SRF/D 960814-09

SUPERLANS/CLANS
Local User Guide

Sergey Belomestnykh
Laboratory of Nuclear Studies, Cornell University, Ithaca, NY 14853

Foreword

The necessity of this Local Guide arose when we recently finished the installation of the SUPERLANS/CLANS groups of codes in the SRF Program Library. We have already several documents published: "SUPERLANS/ SUPERSAM Codes. User's Guide" [1], "SUPERLANS for Pedestrians" [2], and "Using CLANS/CLANS Accuracy Tests" [3] - but all those notes were written and published a while ago and are therefore not up to date in their description of the usage of the programs on the CESR cluster of VAX computers. That is why we decided to write this new Local Guide. It is, in some sense, a compilation of [2] and [3] with corrected information about using the codes on VAX/VMS at LNS, with added description of the difference between the VAX/VMS and Alpha/VMS versions of the codes.

Introduction

SUPERLANS is a computer code that calculates the monopole modes of RF cavities like SUPERFISH. But SUPERLANS uses the finite element method of calculation and a mesh with quadrilateral biquadratic elements in contrast to the finite difference method and triangular mesh used by SUPERFISH. Relative to the finite difference method, the finite element method gives better accuracy with the same mesh size or similar accuracy with a more coarse mesh. Additional features of SUPERLANS include the evaluation of traveling waves in periodic structures, the parameters of longitudinally homogeneous structures, and the cut-off frequencies in longitudinally homogeneous waveguides; the modes (up to 10) are calculated simultaneously in a frequency range set by user. SUPERLANS can handle RF cavities containing ferromagnetic and dielectric materials with low losses.

The CLANS computer code is very similar to SUPERLANS; it differs from SUPERLANS in that it allows the user to input variable ε and μ and/or high-loss materials.

SUPERLANS (CLANS) consists of two parts: the mesh generator, GENMESH, which is common for both codes, and SUPERLANS (CLANS) itself. To introduce the reader to the SUPERLANS code, we consider a simple problem first and then, in subsequent sections, give some more details about the code modules, the differences in geometry input for CLANS, running CLANS, and the Metafile Utilities. Advanced users sooner or later will want to read the SUPERLANS User’s Guide [1] for more details.

Terminals and Graphics

Originally, SUPERLANS was realized on the IBM PC/AT and the graphical capabilities of this computer were widely used. Graphical methods simplified the cavity geometry input in particular. We have a version of this code modified for VMS on VAX and Alpha computers. *Important note: the names of input files for GENMESH and SUPERLANS (CLANS) must have length equal to or less than 8 characters* (as in the PC version). The VMS version has both interactive and batch modes for all stages of calculation except for the output of the results, which must be done interactively. At the present time, we have a version of SUPERLANS which uses the GKS Graphics Standard and allows us to use color and black and white terminals running DEC, DEC/MOTIF or VWS/UIS windows or a VT240 terminal/emulator for graphical features.

SUPERLANS and CLANS are now present in the SRF Library, so running any SUPERLANS (CLANS) program on the CESR VAX cluster or CESR67 is rather simple. If you have the lines

```
$ @[SRF.COM]SRF$LOGIN
$ SDO SRF$COMMANDS
```

in your LOGIN.COM, then you need only type the name of the program or command file to run it.

As far as we use GKS we could either use the default plotting device or choose one of the other available devices. To make this task easier Walter Hartung has made a special command-menu for SRF Library users. You need only type

```
$ GKSET
```

and then choose the number for the desired plot device.

One can run SUPERLANS (CLANS) on VAX stations (for example, CESR18 and CESR19), on CESR10 or on the Alpha machine (CESR67). But if the geometry of your structure requires a rather fine mesh, you probably will want to run the code on CESR10 or the Alpha. You can do this from any VT220 or color NCD terminal or from a VAX or DEC station (LNS277, for example).

VT220.

You will not get any graphics on screen in this case, but the programs will run. This way could be useful if you know your geometry file is correct: you can run faster without graphics and later run SLANSRE or CLANSRE (see below) to see the graphics. And do not forget to type `VT220` to set your terminal properly!

VAX station running VWS/UIS on a local node (CESR18).

By default, the code will direct the graphics to a separate window. A VT240 terminal can also be used: open ReGIS VT200 window on CESR18 and select a VT240 via GKSET. A third alternative is a Tektronix emulator: open a Tek 4014 window on CESR18 and select the corresponding terminal via GKSET.

VAX station running VWS/UIS(CESR18) from remote node.

You can `SET HOST` to CESR10 or CESR67 from CESR18 and run the codes remotely. In this case you will not be able to display the graphics in a separate window, but you can use a VT240 or Tek 4014 terminal to display the graphics, as desribed above.

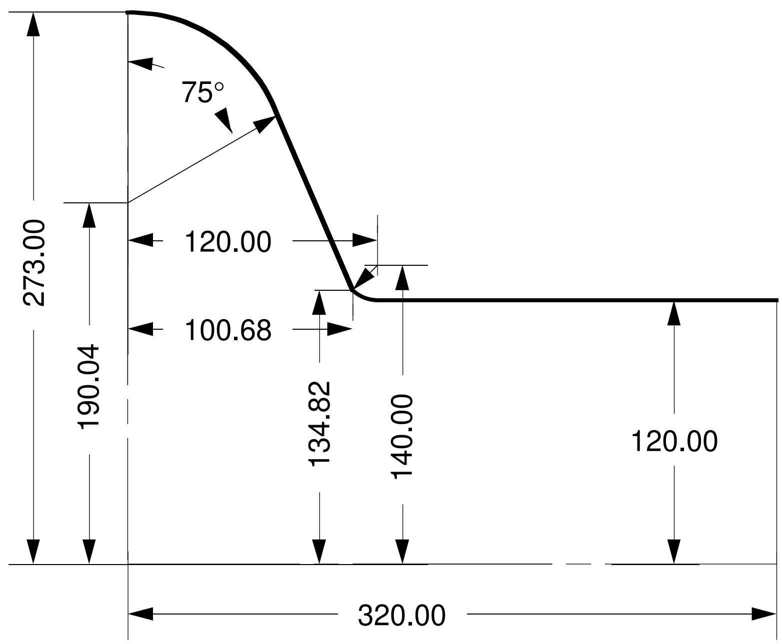

Figure 1. BB1 geometry

VAX station running DEC windows on a local node(CESR19).
One can use GKSET to select a separate Motif window or a VT240.

X terminal (NCD terminal, CESR19, LNS277).
The X session must be opened on CESR10 or CESR67 with the NCD window manager. Alternatively one can `SET HOST` to CESR10 or CESR67 from a VAX station or from a DEC station (LNS277, for example). It is possible to select a separate window or to a VT240 via GKSET. One need `SET DISPLAY` in the case of a VAX station or a DEC station:

```
$ SET DISPLAY /CREATE /NODE=CESR19
```

or

```
$ SET DISPLAY /CREATE /NODE=LNS277
```

Also, insted of using GKSET, one can set two GKS parameters (workstation type and connection ID) by typing

```
$ DEFINE GKS$WSTYPE 230
$ DEFINE GKS$CONID CESR19::0
```

for CESR19 (VAX station under DEC/Motif windows) or

```
$ DEFINE GKS$WSTYPE 230
$ DEFINE GKS$CONID LNS277::0
```

for LNS277 (DEC station under DEC/Motif windows).

A SUPERLANS Example

Consider the 500 MHz superconducting RF cavity BB1 as an example. As the BB1 shape is symmetric relative to the $z=0$ plane, we can input only the right half of the geometry (Figure 1). First of all, we must input the geometry and generate the mesh. Before running any code we should look at the geometry and imagine the corresponding logical mesh. But what is a logical mesh? A logical mesh is a real geometry mapped onto the i j plane, where the i coordinate labels mesh elements in the $z(x)$-direction, and the j coordinate corresponds to the $r(y)$-direction. Each part of the cavity boundary must lie along the i or j direction on the logical mesh.

