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A MULTI-CAVITY KLYSTRON COMPUTER PROGRAM
INCLUDING POTENTIAL DEPRESSION CORRECTION

S. F. Catalano
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ABSTRACT

This report describes a computer program which may be used to investigate the characteristics of a multicavity klystron\(^1,2,3\). It is written for the IBM 7090 in "Fortran" language so that it may be intelligible to people other than the originator of the program. It is written for solid or hollow beam klystrons. For maximum flexibility it is in the form of several subroutines connected by a master control program. It is complete in the sense that it leaves nothing for the user to compute manually.

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</tr>
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</tr>
<tr>
<td>SPCRDP</td>
<td>25</td>
</tr>
<tr>
<td>SPCRDM</td>
<td>26</td>
</tr>
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<td>EFCMH</td>
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</tr>
<tr>
<td>FREQ</td>
<td>28</td>
</tr>
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<td>TERPOL</td>
<td>28</td>
</tr>
<tr>
<td>AINTER</td>
<td>28</td>
</tr>
<tr>
<td>FOMATR</td>
<td>29</td>
</tr>
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<td>DMATRIX</td>
<td>30</td>
</tr>
<tr>
<td>CMMP</td>
<td>31</td>
</tr>
<tr>
<td>CMSUBT</td>
<td>31</td>
</tr>
<tr>
<td>RMMP</td>
<td>31</td>
</tr>
</tbody>
</table>

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I. Introduction

The following describes a multicavity klystron (MCK) computer program which has been written for the IBM 7090 computer at Lincoln Laboratory. It is based upon two papers\(^1,2\) describing an improved MCK analysis and a third\(^3\) in which a potential depression correction is derived.

It has been assumed that the reader is familiar with the above mentioned reports, and this manual is intended only as an aid to the use of the program.

The program was written in the IBM 709 "FORTRAN" language which, in addition to being a compact and efficient language, provides an excellent record of the computation which is easily understood by people other than the originator of the program. The writers have sought to achieve three qualities in the program: generality, adaptability to future changes, and completeness. The program achieves generality insofar as it is good for any solid or hollow beam klystron with from 1 to 6 (this number can be extended by altering input and output format statements) cavities of equal or unequal spacing.

The program is flexible and adaptable to future changes since it has been written in the form of several subroutines connected by a master control program. Any future change will merely require altering or adding subroutines without disturbing the rest of the program. *

The program is complete in the sense that it leaves nothing for the user to compute manually. This can be seen from the following outline in which only the most elementary parameters of the tube are required as input to the program.

---

*No attempt has been made to optimize the program for the sake of brevity or economy of operation, nor is such optimization planned. The writers realize that several correctable redundancies in form do exist, and that some inefficient methods are employed. Users of the program may find it to their advantage to make several minor alterations.
II. Input

The input data are of two kinds. First, there are those which put into storage the mechanical and electrical tube parameters and associated quantities necessary to the computation. Table I lists and defines these parameters. Secondly, there are those inputs, listed in Table II, which determine the quality and quantity of the output data. Some discussion of these is necessary.

The quality of the output is determined to some degree by the number of modes considered, although it has been found for typical tubes that the effect due to modes of order higher than the fourth contribute little to the end results. The decision of the degree of accuracy desired has been left to the user in that the number of modes to be used in the calculation is an input parameter.

Since the output is generally in the form of some parameter as a function of frequency, the number of frequencies at which data is desired partially determines the amount of output data. Output data may be obtained over a 16% or smaller bandwidth for as many frequencies as are desired. The input necessary to determine the bandwidth and number of frequency points is: the fractional deviation from the center frequency of the initial (lowest) operating frequency at which data is desired, the fractional frequency increment, and the total number of points desired.

There are, in addition, three other parameters not directly used in the computation. These will have value 1 or 0 and will determine which of several options in output are to be chosen.

