering system for 10 MeV accelerator.
1967 - Summer	Junior Designer, Leesona Moos Corp., Lake Success, New York. Tool and component design for space borne applications.
1966 - Summer	Machinist, Westchester Tool & Die, Elmsford, New York.
1965 - Summer	Draftsman and Engineer's Aide, Gibbs & Hill, Inc., New York, New York.

PROFESSIONAL ACTIVITIES:

Member of American Physical Society and American Association for the Advancement of Science. Served as consultant to Hughes Aircraft Co., Microwave Tube Division, Torrance, California.

HONORS AND AWARDS:

Dean's List, Cornell University School of Engineering, 1968
New York State Regents Scholarship, Cornell University, 1964-1968
Sigma Phi SigmaPhi Kappa Phi

PATENTS:

"A Converging Guide Collective Ion Accelerator", granted 3/2/79."A Gyrotron Travelling Wave Amplifier," application pending.

RECENT ACTIVITY AND PRESENT DUTIES:

Manager of Applied Physics Operation in SAIC's Technology Research Group. Responsible for supervision of approximately forty research physicist. Actively pursuing research on the modeling of pulsed power diodes for applications to inertial confinement fusion with light ion beams. Involved in numerical simulation and analysis of gyrotron and free electron laser devices. Frequent contributor to the literature and conference presentations on the above topics. He is responsible for the modeling of high power ion beam sources in the NRL Light Ion Beam program and has developed fluid and particle-in-cell codes for this purpose.

Principal Investigator on the dynamics of High Temperature Plasmas contract with the Naval Research Laboratory. As a numerical physicist actively pursuing research in several areas that include, collective acceleration, millimeter and submillimeter sources of microwave radiation, pulsed power devices, and nonlinear plasma phenomena. He has been involved in the development of codes for and in the analysis of free-electron lasers, gyrotron device and high power microwave sources based on relativistic beams. He has a continued involvement in collective acceleration and is co-holder of a patent on the Converging Guide Accelerator. At present he is developing fluid and particle in cell codes for modeling of intense light ion sources to be used as inertial confinement fusion drivers. He has thorough cooperative efforts with the University community and has helped to supervise graduate students in their doctoral work. These include: A. Friedman with R. Sudan at Cornell, A. Palevsky with G. Bekefi at MIT, T. Hughes with E. Ott at Maryland, and R. Jackson with W.O. Doggett at North Carolina. His main interest is the development of advanced numerical simulation methods with particle in all techniques for millimeter and submillimeter devices and relativistic power flow in diodes.

PUBLICATIONS:

1. Stability of an Unneutralized Rigidly Rotating Electron Beam," with H. Vernon Wong, M. Lee Sloan, and James R. Thompson, Phys. Fluids, 16, 902 (1973).

2. "Equilibrium and Stability of Mirror-Confined Nonneutral Plasmas," with R.C. Davidson and C.A. Kapetanakos, Phys. Fluids, 16, 2199 (1973).

3. "Collective Ion Acceleration in a Converging Wave Guide," with P. Sprangle and W.M. Manheimer, Phys. Rev. Lett., 36, 1180 (1976).

4. "Stimulated Collective Scattering from a Magnetized Relativistic Electron Beam," Digest 2nd International Conference on Sub- millimeter Waves and Theory Applications, p. 124, San Juan, Puerto Rico, (1976).

5. "Results of Numerical Simulation of Submillimeter Radiation from Relativistic Electron Beams", Digest 2nd International Conference on Submillimeter Waves and Theory Applications, p. 126, San Juan, Puerto Rico, (1976).

6. "The Linear and Self Consistent Nonlinear Theory of the Cyclotron Maser Instability," with P. Sprangle, Digest 2nd International Conference on Submillimeter Waves and Theory Application, p. 136, San Juan, Puerto Rico, (1976).

7. "A Wave Accelerator for Collective Ion Acceleration," with R. Adler, G. Gammel, H.A. Nation, M.E. Read, R. Williams, and P. Sprangle, Proceedings 2nd International Conference on High Power Electron and Ion Beam Research and Technology, p. 509, Ithaca, N.Y. (1977).

8. "The Electron Cyclotron Maser Instability," with P. Sprangle and V.L. Granatstein, Journel De Physique, Tome 38, p.C6-135 (1977).

9. "The Linear and Self-Consistent Nonlinear Theory of the Electron Cyclotron Maser Instability," with P. Sprangle, IEEE Trans. MTT-25, 528 (1977).

10. "The Electron Cyclotron Maser," with P. Sprangle, K.R. Chu, and V.L. Granatstein, Proceedings 2nd International Conference on High Power Electron and Ion Beam Research and Technology, p. 703, Ithaca, N.Y., (1977).