The BB1 shape consists of four parts: the top of the cavity (a circular arc of 75°), the side (a straight segment at a 75° angle from the z-axis), the iris (a 75° circular arc), and the beam tube (a straight segment parallel to the z-axis). Apart from these, we should add a symmetry plane at $z=0$, and an end plane at $z=L/2$, where L is the length of the cavity. We must map this geometry onto the logical mesh and choose the number of mesh elements for each portion of the boundary. We think it is better to divide the top circular arc into two parts to get a more uniform mesh. So, let the first circular arc subtend 33° and have 4 mesh elements along the i logical coordinate, and the second subtend 42° and have 4 mesh elements along the j coordinate. The side part has a rather large angle of inclination relative to the z-axis, so it is suitable to place it along the j logical coordinate; let it have 4 mesh elements. Proceeding analogically, let us choose 3 mesh elements for the iris along the j coordinate and 6 for the beam tube along the i coordinate, and, finally, 5 mesh elements along the i coordinate for the end plane of the cavity. Thus, we have a mesh size of $N_i*N_j=10*16$. In addition, it will be useful to divide the segment along the axis into two parts (6 and 4 mesh elements) to obtain a more uniform mesh.

We will assume that we are using a default graphical display of one of our workstations, and describe how to run SUPERLANS in interactive mode. Now we are ready to run the mesh generator. The simplest way to do this is to use the GEO command file:

```
$ GEO
```

This command file first runs the program INGEO to input the geometry. The base level menu appears in the upper right-hand corner of the screen. We select the command "I - input geometry" (to select a command from the menu, press the key with the first capitalized letter corresponding to the desired command, or use the cursor keys <Up> and <Down> to highlight the command and then press <Return>). After that, the program asks for the size of graphical window and then we should type "C" in answer to the question about the kind of geometry (electron gun or RF cavity). Then a new menu appears (geometry input level), along with a list of boundary conditions.

We must first define the type and size of the mesh elements. So we select the command "M - mesh size". We choose the number of elements in each direction (10 and 16 in our case), biquadratic elements ("S"), axial symmetry ("A") and the dimensional units ("CM"). The logical mesh is drawn in the upper right-hand quadrant of the plotting area.

Well, at last we can start to input the geometry! We select the command "K - contour begin" from the menu, input the initial point of our contour $(Z=0,R=0)$, and press <Enter>. Now we begin to go around the contour in the clockwise direction. The next contour element in this direction is the segment of the symmetry plane, so we choose the command "S - segment", input the

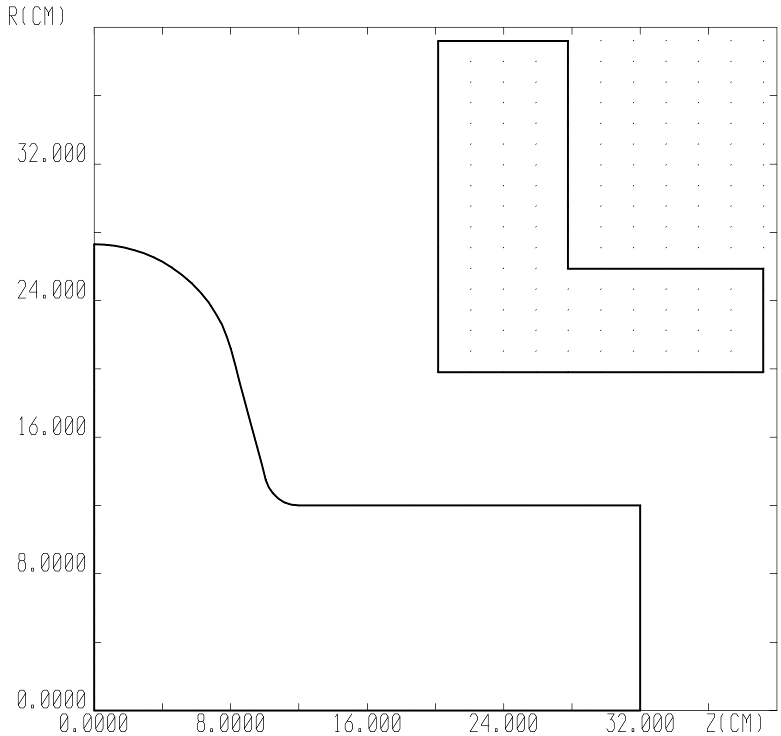

Figure 2. The BB1 geometry. File `BB1_ING01.MTF`

```
           8          10          16     2      2
10    0.00000    0.00000      .00000     .00000    0    0    0    0
 1    0.00000   27.30000      .00000    1.10000    0   16    2    0
 3    0.00000   19.00403   -33.00000    1.00000    4    0    5    0
 3    0.00000   19.00403   -42.00000    1.00000    0   -4    5    0
 1   10.06815   13.48236      .00000    1.00000    0   -4    5    0
 2   12.00000   12.00000      .00000    1.00000    0   -3    5    0
 1   32.00000   12.00000      .00000    1.00000    6    0    5    0
 1   32.00000    0.00000      .00000    1.00000    0   -5    2    0
 1   12.00000    0.00000      .00000    1.00000   -6    0    4    0
 1    0.00000    0.00000      .00000    1.00000   -4    0    4    0
 0     .00000     .00000      .00000     .00000    0    0    0    0
```

Figure 3. Text file `BB1.GEO`

coordinates of the end point *(Z=0,R=27.3)*, shift the cursor on the logical mesh up 16 elements to the point *(0,16)* and press <Enter>. Then we input the other parameters for this segment: the coefficient of mesh compression $Q=1.1$ (to make the variation between elements more smooth), the boundary condition $IB=2$ (for even modes, or $IB=3$ for odd modes), and the volume flag, $IV=0$. The next contour element is a circular arc. We select "A - arc (center, angle)", input the coordinates of the center of the circle *(Z=0,R=19.00403)*, the angle in degrees *(-33)*, shift the cursor on the logical mesh right to the point *(4,16)*, input $Q=1$, $IB=5$ (metal boundary), and $IV=0$. And so on and so forth... The last contour element in our case is the segment to the point *(Z=0,R=0)*, since the contour must form a closed polygon on the logical mesh. The screen should now look like Figure 2.

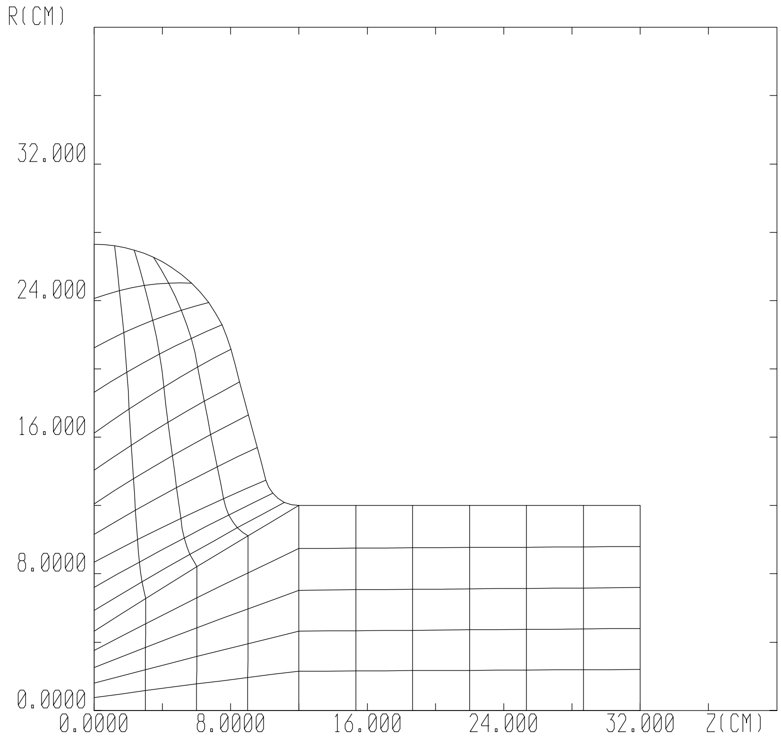

Figure 4. The mesh for the BB1 cavity. File `BB1_GEN01.MTF`

We should remark that there are two possibilities for inputting the iris arc: "arc (center, angle)" and "conjugated arc". We used a conjugated arc in this example. So, we have finished the input of the geometry and can select the command "X - exit" and return to the main menu.