It might be advantageous for a particular tube to change the values of \( \gamma_\pm \) at which the searches for solutions start and the spacing of the points used in the search. (Note \( \gamma_\pm = (\beta_\pm^2 - k^2)^{1/2} \), where \( \beta_\pm \) are the roots of the propagation equation and \( k \equiv \omega/c \).) If the range is too wide or the initial spacing too fine, computer time is wasted; if the range is too narrow or the initial spacing too coarse, the results may be inadequate.
too coarse, a root may be missed. As the program is presently set up, the
search for $\gamma_+$ starts at $0.6\beta_e$ and increases, and the search for $\gamma_-$ starts at
$1.8\beta_e$ and decreases. This change may be effected by altering statement num-
ber 121 and the immediately following (unnumbered) statement which reads
presently:

\begin{align*}
121 & \quad \text{GPOS}(I) = 0.6*\text{BE}(I) \\
& \quad \text{GMINUS}(I) = 1.8*\text{BE}(I)
\end{align*}

(Note $\beta_e = \omega/v$.) This is adequate for conventional multicavity klystrons where
$v/c$ is of the order of 0.5 and where the $\beta_\pm$ are spaced on the order of $\pm 0.1$
from $\beta_e$ (i.e., $\omega_q/\omega \approx 0.1$). Similarly, the initial spacing of the points used to
search for the root can be changed by altering statement number 153 which reads
presently:

\begin{align*}
153 & \quad \text{DDG} = 0.01
\end{align*}

Increasing the value of "DDG" widens the initial spacing.
**INPUT**

**TABLE I**

**TUBE PARAMETERS**

<table>
<thead>
<tr>
<th>Fortran Symbol</th>
<th>Parameter</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCVS</td>
<td>r</td>
<td>Number of cavities</td>
</tr>
<tr>
<td>VO</td>
<td>( V_o )</td>
<td>DC voltage</td>
</tr>
<tr>
<td>FIO</td>
<td>( I_o )</td>
<td>DC current</td>
</tr>
<tr>
<td>FO</td>
<td>( f_o )</td>
<td>Center frequency</td>
</tr>
<tr>
<td>A</td>
<td>a</td>
<td>Drift tube inside radius (inches)</td>
</tr>
<tr>
<td>B</td>
<td>b</td>
<td>*Beam outside radius (inches)</td>
</tr>
<tr>
<td>C</td>
<td>c</td>
<td>*Beam inside radius (inches)</td>
</tr>
<tr>
<td>DGAP</td>
<td>d</td>
<td>Gap half length (inches)</td>
</tr>
<tr>
<td>RQ(I)</td>
<td>((R/Q)^{(i)})</td>
<td>(R/Q) value for each cavity</td>
</tr>
<tr>
<td>QO(I)</td>
<td>(Q_o^{(i)})</td>
<td>Circuit loading for each cavity</td>
</tr>
<tr>
<td>QEXT(I)</td>
<td>(Q_{ext}^{(i)})</td>
<td>External loading for each cavity</td>
</tr>
<tr>
<td>S(I)</td>
<td>(t^{(i+1)} - t^{(i)})</td>
<td>Center gap to center gap distance for each gap pair</td>
</tr>
<tr>
<td>THETA</td>
<td>(\theta_{ext})</td>
<td>Phase shift in external circuits</td>
</tr>
<tr>
<td>FNU(I)</td>
<td>(u^{(i)})</td>
<td>Fractional detuning for each cavity</td>
</tr>
</tbody>
</table>

*In this treatment, infinite magnetic field is assumed, so that there is no variation of beam dimensions.*
<table>
<thead>
<tr>
<th>Fortran Symbol</th>
<th>Parameter</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>( n )</td>
<td>Number of modes</td>
</tr>
<tr>
<td>SFRIQ</td>
<td>( \delta_o = \frac{f-f_o}{f_o} )</td>
<td>Fractional deviation of input frequency ( f ) from center frequency ( f_o ) (SFRIQ ( \geq -0.08 ))</td>
</tr>
<tr>
<td>FFDEL</td>
<td>( \frac{\Delta f}{f_o} )</td>
<td>Fractional frequency increment</td>
</tr>
</tbody>
</table>
| NKK           |          | Number of frequencies at which information is desired  
(Note: SFRIQ + NKK \* FFDEL must be less than or equal to +0.08) |
| POTD          | = 0 do potential depression \( \neq 0 \) omit potential depression |
| SKIP          | = 0 do complete computation thru gain and phase as a function of frequency \( \neq 0 \) do all calculations except gain and phase as a function of frequency |
| WOT           | \( \neq 0 \) print all output parameters \( = 0 \) print only gain and phase information |
III. **Output**

The heading or the first nineteen lines of the printed output which are always printed verify some of the input parameters and serve to identify the tube and conditions being examined. Each of these lines has a label. The contents of these lines are:

1. The contents of identification input card number 1
2. Number of cavities
3. Number of modes
4. DC voltage
5. DC current
6. Center frequency
7. A -
8. B -
9. C -

Lines 10 through 16 give the following parameters for each of the cavities considered and the drift tube.

