CODE DEVELOPMENT FOR 3D RF CAVITIES CALCULATIONS

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ABSTRACT

First version of the RFC-3D code for calculation of several lowest eigenfrequencies and corresponding fields in 3D cavities with arbitrary shape is described. To approximate differential problem, in this version, finite difference method with regular mesh in each direction is used. Numerical algorithm for eigenvalue solvers is based on fictitious components method, which leads to small requirements of computer memory. Results of some test calculations, comparison with URMEL-3D and examples of practical problems are given.

INTRODUCTION

It is difficult to suppose now the development of modern hardware without preliminary numerical simulation of main parameters to find optimal solutions. Essential part takes numerical simulation in the development of accelerating structures and another equipment with RF cavities. The problem of numerical simulation of fields distributions in RF cavities in 2D approximation may be just considered as a solved. There are known many codes, satisfying (in the limits of 2D approximation) practically all wishes of users. Next step in code progress is the development of codes for essentially 3D simulation. There are known not so many really used 3D codes. For accelerators hardware design MAFIA [1] system is widely used. Requirements, which 3D codes provide to computer resources, stimulate usage of modern sophisticated numerical methods for solvers realization. In this paper first version of RFC-3D code for RF cavities of arbitrary shape is described. To solve eigenvalue grid problem fictitious components method is used. Feature of the methods is that, to obtain the result of eigenvalue problem it is needed to solve the set ofauxiliary problems only for boundary mesh nodes. It results in essential reduction of memory and number of arithmetical operations needed.

DESCRIPTION OF THE PROBLEM AND METHOD OF SOLUTION

Assuming harmonic time dependence of the electromagnetic field components and do usual transformations of Maxwell equations, we obtain second order equation for electric components

$$\Delta E + k^2 E = 0 \qquad (1)$$

and boundary condition

$$[E\ n] = 0 \qquad (2)$$

where Δ is Laplace operator and n - unit normal to the boundary.

In order to approximate differential problem (1) finite difference methods is used. The mesh step is constant along each direction, but for different directions it is different also. All details of approximation technique and forming of the discrete problem are described in Ref [2]. The grid problem has the same spectral properties, as initial differential one. To solve grid problem fictitious components method is used. It was proposed for solution of elliptical problems and later generalized for eigenvalue problems Ref. [3]. In this paper we do not consider this method, and all references needed are given in Ref. [2,3]. Note only main features. To solve initial eigenvalue problem it is needed to form and to solve a set of auxiliary eigenvalue problems. This auxiliary problems have essentially less dimension, because they is defined only for nodes at the boundary. The computer memory needed for auxiliary problems solution is of order $N^{2/3}$ where N is the number of nodes in total grid. Lanzosh method is used to solve auxiliary problem. Differing from described in Ref.[2] realization, present one is modified to calculate simultaneously several lowest modes. Algorithm allows successfully calculate not only near eigenvalues, but degenerated one.

It is known well, that in solutions of the problem (1) may be not only rotational, but and potential modes. Separation of potential modes provides when magnetic fields distribution calculates.

THE COMPUTER PROGRAM

Present version of the RFC-3D code consists of several modules. First pre-processor block is intended to provide mesh. The cavity describes by using simple geometrical language with wide possibilities. Geometry design provides by superposition of simple three dimensional bodies (sphere, cube, etc.) and bodies arise as a result of operation (rotation, shift) with two dimensional figures. It is able to provide some operations (rotation, shift, scaling, reflection) with parts of the cavity to construct total one. Certainly, symmetry condition of the problem may be used. Main-processor code provides forming and solution of the set of auxiliary eigenvalue problems. Post-processor code is intended to provide physical results (quality factor, shunt resistance, etc.), to separate potential modes and to represent solution graphically . For data exchange and intermediate information storage direct-acsess files are used.

All codes are written in pure FORTRAN 77. Minimum dependence of computer type and operating system is foreseen. The features of algorithm allow to use computers with small (in present comprehension) memory. Now RFC-3D is available at VAX-like computers and IBM PC AT. Usage IBM PC AT with 286 processor and standard MS DOS system allows to solve not large (with 10000-15000 nodes) problems and to prepare data for big one. The possibility to use personal computers for calculations to estimate results in order of value makes very attractive RFC-3D code.

TEST CALCULATIONS AND APPLICATION

Test calculations for simples cavities (cylindrical, spherical, rectangular) show relative error in frequency in order 10^{-3} with number of nodes in total grid 4000. CPU time for five root calculation is in order 40 minutes for computer with 0.8 Mflops efficiency. Results of comparison with URMEL-3D calculations [4] are given in Table 1 for test #7 and test #5 [4]. For test #7 calculations RFC-3D mesh is identical to URMEL-3D one and results coincide utterly. It was noted in Ref.[4] 'it has been built .....measured and compared with calculation. Excellent agreement was found.' Small difference in results for test #5 is due to nonuniform mesh in URMEL-3D code (total number of nodes was the same in our calculation). As for CPU time, we can not do direct comparison. Indirect comparison shows more high efficiency of the RFC-3D algorithm for large meshes and small number (2-5) modes under calculation.

As example of mesh for cavity, exited in TE-like mode, is given in Fig.1 . This mesh (contains 50653 nodes) is shown only as illustration, because in practical calculations larger meshes are used. For example, mesh in drift-tube cell calculation was 506964 nodes. Computer memory needed was 3.1 Mbytes, CPU time 22 hours of the 0.8 Mflops computer, and relative error in frequency 0.2%.

SUMMARY

First version of the RFC-3D code for three dimensional RF cavities calculations is described. Application of the fictitious components method permits to develop codes with small requirements to computer memory. It allow to do 3D calculations with using personal computers. Work to improve the code and to develop next version is under way.

REFERENCES

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[3] YU.A.Kuznetsov. Iterative methods in subspaces for eigenvalue problem. Opt. Soft. Inc. New York, p.96, 1986

[4] MAFIA User Guide, LANL, Los Alamos, USA, 1988

Table 1. Results of calculations with RFC-3D and URMEL-3D

mode	Test #5		Test #7	
	RFC-3D	URMEL-3D	RFC-3D	URMEL-3D
1	544.223	544.65	1168.18	1168.18
2.	1398.027	1396.79	2253.52	2353.53
3	2434.759	2433.99	2300.49	2300.50
4.	3376.203	3374.50	2441.59	2441.60
5.	4283.319	2433.99	2495.97	2495.98
6.	5231.472	5318.86		
7.	6094.527	6089.52		
8	6992.036	6986.00		
9.	7854.245	7847.64		
10	8276.869	8298.07		

Fig. 1 Cavity exited in TE-like mode. Example of the mesh.