11. "Coherent Microwave Scattering from Intense Relativistic Electron Beams -- A Powerful, Tunable Source of Millimeter and Sub- millimeter Radiation," with V.L. Granatstein, R.K. Parker, J.A. Pasour, and P. Sprangle, Proceedings 2nd International Conference on High Power Electron and Ion Beam Research and Technology, p. 675, Ithaca, N.Y., (1977).

12. "The NRL Ion Ring Program," with C.A. Kapetanakos, J. Golden, R.A. Mahaffey, S.J. Marsh, and J.A. Pasour, Proceedings 2nd International Conference on High Power Electron and Ion Beam Research and Technology, p. 435, Ithaca, N.Y. (1977).

13. "Generation of Intense Ion Beams and Theory Application to Controlled Fusion Research," with P. Dreike, R.L. Ferch, A. Friedman, S. Humphries, R.V. Lovelace, G. Ludwig, R.N. Sudan, D.L. Book, G. Cooperstein, J. Golden, S.A. Goldstein, C.A. Kapetanakos, Roswell Lee, W. Manheimer, S.J. Marsh, D. Mosner, E. Ott, S.J. Stephanakis, and P.J. Turchi, Plasma Physics and Controlled Nuclear Fusion Research 1976, Vol. III, p. 415, IAEA, Vienna, (1977).

14. "Numerical Simulations of Strong Proton Rings," with A. Friedman, R.L. Ferch and R.N. Sudan, Plasma Physics, 19, p. 1101 (1977).

15. "Numerical Simulation of Proton Rings During Static Compression Trapping," with S.J. Marsh, J. Golden, and C.A. Kapatanakos, Phys. Rev. Lett., p. 705 (1977).

16. "A Dielectrically Loaded Converging Guide Accelerator," with P. Sprangle, NRL Memorandum Report 3660, Naval Research Laboratory, Washington, D.C. (1977).

17. "Regulation of the Wave Velocity in the Converging Guide Accelerator (CGA)," with P. Sprangle, Third International Conference on Collective Methods of Acceleration, University of California, Irvine, CA (1978).

18. "Relativistic Electron Beam Interactions for Generation of High Power Millimeter and Submillimeter Waves," with V.L. Granatstein, P. Sprangle, R. Parker, K.R. Chu, L. Seftor, M. Read, and T. Coffey, in Conf. Proc. No. 245, in Millimeter and Submillimeter Wave Propagation and Circuits, AGARD-NATO, p. 39-1 (1978).

19. "Computer Simulation Studies of Strong Proton Rings," with S.J. Marsh, J. Golden, and A. Kapetanakos, Phys. Fluids, 21, 1045 (1978).

20. "Theory and Single Wave Simulation of the Gyrotron Traveling Wave Amplifier Operating at Cyclotron Harmonics," with K.R. Chu, NRL Memorandum Report 3788, Naval Research Laboratory, Washington, D.C. (1978).

21. "Characteristics and Optimum Operating Parameters of a Gyrotron Traveling Wave Amplifier," with K.R. Chu, V.L. Granatstein, and J.L. Seftor, IEEE Microwave Theory and Techniques, Vol. MTT-27, p. 178 (1979).

22. "Stimulated Backscattering from Relativistic Unmagnetized Electron Beams," with P. Sprangle, J. Appl. Phys., in press (1979).

23. "An Investigation of a Magnetron Injection Gun Suitable for Use in Cyclotron Resonance Masers," with J.L. Seftor and K.R. Chu, IEEE Trans. on Electron Devices, Vol. ED-26, No. 10, p.1609- 1616 (October 1979).

24. "NRL Light Ion Beam Research for Inertial Confinement Fusion," with G. Cooperstein, S.A. Goldstein, D. Mosher, R.J. Barker, J.R. Boller, D.G. Colombant, R.A. Meger, W.F. Oliphant, P.F. Ottinger, F.L. Sondel, S.J. Stephanakis, and F.C. Young, Proc. 5th Int'l Workshop on Laser Interaction and Related Plasma Phenomena, Rochester, N.Y., Nov. 5-9, 1979.

25. "Gain, Saturation, and Bandwidth Measurements of the NRL Gyrotron Travelling Wave Amplifier", with L.R. Barnett, K.R. Chu, J. Markbaird, V.L. Granatstein, International Electron Devices Meeting, CAT 79CH1504-OED, p. 164-166, Washington, D.C., Dec. 1979.