10. Cavity numbers *
11. DC cavity voltage (depressed potential)
12. D
13. R/Q
14. QO
15. QEXT
16. S

* The information for the beam in the drift tube is presented with the cavity data in the last column (i.e., as cavity number NCVS + 1).
The heading is completed by printing out the three input parameters:

17. NKK
18. FREQ = (SFRIQ)
19. DEL = (FFDEL)

The second portion of the output is controlled by the WOT input option parameter. It will be printed out if WOT ≠ 0. It consists of major groupings for each frequency and minor groups for each mode at each particular frequency. The major group is denoted by the printed line:

"FDEL = 'xyz...'" where "xyz" is (frequency - f_o) / f_o. This will be followed by as many groups of the following twenty-eight parameters, as there are modes to be considered. Each minor group is headed by the line "M = x" where x is the mode number. Each parameter is given in tabular form for each cavity. The parameters again have a label. They are:

<table>
<thead>
<tr>
<th>Fortran Symbol</th>
<th>Parameter</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>BE</td>
<td>$\beta_e$</td>
<td>Fast wave longitudinal plasma wave number</td>
</tr>
<tr>
<td>B+</td>
<td>$\beta_{+n}$</td>
<td>Slow wave longitudinal plasma wave number</td>
</tr>
<tr>
<td>B-</td>
<td>$\beta_{-n}$</td>
<td></td>
</tr>
<tr>
<td>G+</td>
<td>$\gamma_{+n}$</td>
<td>Fast wave transverse E.M. wave number</td>
</tr>
<tr>
<td>G-</td>
<td>$\gamma_{-n}$</td>
<td>Slow wave transverse E.M. wave number</td>
</tr>
<tr>
<td>T+</td>
<td>$T_{+n}$</td>
<td>Fast wave transverse plasma wave number</td>
</tr>
<tr>
<td>T-</td>
<td>$T_{-n}$</td>
<td>Slow wave transverse plasma wave number</td>
</tr>
<tr>
<td>BQPOS</td>
<td>$\beta_{q+n}$</td>
<td></td>
</tr>
<tr>
<td>BQMIN</td>
<td>$\beta_{q-n}$</td>
<td></td>
</tr>
<tr>
<td>Fortran Symbol</td>
<td>Parameter</td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>-----------</td>
<td></td>
</tr>
<tr>
<td>$WQ^+/WP$</td>
<td>$\omega_{q+n}/\omega_p$</td>
<td></td>
</tr>
<tr>
<td>$WQ^-/WP$</td>
<td>$\omega_{q-n}/\omega_p$</td>
<td></td>
</tr>
<tr>
<td>$WQ^+/W$</td>
<td>$\omega_{q+n}/\omega$</td>
<td></td>
</tr>
<tr>
<td>$WQ^-/W$</td>
<td>$\omega_{q-n}/\omega$</td>
<td></td>
</tr>
<tr>
<td>$ZETA^+$</td>
<td>$\zeta_{+n}$</td>
<td></td>
</tr>
<tr>
<td>$ZETA^-$</td>
<td>$\zeta_{-n}$</td>
<td></td>
</tr>
<tr>
<td>$Y\phi^+/G\phi$</td>
<td>$Y_{o+n}/G_o$</td>
<td></td>
</tr>
<tr>
<td>$Y\phi^-/G\phi$</td>
<td>$Y_{o-n}/G_o$</td>
<td></td>
</tr>
<tr>
<td>$E^+$</td>
<td>$E_{+n}$</td>
<td></td>
</tr>
<tr>
<td>$E^-$</td>
<td>$E_{-n}$</td>
<td></td>
</tr>
<tr>
<td>$F^+$</td>
<td>$F_{+n}$</td>
<td></td>
</tr>
<tr>
<td>$F^-$</td>
<td>$F_{-n}$</td>
<td></td>
</tr>
<tr>
<td>$C^+$</td>
<td>$C_{+n}$</td>
<td></td>
</tr>
<tr>
<td>$C^-$</td>
<td>$C_{-n}$</td>
<td></td>
</tr>
<tr>
<td>$M^+$</td>
<td>$M_{+n}$</td>
<td></td>
</tr>
<tr>
<td>$M^-$</td>
<td>$M_{-n}$</td>
<td></td>
</tr>
<tr>
<td>$H^+$</td>
<td>$H_{+n}$</td>
<td></td>
</tr>
<tr>
<td>$H^-$</td>
<td>$H_{-n}$</td>
<td></td>
</tr>
<tr>
<td>GELGO</td>
<td>$(G_{el}/G_{o'})_n$</td>
<td></td>
</tr>
</tbody>
</table>
At the end of each frequency group, there are printed out (if WOT ≠ 0) the following:

