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1

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ELECTROMAGNETIC DESIGN CODES MAINTAINED ON THE MFE NETWORK BY THE LAACG*

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ABSTRACT

The Los Alamos Accelerator Code Group (LAACG) maintains the two- and three-dimensional (2-D, 3-D) MAFIA[1] codes and the POISSON/SUPERFISH codes at the National Magnetic Fusion Energy Computer Center (NMFECC). These codes, principally electromagnetic field solvers, are used for the analysis and design of electromagnetic components, e.g., magnets, radio-frequency (rf) structures, pickups, etc. We will give a brief description of all the codes and explain how they may be accessed via the Magnetic Fusion Energy Network (MFENET).

INTRODUCTION

Two sets of codes useful for the computer-aided analysis and design of 2-D and 3-D electromagnetic structures are installed at the NMFECC. The 2-D MAFIA codes in cylindrical and cartesian coordinates and the 3-D MAFIA codes in cartesian coordinates, written by Thomas Weiland and coworkers of the Deutsches Elektronen-Synchrotron (DESY), constitute the first group. The 2-D POISSON/SUPERFISH group for cartesian and cylindrical coordinates is the second installed group. Klaus Halbach of Lawrence Berkeley Laboratory (LBL) developed the theory and Ronald Holsinger working at LBL and Los Alamos National Laboratory (LANL) did the programming for the POISSON/SUPERFISH group.

NMFECC provides large-scale computational support to the magnetic fusion energy community and the larger energy research community. There are four CRAY's available for users at NMFECC (located at Lawrence Livermore National Laboratory).

Guidelines are given below for obtaining a computer account at NMFECC; for obtaining documentation; for accessing source codes, executable codes, and test problems; for compiling and executing the run-time modules.

Examples Using MAFIA and POISSON/SUPERFISH Codes

A representative use of the MAFIA codes is a study[2] to minimize the power loss density in the four-rod radio frequency quadrupole (RFQ) shown in Fig. 1.

Figure 2 is a plot of the MAFIA model. Only two cells are modeled because the structure is periodic.

The resonant frequency of 398.9 MHz calculated by MAFIA is within 2.1% of the measured value, 407.5 MHz. Figure 3 is a plot of the magnetic fields in the rod region just in front of the middle metal plate. The arrows show the amplitude and direction of the magnetic field in the plane of the plot surface. The size of the circles shows the magnitude of the magnetic field normal to the plot surface. A "·" in the circle shows the tip of the arrow coming towards the reader and the "×" in the circle shows the tail of the arrow

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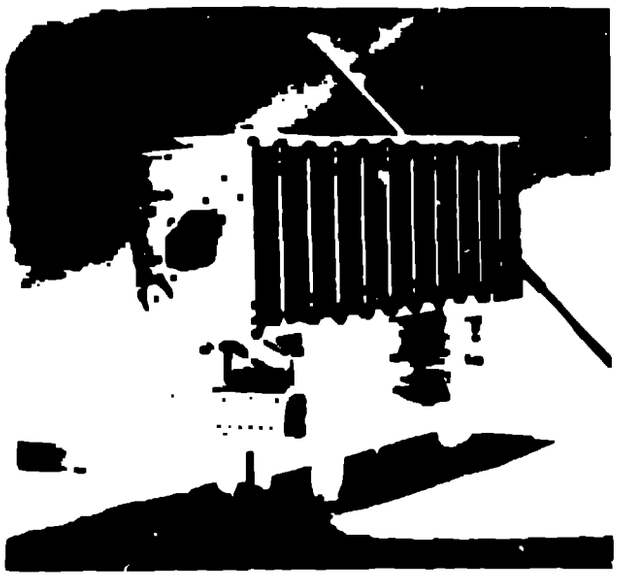

Fig. 1. The four-rod RFQ modeled by the MAFIA codes.