Any plot created by SUPERLANS can be written into a so-called metafile in a special format. There are utilities to view metafiles and to convert them into other formats (see the section Utilities for Metafiles). Metafile names have the following structure: 'NAME'_'PNM'nn.MTF. Here 'NAME' is the unique name of the input geometry (BB1 in our example), 'PNM' is the abbreviated name of the program-creator (3 characters: ING, GEN, SLC, or SLR), and nn is the metafile number (between 00 and 99).

To save our geometry we select "W - write the geometry" in the main menu, and type the file name (let it be BB1). The text file BB1.GEO is created in the current directory (Figure 3). Then we select the command "E - exit and write contour". INGEO creates the binary file KON.KON and finishes its work.

The GEO command file then runs the next program, GENINM. This program calculates the coordinates of the mesh nodes and draws the mesh (see Figure 4). GENINM produces the binary file SET.SET, which contains information about the mesh.

The next step in running of SUPERLANS is to use the SL command file:

```
$ SL
```

This command file executes several programs in sequence: SLANSC, SLANSM, SLANSS, and SLANSRE. Various binary and text files are created in the process. A complete list of files and programs is given in Table 2. But we should mention that only the text files and metafiles are usually important to the user.

```
::B-factory cell #1                                  Date:17-MAY-94
          3 :number of iterative modes 1-10
          2 :number of search modes
 1.0000000E-06 :convergence accuracy
         20 :maximum number of iterations
          0 :continue iterations or not 1,0
  500.0000     :initial frequency shift MHz
          1 :wave type 1-E, 2-H
          1 :struct. 1-cav,2-per.str,3-w.guid.,4-l.-hom.
          1 :symmetry yes or not 1,0
          1 :number of met.surfaces, then:sign and sigma
          5   1.000000
          0 :number of mark volumes,then:sign,EPS,MU,TGE,TGM
```

Figure 5. Text file BB1.DTR

The first program, SLANSC, asks for the name of a text file with parameters for the calculation 'NAME'.DTR. If that file exists, you can update the parameters; if it doesn't exist, you must input all the necessary parameters. For our example, we set parameters as shown in Figure 5.

After that, SLANSC finishes its work, and SL executes the programs SLANSM, SLANSS, and SLANSRE. SLANSRE allows us to examine the results of the calculation on the screen and to choose which results we would like to store in output text files or metafiles. SLANSRE first asks for the name of the file with the results. Then we define the normalization and the parameter β (the ratio of the particle velocity to the light velocity).

Then a menu appears in the upper right-hand corner of the screen. The first command we must select is "M - mode number" to define which mode we want to examine. Now we have various possibilities for looking at and/or storing the results. We will not describe them, but instead give the reader the chance to play with them him/herself. Examples of the available output are shown in Figures 6 - 11.

When you are finished playing with SLANSRE, select the command "E - exit" and then press the <Esc> or <F11> key when the program asks for results file. SLANSRE and SL will finish their work.

To get a hard copy of the results written to the text file BB1.SVL, use a print command, for example:

```
$ CNPRINT BB1.SVL /NAME=F_F612P
```

To display or plot metafiles , we can use the special metafile utilities: MFGKS, MFPS, MFSHOW, MFVIEW, MTFVIEW, and MFHP. MFGKS allows us to output the plot on the screen of a GKS output plotting device:

```
$ MFGKS BB1_ING01.MTF
```

MFPS translates the metafile to PostScript format; we can then print out the PostScript file:

```
$ MFPS BB1_ING01.MTF PLOT1.PS
$ CNPRINT PLOT1.PS
```

More detailed information about these utilities can be found in the section Utilities for Metafiles.

```
::B-factory cell #1                                   Date:17-MAY-94

*SLANS* NUMBER OF MODE  1; ACCURACY  1.564E-07
  CAVITY RADIUS  27.3000 CM, LENGTH  64.0000 CM
  FREQUENCY .............  5.0207E+02 MHZ
  LENGTH OF WAVE .........   59.71137 CM
  WAVE VALUE .............  0.1052259 1/CM
  QUALITY FACTOR ......... 4.1502E+04
  STORED ENERGY .......... 3.5847E+00 J
  TRANSIT TIME FACTOR ....     0.5048
  EFFECTIVE IMPEDANCE ....  4.421E+01 OHM
  SHUNT IMPEDANCE ........    1.83499 MOHM
  MAXIMUM MAG. FIELD .....  1.386E+04 A/M
   NEAR POINT R= 22.101 CM , Z=  7.696 CM
  MAXIMUM ELEC.FIELD .....  8.431E+00 MV/M
   NEAR POINT R= 12.983 CM , Z= 10.278 CM
  ACCELERATION ...........  1.000E+00 MEV
  ACCELERATION RATE ......  1.563E+00 MEV/M
  AVERAGE E.FIELD ON AXIS   3.095E+00 MV/M
  KM (Emax/Accel.rate)....    5.39565
  KH (Hmax*Z0/Accel.rate).    3.34276

*SLANS* NUMBER OF MODE  2; ACCURACY  5.728E-07
  CAVITY RADIUS  27.3000 CM, LENGTH  64.0000 CM
  FREQUENCY .............  9.7409E+02 MHZ
  LENGTH OF WAVE .........   30.77682 CM
  WAVE VALUE .............  0.2041531 1/CM
  QUALITY FACTOR ......... 6.0250E+04
  STORED ENERGY .......... 6.7848E+01 J
  TRANSIT TIME FACTOR ....     0.0395
  EFFECTIVE IMPEDANCE ....  1.204E+00 OHM
  SHUNT IMPEDANCE ........    0.07255 MOHM
  MAXIMUM MAG. FIELD .....  6.969E+04 A/M
   NEAR POINT R= 12.000 CM , Z= 31.968 CM
  MAXIMUM ELEC.FIELD .....  1.256E+01 MV/M
   NEAR POINT R= 18.648 CM , Z=  8.684 CM
  ACCELERATION ...........  1.000E+00 MEV
  ACCELERATION RATE ......  1.563E+00 MEV/M
  AVERAGE E.FIELD ON AXIS   3.958E+01 MV/M
  KM (Emax/Accel.rate)....    8.04147
  KH (Hmax*Z0/Accel.rate).   16.80348

*SLANS* NUMBER OF MODE  3; ACCURACY  5.260E-06
  CAVITY RADIUS  27.3000 CM, LENGTH  64.0000 CM
  FREQUENCY .............  1.0602E+03 MHZ
  LENGTH OF WAVE .........   28.27797 CM
  WAVE VALUE .............  0.2221936 1/CM
  QUALITY FACTOR ......... 6.8359E+04
       .....
```