<table>
<thead>
<tr>
<th>Fortran Symbol</th>
<th>Parameter</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>GELGOP</td>
<td>( G_{el}/G_0 = \sum_n (G_{el}/G_0)_n )</td>
<td></td>
</tr>
<tr>
<td>QEL</td>
<td>( Q_{el} )</td>
<td>( Q ) of electronic load</td>
</tr>
<tr>
<td>Q</td>
<td>( Q )</td>
<td>total ( Q )</td>
</tr>
<tr>
<td>QOEL</td>
<td>( Q_{oel} )</td>
<td>( Q ) of cavity and electronic load</td>
</tr>
<tr>
<td>GEL</td>
<td>( G_{el} )</td>
<td>electronic conductance</td>
</tr>
<tr>
<td>REL</td>
<td>( R_{el} )</td>
<td>( 1/G_{el} )</td>
</tr>
</tbody>
</table>

if WOT ≠ 0 and SKIP = 0

| Y              | \( y^{(i)} \) | \( Q^{(i)}/Q_{el}^{(i)} \) |
| ZGR            | \( \text{Re}(Z_g^{(i)}) \) | Real part of gap impedance |
| ZGI            | \( \text{Im}(Z_g^{(i)}) \) | Imaginary part of gap impedance |
| FIVR           | \( \text{Re}(G_{v}^{(i)}) \) | Real part of over-all transadmittance |
| FIVI           | \( \text{Im}(G_{v}^{(i)}) \) | Imaginary part of over-all transadmittance |
| GVR            | \( \text{Re}(G_{v}) \) | Real part of over-all voltage gain |
| GVI            | \( \text{Im}(G_{v}) \) | Imaginary part of over-all voltage gain |

After all of the major (frequency) groupings are printed out, the cavity detunings are given. These are labeled NU and given for each cavity. Finally, the numerical gain, gain in db, and phase are given as a function of frequency. These quantities are unlabeled but appear in three distinct groups in which
frequency increases from left to right in steps according to the frequency increment chosen. These quantities (gain, phase) are calculated only if SKIP = 0.
IV. The Mechanics of Using the Program

The mechanics of using the program are very simple. They consist essentially of knowing how to get the input parameters into the computer. This is accomplished by punching the values of the input parameters on a set of cards in the format and sequence indicated below, placing these at the end of the program deck, and instructing the operator to clear the core and load the cards. The card format for input parameters is as follows:

<table>
<thead>
<tr>
<th>Card Format for Input Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Card 1</strong></td>
</tr>
<tr>
<td>Column 1 requires a &quot;1&quot; punch if it is desired to skip to a new page for each tube. Columns 2-72 may contain any identifying information for the printed output such as tube name and date.</td>
</tr>
<tr>
<td><strong>Card 2</strong></td>
</tr>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>Columns</td>
</tr>
<tr>
<td>Type Conversion</td>
</tr>
<tr>
<td>Decimal Places</td>
</tr>
<tr>
<td><strong>Card 3</strong></td>
</tr>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>Columns</td>
</tr>
<tr>
<td>Type Conversion</td>
</tr>
<tr>
<td>Decimal Places</td>
</tr>
</tbody>
</table>