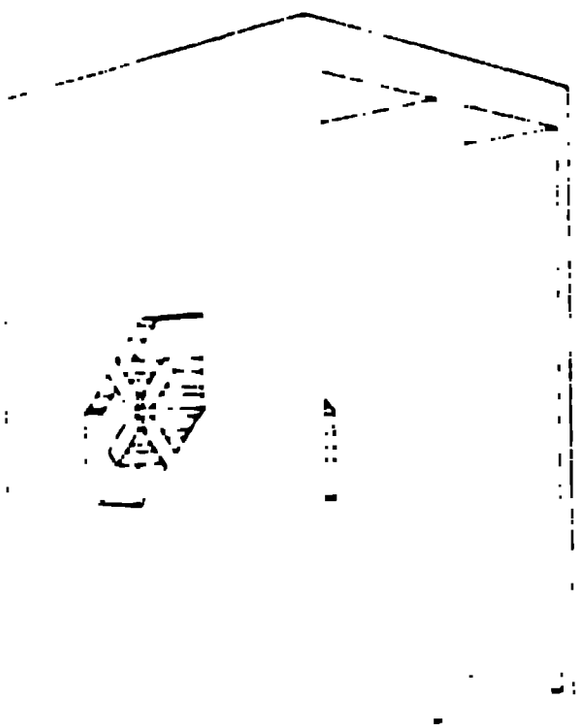

Fig. 2. A plot of the four rod RFQ model produced by the MAFIA codes

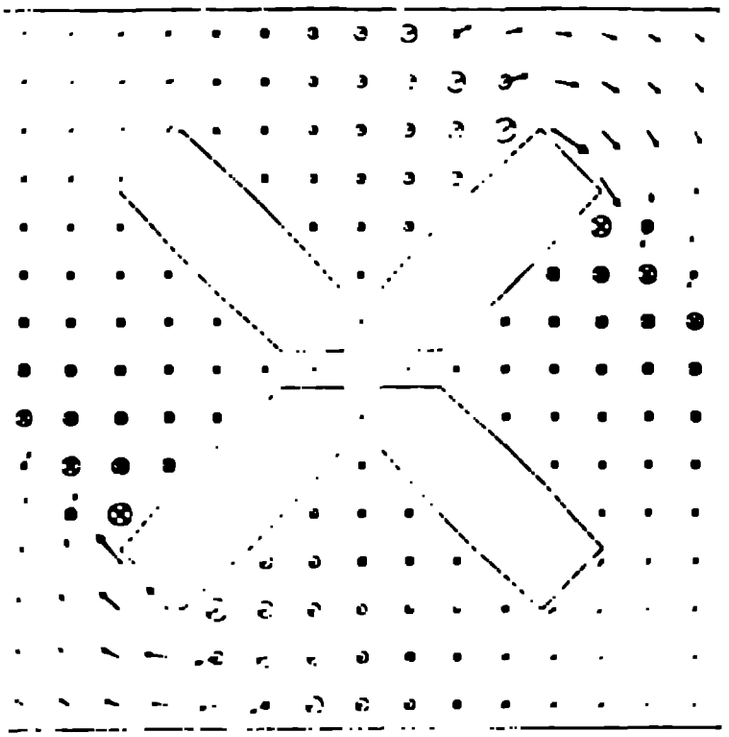

Fig. 3. A magnetic field plot of the rod region just in front of the middle metal plate

going away from the reader. All of the following magnetic field plots were produced by the MAFIA post-processor

Figure 4 is a plot of the magnetic field of the entire x-y plane at the middle metal plate of the modeled structure.

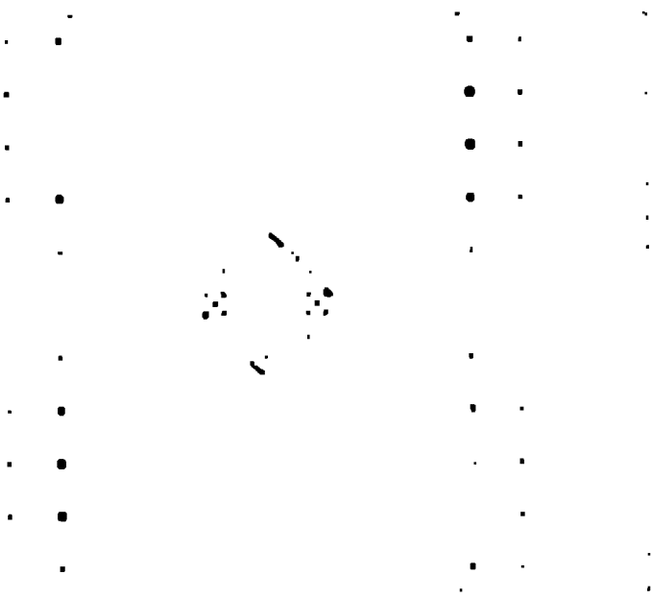

Fig 4. A magnetic field plot of the entire x-y plane at the middle metal plate

The enlarged view of the rod region in Fig. 5 shows the peak magnetic fields. From this plot it can be seen that the peak current flow and power loss is concentrated where the rods are connected to the metal plate.