26. "Simulation Techniques for Self-Consistent Treatment of Electron Dynamics in High-Power Microwave Tubes," (Invited Paper) International Electron Devices Meeting, CAT 79CH1504-OED, p. 663-665.

27. "Progress at NRL and Cornell in Light-Ion Beam Research for ICF," with G. Cooperstein, S.A. Goldstein, D. Mosher, R.J. Barker, J.R. Boller, D.G. Colombant, R.A. Meger, W.F. Oliphant, P.G. Ottinger, F.L. Sandel, S.J. Sephazakis, F.C. Young, G. Giner, D.A. Hammer, S. Humphries, Jr., J.N. Neri, R. Pal and R.N. Sudan, 8th International Conference on Plasma Physics and Controlled Nuclear Fusion Research, IAEA Brussels, 1-10 July 1980.

28. "Field Reversed Ion Layers," with J. Chen, R.C. Davidson, J. Finn, J. Golden, C.A. Kapetanakos, S.J. Marsh, J.A. Pasour, D. Pershing, H.S. Uhm, P.L. Dreike, M.P. Gaydar, J.B. Greenly, D.A. Hammer, G.D. Rondeau, R.N. Sudan, and L.G. Wiley, 8th International Conference on Plasma Physics and Controlled Nuclear Fusion Research, IAEA Brussels, 1-10 July 1980.

29. "Theory and Simulation of the Gyrotron Traveling Wave Amplifier Operating at Cyclotron Harmonics," with K.R. Chu, H.H. Szu, and P. Sprangle, IEEE Trans. MTT-28, No. 4 (1980)

30. "Spatial and Temporal Coherence of a 35 GHz Gyromonotron Using the TE Circular Mode," with M.E. Read, K.R. Chu, V.L. Granatstein, R.M. Gilgenbach, R. Lucey, Jr., NRL Memorandum Report 4244, Washington, D.C. 20375 and, IEEE Trans. MTT-28, No. 8 (1980).

31. "Computer Simulation Studies of the Tearing Mode Instability in a Field-Reversed Ion Layer," with S.J. Marsh and C.A. Kapetanakos, submitted for publication in Plasma Physics 1980.

32. "Practical Considerations in the Design of a High-Power 1-mm Gyromonotron", with J.D. Silverstein, M.E. Read, and K.R. Chu, IEEE Trans. MTT-28, No. 9 (1980).

33. "Numerical Simulation of Oscillating Magnetrons", with A. Palevsky and G. Bekefi, J. Appl. Phys., 52 (8), pp. 4938-4941 (1981).

34. "Space Charge Effects on the Equilibrium of Guided Electron Flow with Gyromotion", with K. Kim, Int. J. Electron., 51 (4), pp. 351-367 (1981).

35. "High Impedance Ion Diode Experiment on Aurora", with R.A. Meger, F.C. Young, G. Cooperstein, S.A. Goldstein, and D. Mosher, J. Appl. Phys., 52(10), p. 6084-6093 (1981).

36. "Nonlinear Development of the Resistive Filamentation Instability" with T.P. Hughes and E. Ott, Phys. Rev. Lett, 47 (21), p. 1529-1532 (1981).

37. "Design Considerations for a Megawatt CW Gyrotron," with K.J. Kim, M.E. Read, J.M. Baird, K.R. Chu, J.L. Vomvoridis, A. Ganguly, D. Dialetis, and V.L. Granatstein, Int. J. Electron., 51 (4), p. 427-445 (1981).

38. "Light-Ion Inertial-Confinement-Fusion at NRL," with G. Cooperstein, R.J. Barker, D.G. Colombant, S.A. Goldstein, R.A. Meger, D. Mosher, P.F. Ottinger, F.L. Sondel, S.J. Stephonakis, and F.C. Young, 9th International Conference on Plasma Physics and Controlled Nuclear Fusion Research, IAEA Baltimore, USA, 1-8 Sept. 1982, paper IAEA-CN-41/N-2, p. 361-370.

39. "Nonlinear Development of the Resistive Filamentation Instability", with T.P. Hughes and E. Ott, Phys. Fluids, 26 (6) (1983).

40. "Relativistic Electron Trajectories in Free Electron Lasers with an Axial Guide Field," with H.P. Freund, Phys. Fluids, 25 (4), p. 736-739 (1982).

41. "Application of Particle Simulation Codes to Fusion Reactor Engineering," with E.C. Morse, A. Friedman, and B. McNamara, Nuclear Technology/Fusion, 3 (2) p. 287-292 (1983).

42. "Propagation of Intense Relativistic Electron Beams through Drift Tubes with Perturbed Walls," with M. Friedman, V. Serlin, and L. Seftor, Phys. Rev. Lett., 50 (24), p. 1922-1925 (1983).