* See FORTRAN manual for an explanation of conversion types.
<table>
<thead>
<tr>
<th>Card 4</th>
<th>Parameter</th>
<th>DGAP(1)</th>
<th>DGAP(2)</th>
<th>DGAP(3)</th>
<th>DGAP(4)</th>
<th>DGAP(5)</th>
<th>DGAP(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Columns</td>
<td></td>
<td>1-8</td>
<td>9-16</td>
<td>17-24</td>
<td>25-32</td>
<td>33-40</td>
<td>41-48</td>
</tr>
<tr>
<td>Type Conversion</td>
<td></td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Decimal Places</td>
<td></td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Card 5</th>
<th>Parameter</th>
<th>RQ(1)</th>
<th>RQ(2)</th>
<th>RQ(3)</th>
<th>RQ(4)</th>
<th>RQ(5)</th>
<th>RQ(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Columns</td>
<td></td>
<td>1-10</td>
<td>11-20</td>
<td>21-30</td>
<td>31-40</td>
<td>41-50</td>
<td>51-60</td>
</tr>
<tr>
<td>Type Conversion</td>
<td></td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Decimal Places</td>
<td></td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Card 6</th>
<th>Parameter</th>
<th>QO(1)</th>
<th>QO(2)</th>
<th>QO(3)</th>
<th>QO(4)</th>
<th>QO(5)</th>
<th>QO(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Columns</td>
<td></td>
<td>1-10</td>
<td>11-20</td>
<td>21-30</td>
<td>31-40</td>
<td>41-50</td>
<td>51-60</td>
</tr>
<tr>
<td>Type Conversion</td>
<td></td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Decimal Places</td>
<td></td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Card 7</th>
<th>Parameter</th>
<th>QEXT(1)</th>
<th>QEXT(2)</th>
<th>QEXT(3)</th>
<th>QEXT(4)</th>
<th>QEXT(5)</th>
<th>QEXT(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Columns</td>
<td></td>
<td>1-10</td>
<td>11-20</td>
<td>21-30</td>
<td>31-40</td>
<td>41-50</td>
<td>51-60</td>
</tr>
<tr>
<td>Type Conversion</td>
<td></td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Decimal Places</td>
<td></td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Card 8</th>
<th>Parameter</th>
<th>S(1)</th>
<th>S(2)</th>
<th>S(3)</th>
<th>S(4)</th>
<th>S(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Columns</td>
<td></td>
<td>1-8</td>
<td>9-16</td>
<td>17-24</td>
<td>25-32</td>
<td>33-40</td>
</tr>
<tr>
<td>Type Conversion</td>
<td></td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Decimal Places</td>
<td></td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>
Card 9

Parameter          THETA
Columns            1 - 10
Type Conversion    F
Decimal Places     4

Card 10

Parameter          POTD    WOT    SKIP
Columns            1 - 10   11 - 20  21 - 30
Type Conversion    F        F        F
Decimal Places     2        2        2

The input should end with card 10 if tunings are not to be included. If there is another tube to be analyzed, the next card will be of the same format as Card 1 above, etc. The program stops when it runs out of cards. In this case, the value of SKIP must be nonzero. Cards 11 and 12 are to be included if, and only if, SKIP = 0.

Card 11

Parameter          FNU(1) FNU(2) FNU(3) FNU(4) FNU(5) FNU(6)
Columns            1 - 10   11 - 20  21 - 30  31 - 40  41 - 50  51 - 60
Type Conversion    F        F        F        F        F        F
Decimal Places     5        5        5        5        5        5

This card may be followed by as many cards of the same format as there are sets of tunings to be investigated.

Card 12

Punching "999.99999" in columns 1 - 10 indicates to the program that there are no more sets of tunings to be investigated for this particular tube and to proceed to the next tube.
REVISED MCK PROGRAM

PART 1

DIMENSION DBGAIN(200), REL(10)
DIMENSION DGAP(10), RO(10), GO(10), QEXT(10), S(10), VI(10), VOC(10), VS(110), RHO(10), BP(10), VBAR(10), BE(10), FK(10), BQPOS(10,10), WQWPP(10, W 20WQPP(10), GPOS(10), BPOS(10), TPOS(10), ZETAP(10,10), YOGOP(10,10), BMINU 35(10), GMINUS(10), TMINS(10), BQMIN(10,10), WQWPM(10), WQWM(10), ZETAM(410,10), YOGOM(10,10), EPOSS(10), FPOSS(10), CKP(10,10), FMP(10,10), FHP(10 5,10), EMIN(10), FMIN(10), CKM(10,10), FMM(10,10), FHMM(10,10), GELGO(10), 6GELG0P(10), QEL(10), G(10), GO(10), GP(10), GM(10), D(10), GQEL(10), GPST(710), GMST(10), GAIN(200), PHERE(200), VPTR(10), VSUBD(10), FFO(200)