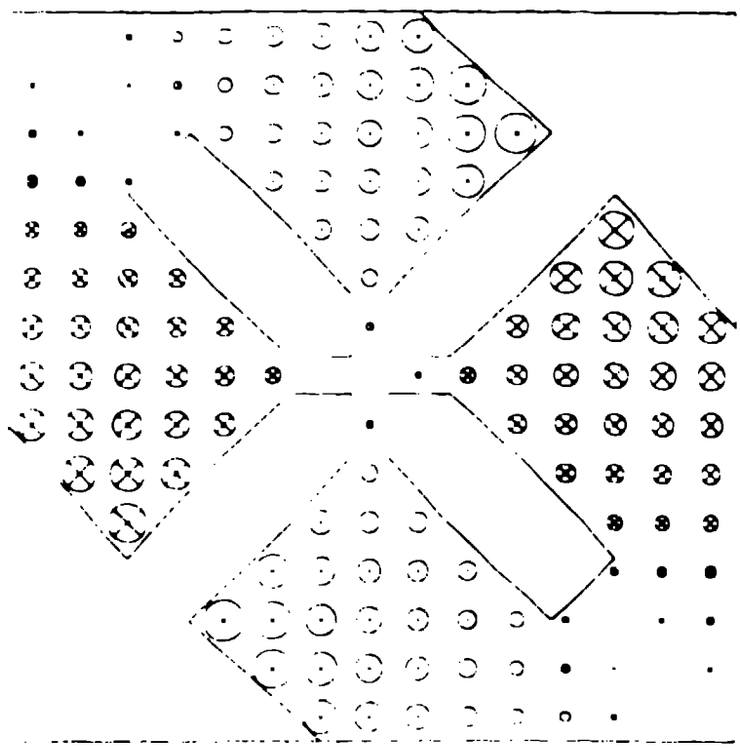

Fig. 5. A magnetic field plot of the rod region at the middle metal plate

Further modeling showed that increasing the width of the base of the rods reduced the power loss density in that region.

A representative use of the POISSON/SUPERFISH codes is magnet design including H magnets, septum magnets, and quadrupoles. These codes have also been used to calculate electric fields between plates of fixed potential in an infinite pipe, and to calculate the fields at both the center and the fringe of a magnetic geometry. Figure 6 is a plot of the magnetic field lines for a quadrupole magnet calculated with POISSON.

Although it is possible to use only one-eighth of the total geometry because of the symmetry, in this case, one-fourth of the geometry was used.

THE MAGNETIC FUSION ENERGY NETWORK AND COMPUTER CENTER

The NMFECC, established in 1974, provides large scale computational support to the magnetic fusion energy community and the larger energy research community. The center facilitates the sharing of information, codes, data, manpower, and computer power among American and Japanese energy researchers.

Currently, the NMFECC user community consists of about 4400 users at about 1[illegible] sites throughout the country and Japan. By means of a nationwide communications network MFENET, users may access the following large scale computers at NMFECC: one CRAY 1 machine (to be phased out shortly), a CRAY XMP 14, and two CRAY 2 machines.

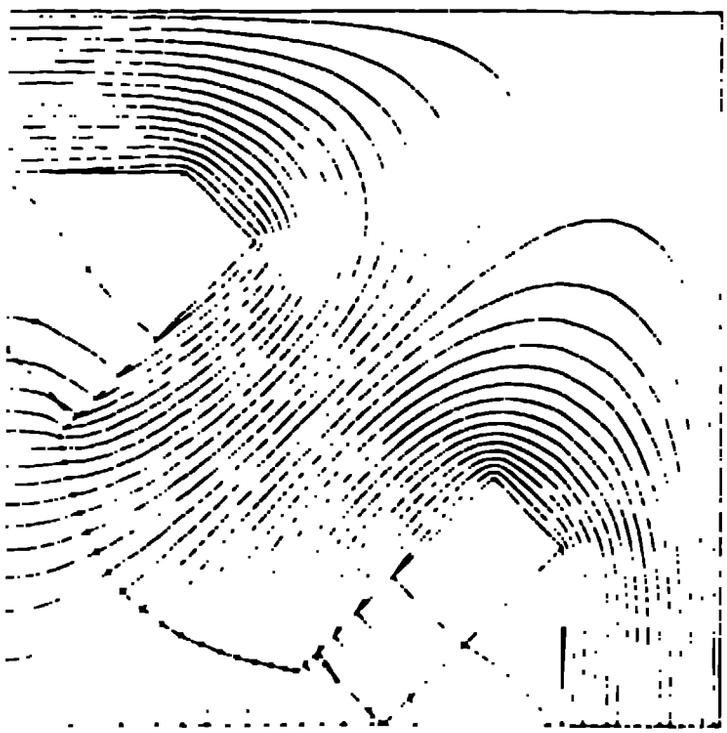

Fig. 6. A plot of the magnetic field lines of one-quarter of a quadrupole

Machine b, a CRAY-2, has 40 Mwords of memory and 4 CPUs; Machine f, a CRAY-2, has 80 Mwords of memory and 4 CPUs; Machine e, the XMP24, has 1.3 Mwords of memory and 2 CPUs. These computers can be accessed via dial-up lines, TYMNET, INTERNET, Remote User Service Station (RUSS), and/or a VAX on MFENET.