Figure 6. Secondary values for the BB1 cavity. Text file `BB1.SVL`

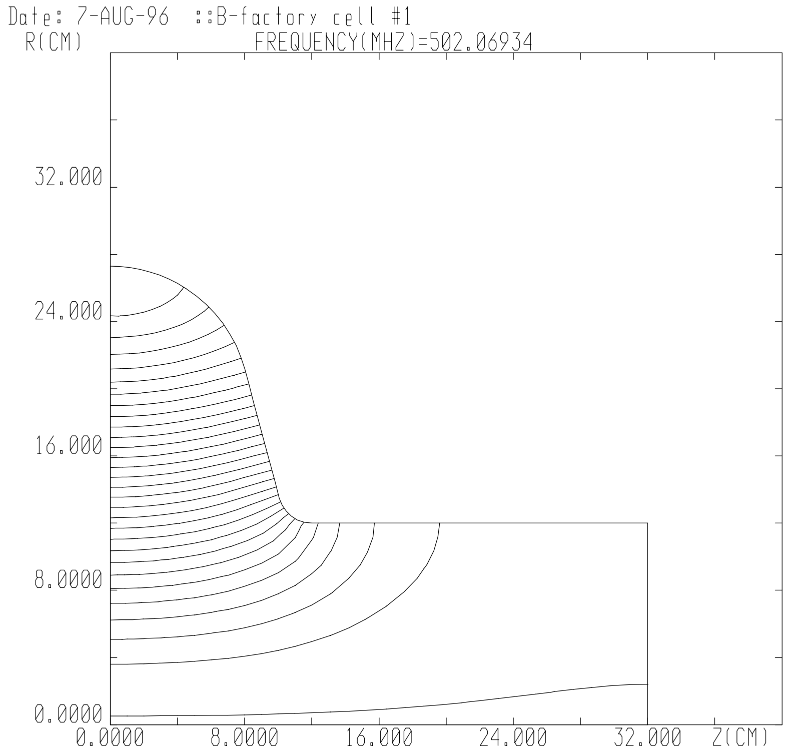

Figure 7. Force lines for the fundamental mode. Metafile `BB1_SLR01.MTF`

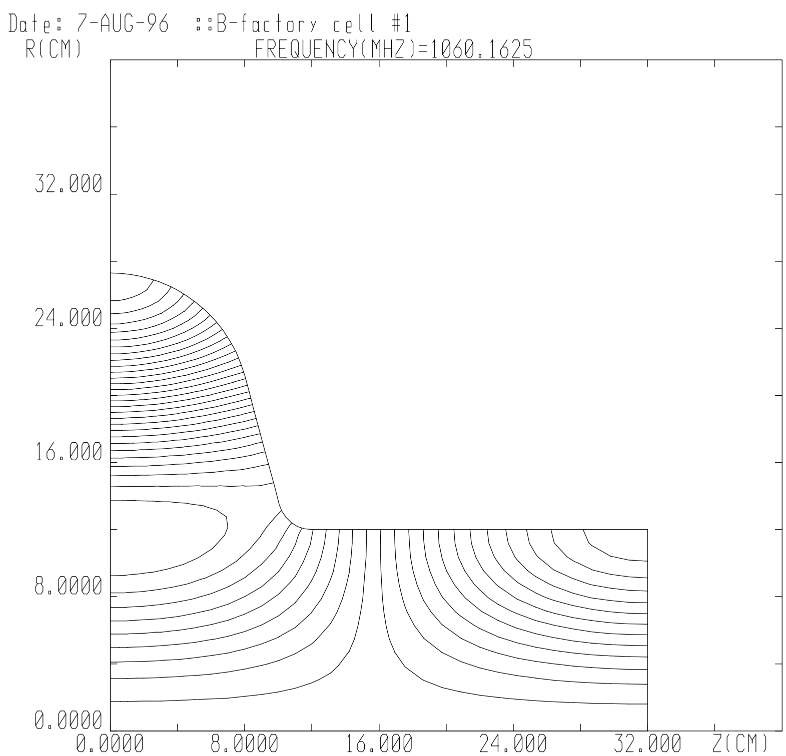

Figure 8. Force lines for one of the HOMs. Metafile `BB1_SLR02.MTF`

```
 ::B-factory cell #1                               Date:17-MAY-94
 Mode number          3;Frequency MHz   1060.163    ;Accuracy  5.2604164E-06
 Fields on metall
Normalization V(MeV)=   1.000000
   ZS(CM)     RS(CM)     ES(MV/M)    HS(A/M)    EZ(MV/M)  ER(MV/M)
 0.000E+00  2.730E+01  2.369E-02  1.201E+04 -5.171E-02 -1.651E-02
 5.968E-01  2.728E+01  1.816E-01  1.199E+04 -4.709E-02 -1.833E-01
 1.190E+00  2.721E+01  3.671E-01  1.192E+04 -7.842E-02 -3.482E-01
 1.190E+00  2.721E+01  3.671E-01  1.192E+04 -7.579E-02 -3.699E-01
 1.778E+00  2.711E+01  5.387E-01  1.181E+04 -1.228E-01 -5.261E-01
 2.356E+00  2.696E+01  7.186E-01  1.165E+04 -2.202E-01 -6.678E-01
 2.356E+00  2.696E+01  7.186E-01  1.165E+04 -2.090E-01 -7.036E-01
 2.922E+00  2.677E+01  8.924E-01  1.145E+04 -3.055E-01 -8.394E-01
 3.473E+00  2.654E+01  1.070E+00  1.120E+04 -4.855E-01 -9.336E-01
 3.473E+00  2.654E+01  1.070E+00  1.120E+04 -4.454E-01 -9.937E-01
 4.006E+00  2.627E+01  1.247E+00  1.090E+04 -5.631E-01 -1.112E+00
 4.518E+00  2.596E+01  1.414E+00  1.056E+04 -3.592E+01  2.168E+01
 4.518E+00  2.596E+01  1.414E+00  1.056E+04 -3.592E+01  2.168E+01
 5.136E+00  2.552E+01  1.639E+00  1.005E+04 -9.769E-01 -1.315E+00
 5.711E+00  2.502E+01  1.847E+00  9.465E+03 -1.257E+00 -1.341E+00
 5.711E+00  2.502E+01  1.847E+00  9.465E+03 -1.282E+00 -1.339E+00
 6.237E+00  2.447E+01  2.067E+00  8.788E+03 -1.540E+00 -1.377E+00
 6.712E+00  2.388E+01  2.268E+00  8.023E+03 -1.821E+00 -1.352E+00
 6.712E+00  2.388E+01  2.268E+00  8.023E+03 -1.814E+00 -1.350E+00
 7.130E+00  2.325E+01  2.484E+00  7.163E+03 -2.128E+00 -1.282E+00
 7.488E+00  2.258E+01  2.686E+00  6.198E+03 -2.420E+00 -1.184E+00
 7.488E+00  2.258E+01  2.686E+00  6.198E+03 -2.376E+00 -1.165E+00
 7.783E+00  2.188E+01  2.910E+00  5.126E+03 -2.750E+00 -1.016E+00
 8.013E+00  2.115E+01  3.252E+00  3.901E+03 -3.078E+00 -8.999E-01
 8.013E+00  2.115E+01  3.252E+00  3.901E+03 -3.234E+00 -9.809E-01
 8.270E+00  2.019E+01  3.573E+00  2.021E+03 -3.394E+00 -9.303E-01
 8.527E+00  1.923E+01  3.588E+00 -3.503E+01 -3.543E+00 -9.763E-01
 8.527E+00  1.923E+01  3.588E+00 -3.503E+01 -3.523E+00 -9.657E-01
 8.784E+00  1.828E+01  3.393E+00 -2.146E+03 -3.251E+00 -8.639E-01
 9.041E+00  1.732E+01  2.994E+00 -4.195E+03 -2.939E+00 -7.911E-01
 9.041E+00  1.732E+01  2.994E+00 -4.195E+03 -2.934E+00 -7.881E-01
 9.298E+00  1.636E+01  2.410E+00 -6.081E+03 -2.309E+00 -6.150E-01
 9.554E+00  1.540E+01  1.621E+00 -7.689E+03 -1.608E+00 -4.146E-01
     .....
```

Figure 9. Surface fields. Text file `BB1.FLS`

Running GENMESH

GENMESH includes two programs: INGEO, for input geometry, and GENINM, for mesh generation.