43. "Stability Theory of Magnetically Insulated Electron Flow," with C.L. Chang, E. Ott, T. Antonsen, Jr., K. Eppley, and P. Wheeler, Proc. 5th International Conference on High Power Particle Beams, San Francisco, CA, Sept. 1983, p. 187-189.

44. "Electron Sheath Dynamics in Magnetically Insulated Diodes," with M.P. Desjarlais, R.N. Sudan, Proc. 5th International Conference on High Power Particle Beams, San Francisco, CA, Sept. 1983, p. 190-193.

45. "Modeling of Diode Emission Processes," with E.L. Kane, D.P. Bacon, Proc. 5th International Conference on High Power Particle Beams, San Francisco, CA, Sept. 1983, p. 194-198.

46. "Numerical Simulation of High Power r.f. Sources," with L. Seftor, K. Ko, H. Hanerfeld, and .B. Herrmansfeldt, IEEE Trans. Nuc. Sci., Vol. NS-30, No. 4, August 1983, p. 3633-3635.

47. "Theory and Numerical Modeling of a Compact Low-Field High- Frequency Gyrotron", IEEE Trans. MTT 32 (4), p. 373-386 (1984).

48. "Theory and Numerical Simulation of a Compact, Low Field, High Frequency Gyrotron," with P. Vitello, and W. Miner, Int. J. of Infr. and MM Waves, 5 (4), p. 507-529 (1984).

49. "Self Modulation of an Intense Relativistic Electron Beam," with M. Friedman, V. Serlin, and L. Seftor, J. Appl. Phys. 56 (9), (1984).

50. "Theory of the Rippled Field Magnetron," with C.L. Chang, E. Ott, and T.M. Antonsen Phys. Fluids 27 (12), (1984).

51. "Instabilities in Magnetically Insulated Gaps with Resistive Electrode Plasmas," with C.L. Chang, T.M. Antonsen, Jr., and E. Ott Phys. Fluids 27, (10) (1984).

52. "Stability of Space-Charge Limited Electron Flow," with T.M. Antonsen, Jr., W.H. Miner, and E. Ott, Phys. Fluids, 27 (5), 1257-1267 (1984).

53. "Theory and Numerical Simulation of a TE Gyroresonant Accelerator," with W.H. Miner and P. Vitello, IEEE Trans. MTT Vol. MTT-32 (10), p. 1293-1301 (October 1984).

54. "Numerical Simulation of High Power Microwave Sources," with C.L. Chang, K.Ko, A. Mankofsky, A. Mondelli, L. Seftor, and P. Vitello, IEEE Trans. Nuc. Sci., Vol. NS-32, No. 5, p.2733-2737, (October 1985).

55. "Results of Simulations of High-Power Klystrons," with K. Eppley, S. Yu, W. Herrmannsfeldt, H. Hanerfeld, D. Nielsen, S. Brandon, and R. Melandez, IEEE Trans. Nuc. Sci. Vol. NS-32 (5) p. 2903-2905 (October 1985).

56. "Two and One-Half Dimensional Particle-in-Cell Simulations of High-Power Klystrons," with S. Yu and P. Wilson, IEEE Trans. Nuc. Sci., Vol. NS-32, (5) p. 2918-2920 (October 1985).

57. "Design of Gyrotron Amplifiers for Driving 1 TeV e-e+ Linear Colliders," with V.L. Granatstein, P. Vitello, K.R. Chu, K. Ko, P.E. Latham, W. Lawson, C.D. Striffler, IEEE Trans. Nuc. Sci. Vol. NS-32 (5) p. 2957-2959 (October 1985).

58. "Frequency Scaling of RF Linacs," with A.A. Mondelli, D.P. Chernin, M. Reiser, and V. Granatstein, IEEE Trans. Nuc. Sci. Vol. NS-32 (5) p. 3157-3159 (October 1985).

59. "Electromagnetic Stability of High-Power Ion Diodes," with C.L. Chang, D.P. Chernin, E. Ott, and T.M. Antonsen, Jr., Phys. Fluids 29, (4) 1258-1267 (1986).

60. "High-Power Modulated Intense Relativistic Electron Sources with Applications to RF Generation and Controlled Thermonuclear Fusion," with M. Friedman, V. Serlin, and A. Mondelli, IEEE Trans. Plas. Sci. Vol. PS-14, No. 3, (June 1986).

61. "Numerical Simulation of a Low-Density Plasma Erosion Opening Switch," with J.M. Grossmann, P.F. Ottinger, J.M. Neri, Phys. Fluids 29 (8) 2724-2735 (1986).