Potential users with no access to an NMFECC account need to contact their DOE monitor to determine eligibility for an account. Those eligible then need to contact Dan Hitchcock at the Office of Energy Research at DOE in Washington, D.C.

New users can be added to existing accounts by having their Principal Investigator contact JoAnne Revelli at NMFECC, phone (415) 422-4228.

OVERVIEW OF THE 2-D AND 3-D MAFIA CODE

The 2-D and 3-D MAFIA Systems

The 2-D and 3-D MAFIA systems are sets of computer programs used for the computer aided analysis and design of three dimensional electromagnetic structures including electrostatic and magnetostatic devices, rf cavities, bellows, etc. The programs are the result of an ongoing collaboration between the DESY Laboratory, the Los Alamos National Laboratory, and the Kernforschungs Anlage Jülich. MAFIA is an acronym for the solution of MAxwell's equations using the Finite Integration Algorithm.[3] This algorithm reduces the integral representation for each of MAxwell's equations to a fully generalized matrix equivalent that is convenient for use in large scale computers. Solutions can be obtained in either the frequency domain or the time domain. The theory behind the MAFIA codes is well documented.[4-7] The latest versions, 5.0+ for URMEL and TBCI, 2.0+ for URMEL-T and the 3-D MAFIA codes, are installed and maintained at NMFECC. Figure 7 shows a 3-D MAFIA system diagram.

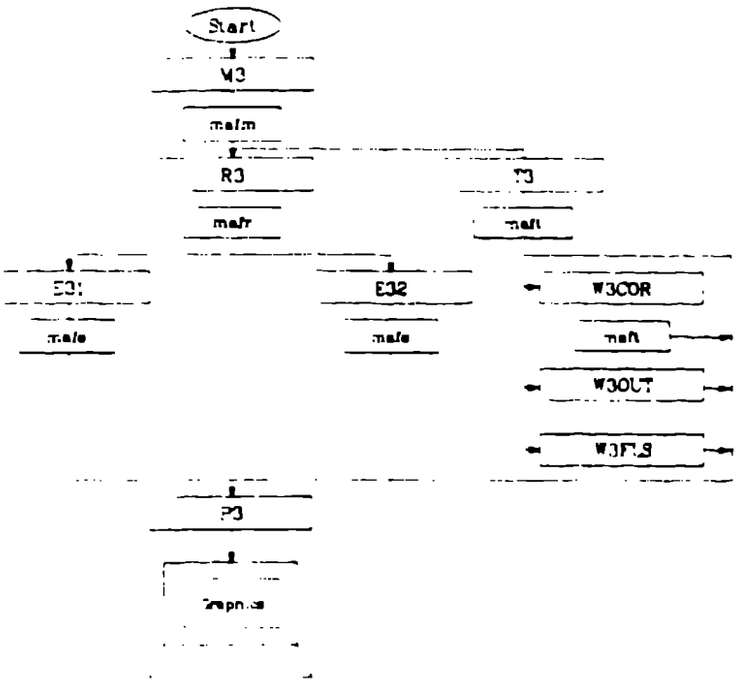

Fig. 7. The 3-D MAFIA system on the NMFECC CRAY computers

The 2-D MAFIA Codes

URMEL *Version 5.02* calculates TM modes in cylindrically symmetric cavities and cutoff frequencies of waves in longitudinally invariant waveguides. The cavity electromagnetic fields may have any azimuthal dependence. The code uses a variable rectangular mesh, which may be subdivided into triangles. The semianalytic processor (SAP)[8] is used to find the eigensolutions. Plots of the geometry and electric and magnetic fields are available.

URMEL-T *Version 2.01* is similar to URMEL but uses a triangular mesh. It also provides for dielectric and for permeable materials; it calculates TE and TM modes and waveguide propagation constants.

TBCI *Version 5.02* calculates the time dependent electric and magnetic fields in cylindrically symmetric structures in which charged particle beams occur. The code also calculates the integrals of the forces acting back upon the particles of the beam as well as force integrals (wake potentials) for test particles accompanying or following the beam. The code uses a square mesh. Plots of the geometry, the electric and magnetic fields, and the wake potential are available.

The 2-D MAFIA Postprocessors

WAKCOR *Version 5.02* calculates the difference between the values of two separate TBCI solutions at identical mesh points. Plots of the resultant wake potential are available.