INGEO allows us to input a new geometry, save a geometry into a file, read a geometry from an existing file, and create a contour for the program GENINM. If you would like only to input a new geometry or to edit (or just look at) an old one, type

```
$ INGEO
```

To create a mesh after inputting the geometry, type

```
$ GENINM
```

after running INGEO. Instead of running INGEO alone, one can run the special command file GEO, which will run first INGEO and then GENINM, by typing

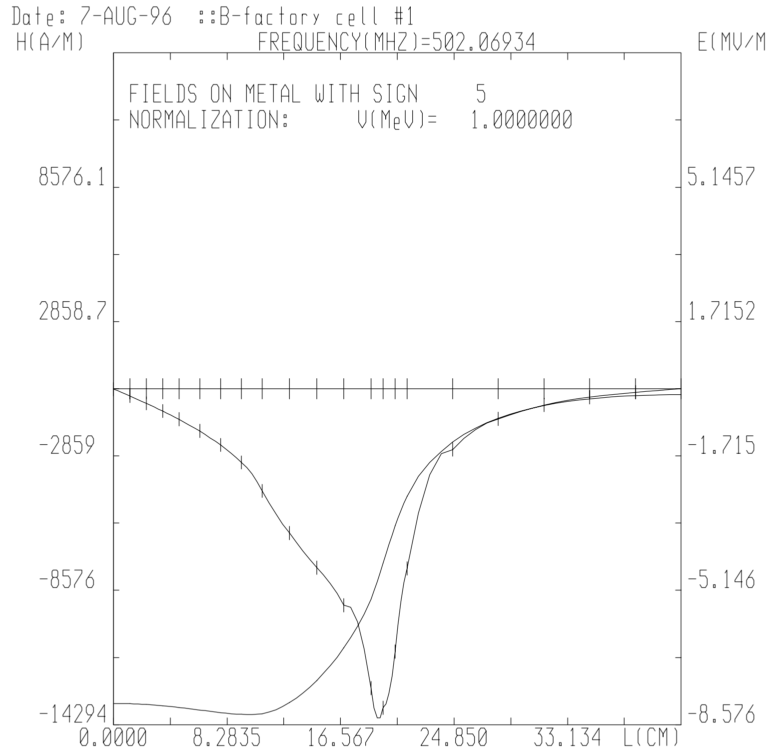

Figure 10. Surface fields for the fundamental mode. Metafile `BB1_SLR04.MTF`

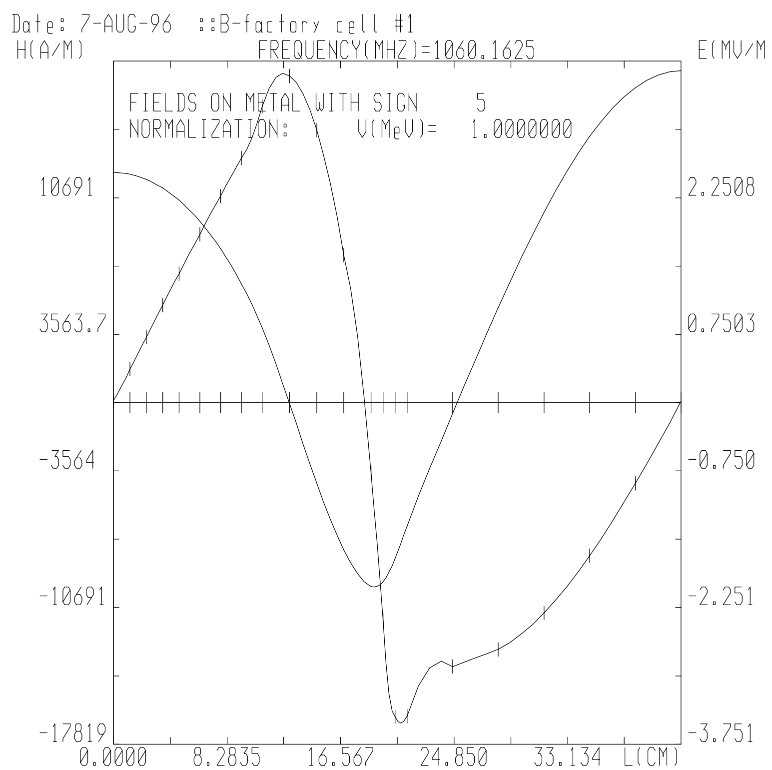

Figure 11. Surface fields for one of the HOMs. Metafile `BB1_SLR06.MTF`

$ GEO

SUPERLANS has a rather friendly designing system of interactive menus. One can select a command from the menu by pressing the key with the first capitalized letter corresponding to the desired command or by using the cursor keys <Up> and <Down> to highlight the desired command and then pressing <Return>. *Remember: SUPERLANS uses mainly upper case characters and it doesn't allow you to use the numeric keypad for inputting numbers!*

The library VIDIG, written by Serguei Mankov [4], is used by SUPERLANS to support the interactive dialog. This library allows us to edit character strings during input. The keys <Left>, <Right>, <Backspace>, <Insert> (<0> on the numeric keypad of the VT220), and <Delete> (<.> on the numeric keypad of the VT220) are used as in a text editor. The <Up> key erases the entire input string, while the <Down> key erases the substring between the cursor and the end of the line. <Home> (<7> on the numeric keypad of the VT220) moves the cursor to the beginning or the end of the input string. <Control><G> switches between overstrike and insert mode. SUPERLANS allows three input terminators: <Return>, <F11> and <Esc><Esc>. The first is used for normal termination, while the last two are used mainly to quit the program or to stop the information input in progress.

The detailed information on how to use INGEO and examples are given in the User's Guide [1], so we shall make only some important remarks here. At first you are at the base level. The menu for this level allows you to read an existing geometry from a text file 'NAME'.GEO , where 'NAME' is the unique name of your geometry. You can then draw the geometry on the screen or edit it, using the edit menu. Alternatively, you can input a new geometry using the input menu. The geometry of the cavity can consist of contour elements of several types: straight line segments, circular arcs (two possible types), and quarters of ellipses. You can input either the whole cavity shape, or, if the geometry is symmetric, only the right half.

Contour elements, having different boundary condition indices (see below), will be drawn in different colours on a colour terminal or in different line types on a black and white terminal. The correspondence between the boundary condition index and line type is given in Table 1.

Table 1. Line types in the INGEO program.

Boundary condition index (sign)	Line type
1 (inner contour)	dotted
2	dashed
3	dotted
4 (axis, r = 0)	solid
5, 7, ... (metal)	solid
6, 8, ... (metal)	dashed-dotted

In any case, don't forget to write the geometry in the text file 'NAME'.GEO after creating or revising it! Then you can either quit without writing the contour or exit and write the contour into the binary file KON.KON for the mesh generator GENINM.

If the cavity geometry file exists already, we prefer to edit it using a text editor (EDT or TPU). We think it is easier to use this way because the file 'NAME'.GEO has a rather simple structure (see Figure 3). The first line of this file contains information about the number of element nodes (8 for biquadratic elements), the number of logical mesh elements along the x-axis, the number of logical mesh elements along the y-axis, the problem type (1 = flat, 2 = axisymmetric), and the dimensional unit index (m, cm, mm or µm). The rest of the lines have a regular structure and contain information about the type of each contour segment, coordinates, mesh compression coefficient, increasing logical mesh coordinates, the boundary condition index, and the volume flag. The mesh compression coefficient allows us to make the variation in mesh element size more smooth. This coefficient is equal to ratio of the length of the last and first mesh elements of the contour segment. The boundary condition index is used to determine the boundary condition along the contour (for details, see [1], pp. 2-9, 2-10). The volume flag has a nonzero value when the cavity contains materials ([1], p. 2-4). After editing the geometry file, one must run the INGEO program or the GEO command file to check the changes, write a new contour, and generate the mesh. The geometry of the BB1 cavity with its logical mesh is shown in Figure 2.