DIMENSION FNU(10), FREAL(10,10), FIMAG(10,10), Y(10), GEL(10), ZGR(10), 12G1(10), PPLUS(20,20), PPLUSI(20,20), COLMR(20,20), COLMI(20,20), FMLP 2R(20,20), FLMPI(20,20), DRI(20,20), DI(20,20), FMR(20,20), FII(20,20), FM 3ULTR(20,20), FMULTI(20,20), SUMR(20,20), SUMI(20,20), CR(20,20), CI(20, 420), ZGLLR(20,20), ZGGLI(20,20)

DIMENSION BFF(3,10), FKKKK(3,10,10), GPOSS(3,10,10), BPOSS(3,10,10), TPOSS(3,10,10), BPQPOSS(3,10,10), WQWQPP(3,10,10), WQWPW(3,10,10), 2E0, GMINSS(3,10,10), BMINS(3,10,10), TMINS(3,10,10), WQWM(3,10,10), ZETAMM( 43,10,10), YOGO(3,10,10), GELGP(3,10,10), EPOSSS(3,10,10), FPOSSS(3,10,10), 5,10), CKPP(3,10,10), FMP(3,10,10), FHP(3,10,10), FMINN(3,10,10), EMINN(3,10,10), FMIN 6N(3,10,10), CKMM(3,10,10), FMM(3,10,10), FHMM(3,10,10), GELGO(3,10,10,10)

COMMON BEE, FKKKK, GPOSS, BPOSS, TPOSS, BPQPOSS, WQWQPP, WQWPW, ZETAPP, YOGO 1PP, GMINSS, BMINS, TMINS, BQMIN, WQWM, ZETAMM, YOGO, GELGP, E 2POSS, FPOSS, CKPP, FMP, FHP, FMINN, EMINN, CKMM, FMM, FHMM, GELGO

101 READ INPUT TAPE 2.1
102 READ INPUT TAPE 2.2, N, NCVS, VO, FIO, FO, A, B, C
103 READ INPUT TAPE 2.3, SG, FRO, FFDEL
104 READ INPUT TAPE 2.4, (DGAP(I), I=1, NCVS)
105 READ INPUT TAPE 2.5, (ROB(I), I=1, NCVS)
106 READ INPUT TAPE 2.6, (GOB(I), I=1, NCVS)
107 READ INPUT TAPE 2.7, (QEXT(I), I=1, NCVS)
108 FRIO = FROI
109 NK = 3
110 FREOM = -0.000
111 FFDEL = 0.0800
112 NCVSL1 = NCVS - 1
113 NCVSP1 = NCVS + 1
114 READ INPUT TAPE 2.8, (S(I), I=1, NCVSL1)
115 READ INPUT TAPE 2.9, TGTHA
116 READ INPUT TAPE 2.10, (QEXT(I), I=1, NCVS)
117 EM = 1.759E11
118 CL = 2.998E8
119 EMCZ = EM/CL**2
120 THETA = THETAX*3.14159265/180.0
121 FPSO = 8.854E-12
122 PI = 3.14159265
123 IF (POTD) 106, 107, 106
124 CALL POTDEP(NCVS, VO, FIO, A, B, C, DGAP, VPTR, RSUBD, VBAR, VSUBD)
125 DO 110 I = 1, NCVS
126 VI(I) = VBAR(I)
127 GO(I) = FIO/VII
128 CONTINUE
129 VI(NCVSP1) = VSUBD(NCVSP1)