WAKFLS *Version 5.02* prints the wakefields and wake potentials saved at selected locations for every time step and optionally does a Fourier transform of the fields at selected points.

WAKOUT *Version 5.02* prints the wake potentials saved at selected time steps. Plots of the wake potential are available.

The 3-D MAFIA Preprocessor

M3 – *Version 2.02* generates a rectangular variable mesh for the problem geometric data in cartesian coordinates on a direct access (da) file. At NMFECC, the da file is an absolute file. Selected rectangular mesh cells (bricks) can be subdivided into two triangular bricks. Color plots of the geometry, mesh, and materials used are available in 3-D and in 2-D cut planes.

The 3-D MAFIA Codes

R3 – *Version 2.01* generates the equations and coefficients for the eigenvalue solvers E31 and E32 and appends them on a copied da file. The R3-E3 combination is the 3-D frequency-domain solver.

E31 – *Version 2.02* solves for the eigenvalues and calculates the resonant frequencies and the electric and magnetic fields. The SAP is used to find the solutions. These solutions are appended on a copied da file.

E32 – *Version 2.01* generates solutions as E31 but uses a multigrid technique.

T3 – *Version 2.03* solves for the electric and magnetic fields in the time domain; it also calculates the integrals of the forces acting back upon the particles of the beam as well as force integrals (wake potentials) for test particles accompanying or following the beam. These solutions are appended on a copied da file.

The 3-D MAFIA Postprocessors

P3 – *Version 2.03* analyzes and displays the electric and magnetic field solutions calculated by the main codes and stored on the da file. It provides printouts of the frequencies, field components, electric field energies, power losses, quality (Q) factors, integrals of the field, and net forces for particles with phases 0° and 90°. Color plots are available for the geometry and materials in 3-D and for the electromagnetic fields in 1-D, 2-D, and 3-D.

W3COR – *Version 2.02* calculates the difference between the values of two wake potentials at identical mesh points from two separate T3 solutions stored on da files. Plots of the resultant wake potential are available. The calculated difference is appended on a copied da file.

W3FLS – *Version 2.02* plots the fields and wake potentials saved at specified points at each time step from a T3 solution stored on a da file. This code optionally calculates a Fourier transform of the fields at selected points.

W3OUT – *Version 2.02* prints and plots the scaling function $G(u,v,s)$ for every position s in the beam bunch; also, this code can plot the wake potentials from a T3 solution stored on a copied da file.

OVERVIEW OF THE POISSON/SUPERFISH GROUP OF CODES

The POISSON/SUPERFISH Group of Codes is used in the computer aided design of magnets and rf structures. These codes provide the user with a choice between cartesian (x, y) coordinates and cylindrical (r, z) coordinates. POISSON calculates magnetostatic and electrostatic fields while SUPERFISH computes the resonant frequencies and fields of circularly symmetric TM modes in cylindrically symmetric radio frequency cavities. Dielectric materials and linear magnetic materials can be included in the calculations. These codes use a variable triangular mesh that distorts to fit the problem geometry. The codes are the original eleven programs, the standardized version for the accelerator

community. The latest version, 2.003, November 1, 1988, is installed at NMFECC. Changes include a corrected stored energy calculation[9] in POISSON, PANDIRA, and MIRT; addition of the codes PANT and FORCE; addition of the DISSPLA-based[10] plotting program, DISPLOT, and numerous programming changes bringing the codes closer to FORTRAN77 standards. Figure 8 shows a POISSON/SUPERFISH system diagram.

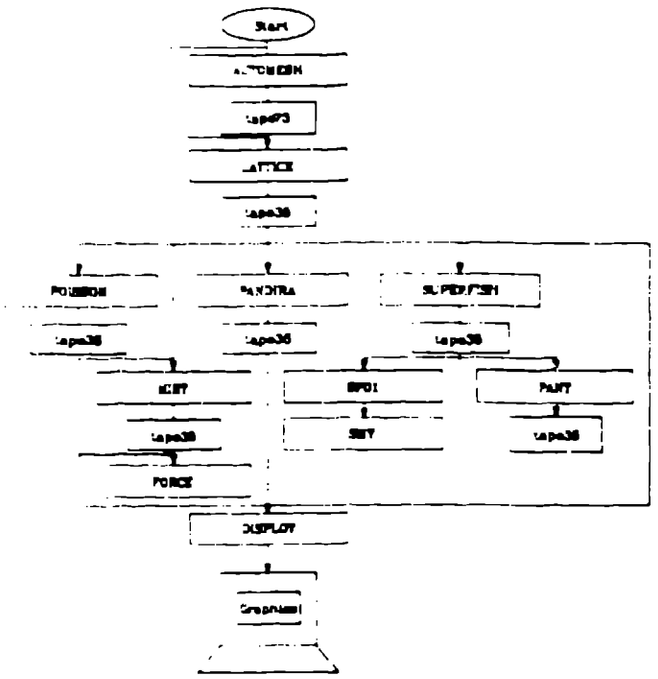

Fig. 8. The POISSON/SUPERFISH system on the CRAY Machine e at NMFECC.