The current version of SUPERLANS (as well as CLANS) has a limit on the number of mesh nodes: this number must be less than 20,000 (3,000 in earlier versions). One can calculate this number using the formula

$$N_{nodes} = 3N_iN_j + 2N_i + 2N_j + 1 .$$

There is also a limit on the number of contour elements (< 100).

The GENINM program calculates the coordinates of the mesh nodes and draws the mesh. Information about the mesh GENINM is recorded in the binary file SET.SET. GENINM also creates the matrix file A.MTX, but if one uses GEO, KON.KON and A.MTX are deleted when GENINM is finished. Before starting the calculation, *make sure that you have enough free space on you disk for the files* created by the programs. For example, when I calculated a spherical cavity with mesh size 30 by 30, A.MTX occupied 7722 blocks on disk!

GENMESH also has a batch mode. To use this mode, one should run INGEO or GEO with a parameter:

```
$ GEO 'NAME'.GEO
```

In batch mode, the programs will not draw plots or create metafiles.

Running SUPERLANS

SUPERLANS consists of five programs: SLANSC, SLANSM, SLANSS, SLANSRE, and SLANSD. The first four are used in calculating cavity modes. SLANSD is used in addition to the others to calculate dispersion curves for periodic structures. The programs are executed in the order given above. One can run the programs individually or use one of the five command files: SL, SL1, SLBG, SLBP, SLD.

SL executes SLANSC, SLANSM, SLANSS, and SLANSRE in sequence. SL1 executes all of the codes except SLANSRE (which is useful for batch jobs). There is also a batch regime for repeated calculation. If the geometry is different in each calculation, one must use SLBG batch file. It executes GEO and SL1 for up to 8 different geometries. The command string is, for example:

```
$ SLBG TEST1,TEST2,TEST3,TEST4
```

TEST1, TEST2, ... are the names of .GEO and .DTR files. If the geometry is the same for all the runs and only the calculation parameters are different, one can use the SLBP file. It executes SL1 up to 8 times. The command string has the same structure. But now TEST1, TEST2, ... are the names of .DTR files only; the geometry from the last GEO run is used in all cases.

The first program, SLANSC, requests interactive input if one runs it without a parameter. The parameter is the name of .DTR text file without its extension. This file contains parameters for the calculation (see Figure 6).

When all the calculations are finished, we use the program SLANSRE to choose which results we would like to store in output text files or metafiles (see Table 2). Several examples of possible output are shown in Figures 6 - 10. SLANSRE can normalize the results using the stored energy (W), the accelerating voltage (V), or the average field on axis (E). If you would like to use the latter option, make sure that you have calculated even modes - for odd modes, $E = 0$ and the program will terminate with an error message! In the case of a fatal error you will see the files FOR010.DAT, FOR011.DAT and FOR012.DAT in your directory. These are temporary files created by SLANSRE and you can delete them.

SUPERLANS and CLANS use the following definition of the R/Q (`EFFECTIVE IMPEDANCE` in the 'NAME'.SVL file):

$$R/Q = \frac{V_{acc}^2}{2\omega_0 U} ,$$

where U is the stored energy in the cavity, ω_0 is the resonant angular frequency, and V_{acc} is the accelerating voltage.

As we mentioned above, SUPERLANS allows you to calculate periodic structures. To use this option, use the SLD command file. SLD executes SLANSC, then N times SLANSM, SLANSS, and SLANSD, and then SLANSRE. Here N is the number of points that are calculated on the dispersion curve.

NM	TETA (RAD)	F (MHZ)	Q	BETGR	ROEFF (OM/CM)	RSHUNT (MOM/CM)
Next mode						
1	0.000000	1.277E+03	2.861E+04	-6.301E-10	1.460E+01	4.176E-01
1	0.285599	1.277E+03	2.861E+04	8.049E-03	1.586E+01	4.538E-01
1	0.571199	1.278E+03	2.861E+04	1.548E-02	1.684E+01	4.817E-01
1	0.856798	1.281E+03	2.861E+04	2.172E-02	1.742E+01	4.984E-01
1	1.142397	1.284E+03	2.861E+04	2.627E-02	1.754E+01	5.019E-01
1	1.427997	1.287E+03	2.861E+04	2.875E-02	1.719E+01	4.919E-01
1	1.713596	1.290E+03	2.861E+04	2.892E-02	1.641E+01	4.695E-01
1	1.999195	1.294E+03	2.861E+04	2.673E-02	1.529E+01	4.374E-01
1	2.284795	1.296E+03	2.861E+04	2.233E-02	1.394E+01	3.989E-01
1	2.570394	1.299E+03	2.861E+04	1.604E-02	1.251E+01	3.578E-01
1	2.855994	1.300E+03	2.860E+04	8.379E-03	1.112E+01	3.180E-01
1	3.141593	1.301E+03	2.860E+04	-9.698E-09	9.872E+00	2.824E-01

Figure 12. A table of dispersion curves for the TeSLA structure. Text file `TESLA.SVD`