N.B.: The Bessel function subroutine called for in this program as BESSELF is GEBSEL, Share distribution number 271.
GO(NCVSP1)=FI0/VI(NCVSP1)
GO TO 111
106 DO 104 I=1,NCVSP1
   VI(I)=VO
104 GO(I)=FI0/VI(I)
111 WRITE OUTPUT TAPE 3,1
WRITE OUTPUT TAPE 3,6,NCVS,N,VO
WRITE OUTPUT TAPE 3,14*FI0,F0,A,B,C
WRITE OUTPUT TAPE 3,13
WRITE OUTPUT TAPE 3,12*(VI(I),I=1,NCVSP1)
WRITE OUTPUT TAPE 3,15*(DGAP(I),I=1,NCVS)
WRITE OUTPUT TAPE 3,16*(RO(I),I=1,NCVS)
WRITE OUTPUT TAPE 3,17*(GO(I),I=1,NCVS)
WRITE OUTPUT TAPE 3,18*(QEXT(I),I=1,NCVS)
WRITE OUTPUT TAPE 3,19*(S(I),I=1,NCVS)
WRITE OUTPUT TAPE 3,56,NKK,FRIQ,FFDEL
IF(NKK-1) 320,321,322
320 PAUSE
321 NK=1.00
FREQM=0.00
322 DO 103 K=1,NK
   FFO(K)=FREQM*FO+F0
DO 115 I=1,NCVSP1
   VOC(I)=SORTF(1.0-1.0/1.0+EMC2*VI(I))**2)
   VS(I)=VOC(I)*CL
   RHO(I)=(39.37*2)*FI0/(PI*(B**2-C**2)*VS(I))
   BP(I)=SORTF(EM*RHO(I)/EPS0*SQRTF(1.0-VOC(I)**2)**3))/(VS(I)*39.37)
   BE(I)=2.0*PI*FFO(K)/VS(I)**39.37)
   FK(I)=BE(I)*VOC(I)
   IF(K-1) 120,121,122
120 PAUSE
121 GPOS(I)=0.6*BE(I)
   GMINS(I)=1.8*RE(I)
   GO TO 115
122 GPOS(I)=0.97*GPST(I)
   GMINS(I)=2.30*GMST(I)
115 CONTINUE
128 DO 105 L=1,N
102 I=1,NCVSP1
   IF(1-1) 160,161,162
160 PAUSE
162 III=1-1
163 CONTINUE
161 GP(I)=GPOS(I)
   GM(I)=GMINUS(I)
153 DDG=0.001
154 CALL SPCRDP(1,A,B,C,DDG,GP,BP,RE,FK,GGPOS,BBPOS,TPOS)
   GPOS(I)=GGPOS
   RPOS(I)=BBPOS
   TPOS(I)=TPOS
   BQPOS(L+I)=BE(I)-BPOS(I)
   WQWP(I)=BQPOS(L+I)/BP(I)
   WQWP(I)=BQPOS(L+I)/BP(I)
   ZETAP(L+I)=BQPOS(I)*BQPOS(L+I)*TPOS(I)**2/(GPOS(I)**2*(GPOS(I)**2+TPOS(I)**2))
Y0GP (L, I) = BE (1) / (BQPOS (L, I) * (1.0 + EMC2 * VI (1)) * (2.0 + EMC2 * VI (1)))
CALL SPCRDM(M, A, B, C, D, G, B, M, F, K, GMIN, BBMIN, TMIN)
GMINUS (I) = GMIN
BMINUS (I) = BBMIN
TMINUS (I) = TMIN
BQMIN (L, I) = -(BE (1) - BMINUS (I))
WOWPM (I) = BOMIN (L, I) / BP (I)
WOWM (I) = BOMIN (L, I) / BE (I)
ZETAM (L, I) = BMINUS (I) * BQMIN (L, I) * TMINUS (I) ** 2 / (GMINUS (I) ** 2 * GMINUS (I))
YOGOM (L, I) = BE (1) / (BQMIN (L, I) * (1.0 + EMC2 * VI (1)) * (2.0 + EMC2 * VI (1)))
GO TO 181
GPOS (I) = GPOS (I)
BPOS (I) = BPOS (I)
TPOS (I) = TPOS (I)
BQPOS (L, I) = BQPOS (L, I)
WQWPP (I) = WQWPP (I)
WQWP (I) = WQWP (I)
ZETAP (L, I) = ZETAP (L, I)
YOGO (L, I) = YOGO (L, I)
GMINUS (I) = GMINUS (I)
RMINUS (I) = BMINUS (I)
TMINUS (I) = TMINUS (I)
BQMIN (L, I) = BQMIN (L, I)
WOWPM (I) = WOWPM (I)
WOWM (I) = WOWM (I)
ZETAM (L, I) = ZETAM (L, I)
YOGO (L, I) = YOGO (L, I)