POISSON/SUPERFISH Preprocessors

AUTOMESH generates an ASCII file for input to LATTICE from the problem geometric and material data.

LATTICE generates a binary file, describing the problem to be solved, for input to the main codes.

POISSON/SUPERFISH Codes

POISSON solves Poisson's (or Laplace's) equation for the vector (or scalar) potential for 2-D cartesian geometry or geometry with cylindrical symmetry using "successive point over relaxation" (SPOR).

PANDIRA is similar to POISSON but uses a direct method of solution.

SUPERFISH solves for the TM resonant frequencies and field distributions in an rf cavity with three dimensional cylindrical symmetry; it also solves for the cutoff frequencies and mode patterns for a waveguide. For the cylindrically symmetric cavities, the only modes found are azimuthally symmetric.

MIRT optimizes magnet profiles, coil shapes, and current densities based on a field specification defined by the user. The code can be used as a main code or it can use a POISSON or PANDIRA solution as a starting solution.

PANT calculates a thermal distribution in the walls of an rf cavity. The code can be used as a main code or to postprocess a SUPERFISH solution.

POISSON/SUPERFISH Postprocessors

MIRT and *PANT* see above.

FORCE calculates forces on coils and iron regions from a POISSON, PANDIRA, or MIRT solution.

SF01 calculates auxiliary quantities for the design of drift-tube linacs from a SUPERFISH solution.

SHY calculates H_ϕ and the E fields for a specified region from a SUPERFISH and SF01 solution.

TEKPLOT and *DISPLOT* plot the physical geometry and meshes from a LATTICE solution; plot the equipotential lines from a POISSON, PANDIRA, or MIRT solution; plot the field lines from a SUPERFISH solution; or plot the isothermal lines from a PANT solution.

Documentation of the LAACG NMFECC Codes

On-Line Documentation. NMFECC users logged on to any CRAY and wanting basic information on MAFIA and POISSON/SUPERFISH codes may type in

```
cfs get /lacc/info/readme
end
cat readme
```

for a brief description of each code, documentation available, code storage, and information on accessing, compiling, and executing the codes.

NMFECC users logged on to any CRAY may also read the up-to-date messages on the bulletin board, LAACG POISSON MAFIA, by typing

```
bulletin laacg
```

Hard Copy Documentation. MAFIA Documentation: URMEL and URMEL-T User Guide,[12] TBCI Short User Guide,[13] MAFIA User Guide.[14]

POISSON/SUPERFISH Documentation: POISSON/SUPERFISH User's Guide,[15] POISSON/SUPERFISH Reference Manual.[16]

Any of these manuals, code access permission, or a nine-track POISSON/SUPERFISH tape may be requested from the LAACG by messages sent as follows:

NMFECC users logged on to any computer on MFENET may type in

```
tell at6tcb@lmp
```

BITNET users may use the address:

```
at6tcb@lampf
```

U.S. mail requests may be sent to

```
LAACG
AT-6, MS H829
Los Alamos National Laboratory
Box 1663
Los Alamos, NM 87545
```

Storage of LAACG NMFECC Codes

Central File System (CFS). On the Central File System (CFS) there is a root node, `/lacc`. Under `/lacc` are three directory nodes: `/info`, `/mafia`, and `/poicodes`. Under `/lacc/info` is the file `/readme`.

CFS MAFIA Storage. Only CRAY-executable MAFIA codes (controllees) are available to NMFECC users. Standard length versions named with an `x` concatenated to the source code name, for example `xm3`, are available for Machine e and the CRAY-2 machines. In addition, one million point versions are available for the CRAY-2 machines for all MAFIA codes except URMEL-T. URMEL-T is a 350,000 point version. These versions have a + as the last character of their names, for example `xm3+`. The controllees can be found under the node `/lacc/mafia/e` for Machine e and under the node `/lacc/mafia/2` for the CRAY-2 machines. Test problems are found under the latter nodes under the `tps` directory. The controllees are stored for execution at NMFECC.