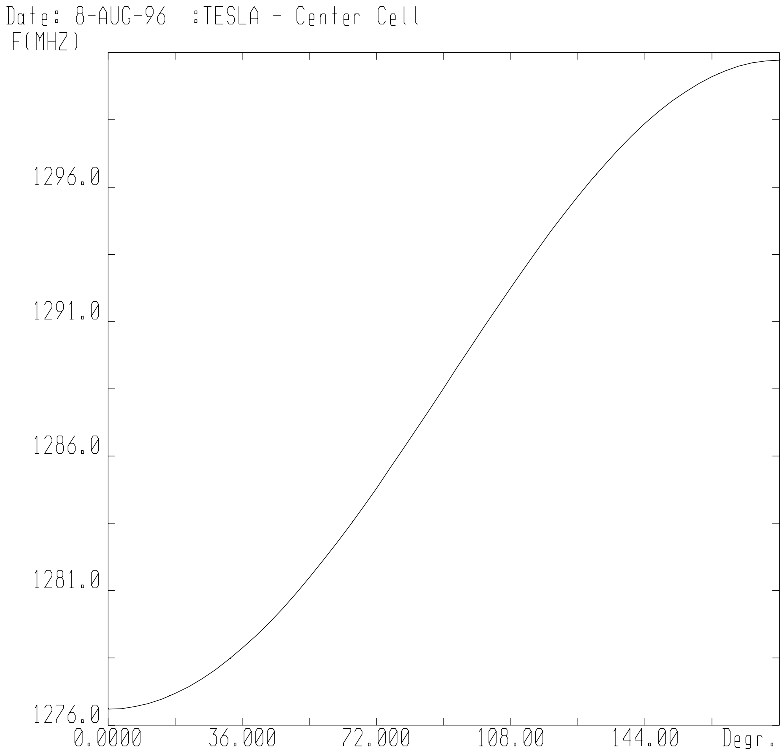

Figure 13. A dispersion curve for the TeSLA structure. Metafile TESLA_SLR01.MTF

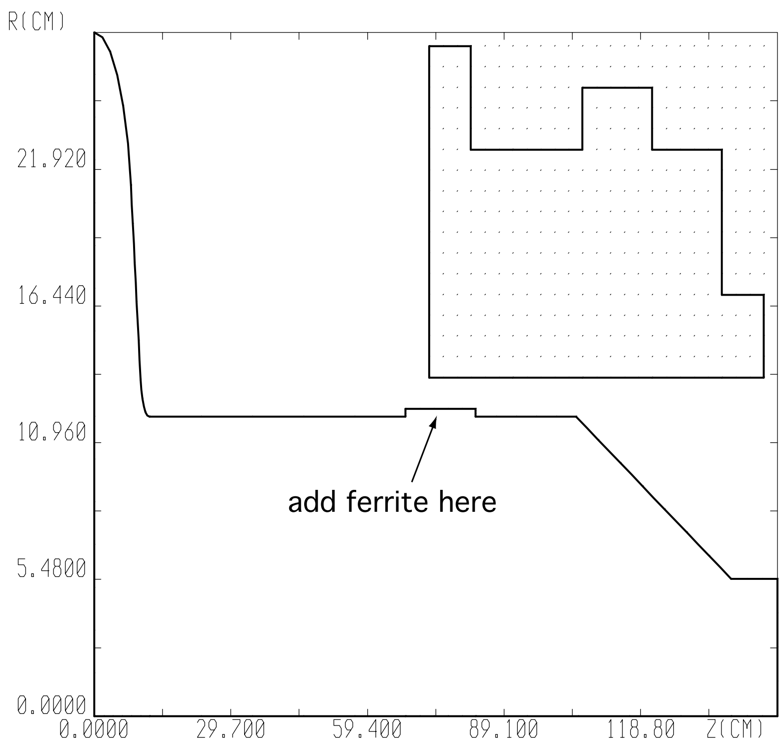

Figure 14. Cavity Geometry

```
          8            24            16            2          2
 10   .0000      .00000     .00000     .00000     0    0    0    0
  1   .0000      27.4000    .00000     1.00000    0   16    2    0
  3   .0000      19.1400    -75.00     1.00000    3    0    5    0
  1   10.0680    13.4820    .00000     1.00000    0   -5    5    0
  3   12.0000    14.0000    75.000     1.00000    3    0    5    0
  1   67.6900    12.0000    .00000     1.00000    5    0    5    0
  1   67.6900    12.3180    .00000     1.00000    0    3    5    0
  1   82.9300    12.3180    .00000     1.00000    5    0    5    0
  1   82.9300    12.0000    .00000     1.00000    0   -3    5    0
  1   104.7800   12.0000    .00000     1.00000    5    0    5    0
  1   138.5000   5.50000    .00000     1.00000    0   -7    5    0
  1   148.5000   5.50000    .00000     1.00000    3    0    5    0
  1   148.5000   .00000     .00000     1.00000    0   -4    5    0
  1   138.5000   .00000     .00000     1.00000   -3    0    4    0
  1   82.9300    .00000     .00000     1.00000   -5    0    4    0
  1   67.6900    .00000     .00000     1.00000   -5    0    4    0
  1   12.0000    .00000     .00000     1.00000   -5    0    4    0
  1   .0000      .00000     .00000     1.00000   -6    0    4    0
 10   67.6900    12.00000   .00000     1.00000   11   11    0    0
  1   82.9300    12.00000   .00000     1.00000    5    0    1    1
  0   .0000      .00000     .00000     .00000     0    0    0    0
```

Figure 15. Text file 'NAME'.GEO

The Floquet theorem [5] is used in the calculations to construct a traveling wave with a given phase shift over the structure period from two real functions. Possible output includes dispersion curves (plotted or stored in the text file 'NAME'.SVD) and information about both the symmetric and antisymmetric standing-wave functions for each mode and each phase shift. *Remember that for a periodic structure, you must input only half of the cavity geometry and set the proper boundary conditions (see [1])!* Sample output is shown in Figures 12 - 13.

Inputting the Geometry for CLANS

CLANS uses the same type of input file as SUPERLANS ('NAME'.GEO). To add a volume with variable ε and μ material, you need to add a contour to your input file. One can do it using INGEO, but it is probably easier to just edit the text file 'NAME'.GEO. You should insert your new lines directly above the last line (which should start with 0). As an example, consider adding a piece of ferrite to the geometry is shown in Figure 14. The new input file is shown in Figure 15 (with added lines in italics).

The first added line defines the new contour beginning point, so it begins with 10. The next two numbers are the Z and R coordinates of the starting point respectively. The next two numbers don't matter for this line and can be 0 and 1 respectively. Now, the next two numbers usually define the increase in mesh lines in the Z and R directions respectively. However, it is a little more tricky now because we must be consistent with the mesh lines we defined on the previous contour (non-italic type). For this first line, we define how many mesh lines over/up this point is from (0,0). We believe this starting point must lie exactly at a previously defined Z and R mesh line. In our example, we can see that in the previous contour the point (67.69,12.0) was 11 mesh lines in the Z direction and 11 mesh lines in the R direction from (0,0). Therefore, we must enter 11 and 11 for our new contour to be consistent.

0.40000E+09	10.153	-22.603	14.525	-0.45130
0.41000E+09	9.9037	-22.245	14.518	-0.44479
0.42000E+09	9.6691	-21.907	14.512	-0.43193
0.43000E+09	9.4402	-21.589	14.509	-0.41924
0.44000E+09	9.2174	-21.282	14.505	-0.41280
0.45000E+09	9.0043	-20.998	14.501	-0.40446
0.46000E+09	8.8012	-20.725	14.502	-0.39317
0.47000E+09	8.5980	-20.478	14.495	-0.38652
0.48000E+09	8.3955	-20.232	14.495	-0.37596
0.49000E+09	8.1969	-20.008	14.495	-0.36526
0.50000E+09	7.9958	-19.784	14.493	-0.36215
0.51000E+09	7.8013	-19.579	14.490	-0.35205
0.52000E+09	7.5965	-19.376	14.492	-0.34764
0.53000E+09	7.3937	-19.180	14.491	-0.34175
0.54000E+09	7.1895	-18.983	14.489	-0.33071
0.55000E+09	6.9934	-18.795	14.492	-0.32706
0.56000E+09	6.7909	-18.605	14.493	-0.32105
0.57000E+09	6.5846	-18.416	14.491	-0.31576
0.58000E+09	6.3812	-18.228	14.493	-0.30792
0.59000E+09	6.1814	-18.041	14.495	-0.30236
......				

Figure 16. Text file `'NAME'.EM1`

The next two numbers can be 0 and 0. Next, you define your contour as before You must continue to be consistent with the mesh lines you define here and those defined previously. In the example, the next line is a line segment from our starting point (67.69,12.0) to (82.93,12.0). Therefore we must increase our mesh line by 5 in the Z direction and 0 in the R directions because that is what we did in the previous contour. The next number should be 1. The last number is called the volume flag. This tells CLANS where to place the material. If it is positive, the material fills the volume to the left of the new contour. If it is negative, the material fills the volume to the right of the new contour. Left and right are defined by the direction in which you define the contour. For example, if you define a circle in the clockwise direction, left points outside the circle and right points inside the circle. If you define it in the counter-clockwise direction, left points inside and right points outside. In our example, we used 1 (positive) because we want to fill the little rectangular area above our new contour. If we had used -1, CLANS would fill the cavity with ferrite and leave the little rectangular area above the contour empty. You can add more lines like the last one if necessary (but the volume flag must be the same for every element of a particular contour). To add a second material volume of a different material, use another number for the volume flag (i.e. 2/-2). When you're finished, run GEO as with SUPERLANS to read in your geometry and write the contour.

Inputting ε & μ.

You need a file which contains the real and imaginary values of ε and μ for your material at many different frequencies. When you have this, it should be saved as 'NAME'.EMn where 'NAME' is the same as that used in the input file, 'NAME'.GEO, and n is the absolute value of your volume flag for the material volume which the data defines. For example, the values of μ and ε for a material volume with volume flag -1 are in a file 'NAME'.EM1 and the values of

μ and ε for a second material volume with volume sign 2 are in a file "NAME".EM2. The structure of these files is:

```
frequency(Hz)  Re(μ)  Im(μ)  Re(ε)  Im(ε)
```

CLANS uses a sign convention in which the imaginary parts of μ and ε are negative in a microvawe-absorbing material. A sample file with μ and ε values is shown in Figure 16.