CFS POISSON/SUPERFISH Storage. Both sources and controllees are stored for POISSON/SUPERFISH codes for the CRAY XMP (Machine e) and also for any VAX running under VMS. File names are identical to those cited in the POISSON/SUPERFISH User's Guide. The CRAY sources are stored under `/lacc/poicodes/cray/src` with names such as `autso`, `latso`, etc. and the CRAY controllees are stored under `/lacc/poicodes/cray/xeq` with names such as `automesh`, `lattice`, etc. Test examples are stored under `/lacc/poicodes/cray/examples` on separate files and in libraries with names such as `poisex` for a complete POISSON run. Output files in the `poisex` library have a `po` appended to their names for example `outautpo`. A cosmos `jci` file with a name such as `jcipo` that will execute the actual run is included in each example library. The source codes are stored for compiling at NMFECC or for file transfer, and the controllees are stored primarily for execution at NMFECC.

VAX sources are stored under `/lacc/poicodes/vax/src` with names such as `autso.for`, `latso.for`. The executables are stored under `/lacc/poicodes/vax/xeq` with names such as `automesh.exe`, `lattice.exe`. Test examples are stored under `/lacc/poicodes/vax/examples` on separate files and in libraries with names such as `poisex.tlb` for POISSON examples. These files are stored at NMFECC primarily for file transfer.

Access of LAACG NMFECC Codes

MAFIA Code Access. Source codes for the MAFIA systems are distributed solely by DESY, Notkestrasse 85, D2000 Hamburg, The Federal Republic of Germany. Requests for hard copies of release forms may be made to `at6tct@lmp` via MFENET or to `at6tcb@lampf` via BITNET or to the mailing address included in the section on Documentation. Profit-making organizations should expect to negotiate a contract with DESY for use of the MAFIA codes.

POISSON/SUPERFISH Code Access. Anyone with an NMFECC account may have access to the POISSON/SUPERFISH codes. The LAACG requires that a request be made for permission to access either the source or executable codes, but this is only for the purpose of keeping an up-to-date data base of users. Requests may be made to the same network or mailing addresses listed under Hard Copy Documentation.

Execution and compilation of the LAACG—NMFECC Codes

MAFIA Execution. All controllees are stored on CFS as described in the section on storage. To get a controllee in a CRAY local file space type in (for example)

```
cfs get dir=/lacc/mafia/e xm3
end
```

All 2-D and 3-D codes except for P3 require an ASCII input file. The CRAY input files are always the name of the source code concatenated with `in`. For example, the input file for M3 is `m3in`. All the MAFIA codes except P3 (where it is optional) produce an ASCII output (print) file. The output file name is again the source code name concatenated with `out`. URMEL-T is the exception; its ASCII output file is named `urmeltou`. The 3-D MAFIA codes use a da absolute file for intercommunication. That file name is `maf` concatenated with the first letter of the 3-D code name. M3 produces `mafm`, which is used for communication with R3. P3 in turn produces `mafr`, etc. For large problems familying will place on the da files. The scheme used at NMFECC is that if the first file is named `mafm`, for example, then the second is `mafm01`, etc., but the last file has a name ending in `x`, such as `mafm1x`. Libraries of test examples are in `/lacc/mafia/tps`. For 3-D MAFIA, the file `-3r3e31` contains inputs and outputs for a complete 3-D frequency-domain calculation.

In codes where plots are available, a menu will request that the user select one option from 20 plot options. Some options will be followed by queries for baud rate and box number. The experienced user may select the file substitution option available and freely substitute file names for expected file names and also may type in `po=` for plot option, `baud=` for baud rate, `xob=` for box number right on the execution line. For example, typing in

```
xm3 po=2 xob=q36 mafm=maftest
```

results in `xm3` executing with plot option 2 box number q36; the da file produced will be named `maftest`. File substitution is not available for plot file names.

Input files for test problems can be obtained by typing in (for example)

```
cfs get /lacc/mafia/tps/m3r3e31
end
lib m3r3e31
x
end
```

All input and output files will be in the local file space. Output files will have a 1 appended or substituted for the last character in file names over seven characters long so that comparisons can be made.

POISSON/SUPERFISH Execution. All controllees are stored on CFS as described in the section on storage. To get a controllee in a CRAY local file space type in (for example)

```
cfs get dir=/lacc/poicodes/cray/xeq automesh
end
```

For each test example library included in CFS under `/lacc/poicodes/cray/examples`, there is a `jci` file that will execute with COSMOS. This `jci` file will get all the necessary files from CFS, extract all files from the library, and execute the problem with a running log displayed at the terminal. A log file is also produced for later viewing. Each test example library also has a `readme` file with a more detailed explanation of how the codes run. For example, to run the POISSON test example, type in
example, type in

```
cfs get /lacc/poicodes/cray/examples/jcipo
end
cosmos jcipo
```

At NMFECC, all plots are made with the code DISPLOT. A menu similar to the MAFIA initial plotting menu will be displayed and will request that the user select one of the 20 plot options presented. Some options will be followed by queries for baud rate and box number. The experienced user may type in `po=` for the plot option, `baud=` for the baud rate and `xob=` for the box number right on the execution line. For example, typing in

```
displot po=3 baud=9600
```

will result in DISPLOT executing the plot option 3 at 9600 baud. Please note that TEK PLOT based on PLOT10[17] stored in CFS node `/lacc/poicodes/cray/xeq` will not execute at NMFECC and is stored in CFS for file transfer convenience only.

POISSON SUPERFISH Compilation. All POISSON/SUPERFISH CRAY source codes in local disk space can be compiled on Machine e by typing in (for example)

```
trixgl o(libso) run end
```

The library source code `libso` must be compiled first followed by `poiso`, then the remaining source codes may be compiled in any order.

Up-to-date instructions for compiling on the CRAYs or VAXes will always be available in the `readme` files stored in

```
/lacc/poicodes/cray/info/readme.c
or
/lacc/poicodes/vax/info/readme.v
```

To transfer files to an MFNET computer type in (for example) `netout libso.for site=lmp user=at6tcb binary`. Use the `binary` option for all file types. If the transfer site is a VAX-VMS, there must be a directory with all world privileges named `user.net`: for the above example: `at6tcb.net`.

REFERENCES

[1] R. Klatt, F. Krawczyk, W. R. Novender, C. Palm, T. Weiland, B. Steffen, T. Barts, M. J. Browman, R. Cooper, C. T. Mottershead, G. Rodenz, and S. G. Wipf, "MAFIA – A Three-Dimensional Electromagnetic CAD System for Magnets, RF Structures, and Transient Wake-Field Calculations," Proc. 1986 Linear Accelerator Conference, Stanford Linear Accelerator Center report SLAC-303 (June 1986), pp. 276-278.

[2] M. J. Browman, G. Spalek, P. B. Friedrichs, T. C. Barts, "Studies of the Four-Rod RFQ using the MAFIA Codes," Los Alamos National report LA-UR-88-3263, Proceeding the 1988 Linear Accelerator Conference (October 1983), to be published.

[3] T. Weiland, "On the Numerical Solution of Maxwell's Equations and Applications in the Field of Accelerator Physics," *Particle Accelerators* 15 (4), 245-292 (1984).

[4] T. Weiland, "Numerical Solution of Maxwell's Equation for Static, Resonant and Transient Problems," in *U.R.S.I. International Symposium on Electromagnetic Theory*, Akademiai Kiado, Ed. (Budapest, Hungary, 1986), Part B., pp. 537-542.

[5] T. Weiland, "On the Unique Numerical Solution of Maxwellian Eigenvalue Problems in Three Dimensions," *Particle Accelerators* 17(3-4), 117-242 (1985).

[6] T. Weiland, "Transverse Beam Cavity Interaction, Part I: Short Range Forces," *Nuclear Instruments and Methods* (NIM) 212, 13-34 (1983).

[7] R. Klatt and T. Weiland, "Wake Field Calculations with Three Dimensional BCI Code," in *Proceedings of the 1986 Linear Accelerator Conference*, Stanford Linear Accelerator Center report SLAC-303 (June 1986), pp.282-285.

[8] J. Luckmantel, "Application of SAP in URMEL," CERN report EF/RF 85-4 (September 1985).

[9] J. Liu and R. A. Thiessen, "A Correction of the Magnetic Stored Energy Calculation for the POISSON Computer Code," (AHF Technical Note 88-008), (Los Alamos, March 1988).

[10] Computer Associates International, "DISSPLA 10.0 User's Manual," (Garden City, New York, 1988).

[11] American National Standards Institute, Inc., "American National Standard Programming Language FORTRAN," (NewYork, 1978).

[12] U. Laustroer, U. van Rienen, T. Weiland, "URMEL and URMEL-T User Guide," DESY M-87-03 (February 1987).

[13] R. Klatt and T. Weiland, "TBCI Short User Guide" (unpublished) (January 1, 1988).

[14] The Mafia Collaboration, "MAFIA User Guide," Los Alamos National Laboratory (in process).

[15] M. T. Menzel, H. K. Stokes, "User's Guide for the POISSON/SUPERFISH Group of Codes," Los Alamos National Laboratory report LA-UR-87-115 (January 1987).

[16] Los Alamos Accelerator Code Group, "POISSON/SUPERFISH Reference Manual," Los Alamos National Laboratory report LA-UR-87-126 (January 1987).

[17] Tektronix Incorporated, "PLOT 10 Terminal Control System User's Manual," (Beaverton, Oregon, 1979)