Running CLANS

CLANS consists of five programs run in succession. The first, CLANSC, allows you to input various parameters such as initial frequency shift. Then CLANSM calculates matrices. CLANSS runs the first set of iterations to calculate the modes. CLANSI modifies each mode by running a second set of iterations with the values of μ and ε you input for the material volumes. Finally, CLANSRE allow you to view the results. As far as CLANS is a part of the SRF Program Library, one can run it using the CLS command file:

```
$ CLS
```

The program proceeds as SUPERLANS does. When CLANS prompts you for the parameters such as number of modes, etc., it will also prompt you for Q_O. If you are looking for regular cavity modes then enter zero. However, if you are looking for ferrite “ghost” modes then you should enter the value of Q for these modes (probably around the Q factor of the ferrite). CLANS may not find such modes if you enter zero for Q_O. Also, you need to enter several values which define your material volumes, namely, EPS, MU, TGE, and TGM. EPS is the real value of ε. MU is the real value of μ. TGE is defined as

$$TGE = \left|\frac{\mathrm{Im}(\varepsilon)}{\mathrm{Re}(\varepsilon)}\right|.$$

Likewise, TGM is defined as

$$TGM = \left|\frac{\mathrm{Im}(\mu)}{\mathrm{Re}(\mu)}\right|.$$

These are just starting values so you should choose them at the frequency shift which is starting frequency for the calculations.

When CLANS is done with the frequency iterations it runs another set of iterations with the ε and μ file (note: CLANS will not prompt you for the file with the ε and μ data. It must by saved under 'NAME'.EMn or the program will stop in the middle of the run). After this, you will be able to display your results as you can with SUPERLANS.

Programs and Files

SUPERLANS and CLANS create a lot of binary and text files. The complete list of files and programs is given in Table 2. But we should mention that the text files and metafiles are the most important to the user. To be able to return to the analysis of the results later without recalculation, one should keep three binary files in addition to text files and metafiles: ‘NAME’.KON, ‘NAME’.GEM, and ‘NAME’.RES. If you delete any of these files you will not be able to run SLANSRE (CLANSRE) on your data without rerunning SUPERLANS (CLANS). Therefore, if you run the same 'NAME'.GEO file again to find different modes, your old 'NAME'.* files will be written over and you will lose the results so you should probably use different names for different runs (i.e. BCELL1.* for the first ten modes, BCELL2.* for the next ten modes, etc.)

File 'NAME'.HIS saves the results of the CLANSS iterations.

Utilities for Metafiles

If we use the interactive mode, we can display many plots on the screen as we input the geometry, generate the mesh and examine the results. We can write all of these plots into special metafiles, which we can subsequently display on the terminal screen or convert to PostScript or HPGL format and then print out. There are special utilities: MFSHOW (VAX only), MFGKS, MFVIEW (VAX only), MTFVIEW (Alpha only), MFPS, and MFHP.

The most important utilities are MFPS and MFGKS. MFGKS is used to display graphics written into a metafile on the screen of a GKS output plotting device. The command string is

```
$ MFGKS [options] 'INPUT_NAME'[.MTF]
```

MFPS converts data from a metafile into PostScript format. The command string for this utility is

```
$ MFPS [options] 'INPUT_NAME'[.MTF] ['OUTPUT_NAME'[.PS]]
```

If the output file is not specified, it is assumed to be the default output device (i.e. terminal or console screen). The utilities give built-in help when no parameters are specified. The most important options are *-p:xval:yval* for setting the reference point of the picture and *-s:xval:yval* for setting the picture size. The units of *xval* and *yval* are mm in the case of MFPS.

In addition to MFGKS, one can use (on VAX) a metafile viewer for a VT240, MFSHOW, and a metafile viewer for X Windows, MFVIEW. A different metafile viewer for X Windows, MTFVIEW, is available on the Alpha machine.

MFHP converts metafiles into HPGL format.

Conclusion

One can get more detailed information about SUPERLANS from the User's Guide [1] and articles [6, 7, 8]. Questions about running SUPERLANS and CLANS at Cornell can be addressed to me, Sergey Belomestnykh, by e-mail (sab@lns62.lns.cornell.edu). Online help is available on the CESR cluster. To access it, type

```
$ HELP @SRF
```

and select the topic you are interested in.

Good luck in using these codes!

Table 2. Files and programs.

programs	*output files* *text files*	 *binary files*	 *metafiles*	*command files*
		GENMESH		
INGEO.EXE	'NAME'.GEO *(input/ output)*	KON.KON 'NAME'.SAM	'NAME'_INGnn.MTF	GEO = INGEO + GENINM
GENINM.EXE		A.MTX SET.SET	'NAME'_GENnn.MTF	
		SUPERLANS		
SLANSC.EXE	'NAME'.DTR *(input/ output)*	SLANS.NAM 'NAME'.GEM 'NAME'.KON 'NAME'.SPL	'NAME'_SLCnn.MTF	SL = SLANSC +SLANSM +SLANSS +SLANSRE SL1 = SLANSC +SLANSM +SLANSS
SLANSM.EXE		ASLANS.MTX BSLANS.MTX		SLBG = N*(GEO+SL1)
SLANSS.EXE		'NAME'.RES		SLBP = N*SL1
SLANSD.EXE		'NAME'.DSP		SLD = SLANSC + N*(SLANSM +SLANSS +SLANSD) + SLANSRE
SLANSRE.EXE	'NAME'.SVL 'NAME'.FLS 'NAME'.SVD		'NAME'_SLRnn.MTF	
		CLANS		
CLANSC.EXE	'NAME'.DTR *(input/ output)*	SLANS.NAM 'NAME'.GEM 'NAME'.KON 'NAME'.SPL	'NAME'_CLCnn.MTF	CLS = CLANSC +CLANSM +CLANSS +CLANSI +CLANSRE
CLANSM.EXE		ASLANS.MTX BSLANS.MTX LOCAL.MTX		
CLANSS.EXE	'NAME'.HIS	'NAME'.RES		
CLANSI.EXE	'NAME'.EMn	'NAME'.RES		
CLANSRE.EXE	'NAME'.SVL 'NAME'.FLS		'NAME'_CLRnn.MTF	
		METAFILE UTILITIES		
MFPS.EXE	*.PS			
MFGKS.EXE				
MFHSOW.EXE (VAX)				
MFVIEW.EXE (VAX)				
MFTFVIEW.EXE (Alpha)				
MFHP.EXE	*.HPA			

References

1. D. G. Myakishev, et al. "SUPERLANS/SUPERSAM Codes. User's Guide," Novosibirsk, Russia, 1992, also Report SRF/D 940314-02, Cornell Laboratory of Nuclear Studies, Ithaca, NY (1994).
2. S. Belomestnykh. "SUPERLANS for Pedestrians," Report SRF 941208-11, Cornell Laboratory of Nuclear Studies, Ithaca, NY (1994).
3. B. Vakoc. "Using CLANS/CLANS Accuracy Tests," Report 941208-12 Cornell Laboratory of Nuclear Studies, Ithaca, NY (1994).
4. S. Mankov (Budker Institute of Nuclear Physics, Novosibirsk, Russia), private communication.
5. M. Bell and G. Dome. "Numerical Computation of Field Distribution and Frequency in the Lower Passbands of a Symmetrical Periodic Structures," Preprint CERN 73-1, Geneva, 1973.
6. B. M. Fomel, et al. "LANS - A New Code for Evaluation of the Electromagnetic Fields and Resonance Frequencies of Axisymmetrical RF Cavities," *Part. Accel.*, No. 3, 1981, Vol. 11, pp. 173-179.
7. D. G. Myakishev, V. P. Yakovlev. "An Interactive Code SUPERLANS for Evaluation of RF-Cavities and Acceleration Structures," *Conference Record of the 1991 IEEE Particle Accelerator Conference,* San Francisco, CA, May 1991, Vol. 5, pp. 3002-3004.
8. D. G. Myakishev, V. P. Yakovlev. "The New Possibilities of SUPERLANS Code for Evaluation of Axisymmetric Cavities," *Proceedings of the 1995 Particle Accelerator Conference and International Conference on High-Energy Accelerators,* Dallas, TX, May 1995, Vol. 4, pp. 2348-2350.