181
BEEK (L, I) = BE (1)
FKKKK (K, L, I) = FK (I)
GPOSS (K, L, I) = GPOS (I)
BPOSS (K, L, I) = BPOS (I)
TPOSS (K, L, I) = TPOS (I)
BQPOSS (K, L, I) = BQPOS (L, I)
WQWPPP (K, L, I) = WQWPP (I)
WQWPW (K, L, I) = WQWP (I)
ZETAPK (K, L, I) = ZETAP (L, I)
YOGOP (K, L, I) = YOGO (L, I)
GMINUSK (K, L, I) = GMINUS (I)
RMINUSK (K, L, I) = BMINUS (I)
TMINUSK (K, L, I) = TMINUS (I)
BQMINNK (K, L, I) = BQMIN (L, I)
WQWPMMK (K, L, I) = WOWPM (I)
WOWM WK (K, L, I) = WOWM (I)
ZETAMK (K, L, I) = ZETAM (L, I)
YOGOMMK (K, L, I) = YOGO (L, I)
IF (L - 1) = (125, 126, 102)
PAUSE
125
GPST (1) = GPOS (I)
GMST (1) = GMINUS (I)
102
CONTINUE
CALL EFCH1 (L, A, B, C, NCVS, VI, TPOS, GPOS, BPOS, EPOS, FPOS, CKP, DUM1, DUM2, DUM3)
CALL EFCH2 (L, A, B, C, NCVS, VI, TMINUS, GMINUS, BMINUS, EMIN, FMIN, CKM, DUM1, DUM2, DUM3)
DO 108 I = 1, NCVS
FMP (L, I) = BESSELF (DGAP (I) * BPOS (I) ** 0.1)
FMMIL (L, I) = BESSELF (DGAP (I) * BMINUS (I) ** 0.1)
108
16
FHP(L*I)=EPOS(I)+(ZETAP(L*I)*FPOS(I))
FHM(L*I)=EMIN(I)-(ZETAM(L*I)*FMIN(I))
GELGO(I)=0.25*(FHP(L*I)*YOGOP(L*I)*CKP(L*I)**2*FMP(L*I)**2/(1.0+ZETAP(L*I)**2)-(FHM(L*I)*YOGOM(L*I)*CKM(L*I)**2*FMM(L*I)**2/(1.0-2ZETAM(L*I)**2))
GELGOO(K,L*I)=GELGO(I)
EPOSS(K,L*I)=EPOS(I)
FPOSS(K,L*I)=FPOS(I)
CKPP(K,L*I)=CKP(L*I)
FMPP(K,L*I)=FMP(L*I)
FHPP(K,L*I)=FHP(L*I)
EMINN(K,L*I)=EMIN(I)
FMINN(K,L*I)=FMIN(I)
CKMM(K,L*I)=CKM(L*I)
FMMM(K,L*I)=FMM(L*I)
FHMM(K,L*I)=FHM(L*I)
108 CONTINUE
105 CONTINUE
FREOM=FREOM+FDEL
103 CONTINUE
MM=0
IF(SKIP) 176,175,176
175 READ INPUT TAPE 2,49,(FNU(I),I=1,NCVS)
IF(FNU(I)=-999.999) 400,101,101
400 FRIO=FRIO
176 DO 171 K=1,NKK
FFO(K)=FRIO*FO+FO
DO 189 I=1,NCVS
GElGOn=0.0
189 CONTINUE
IF(WOT) 179,180,179
179 IF(MM) 180,401,180
401 WRITE OUTPUT TAPE 3,10,FRIO
180 DO 172 L=1,N
IF(NKK-l) 323,324,325
323 PAUSE
325 CALL TERPOL(NCVSP1,L,BEE*FRIO,BE)
CALL TERPOL(NCVSP1,L,BEE*FRIO,BE)
CALL TERPOL(NCVSP1,L,FKKK*FRIO,FK)
CALL TERPOL(NCVSP1,L,GPOSS*FRIO,GPOS)
CALL TERPOL(NCVSP1,L,BPOSS*FRIO,BPOS)
CALL TERPOL(NCVSP1,L,TPOSS*FRIO,TPOS)
CALL TERPOL(NCVSP1,L,WOPPP*FRIO,WOPP)
CALL TERPOL(NCVSP1,L,WOWMM*FRIO,W0WM)
CALL TERPOL(NCVSP1,L,WOWPPP*FRIO,WOPPP)
CALL TERPOL(NCVSP1,L,GMINSS*FRIO,GMINUS)
CALL TERPL(NCVSP1,L,MINSS*FRIO,MINUS)
CALL TERPOL(NCVSP1,L,TMINSS*FRIO,TMINUS)
CALL TERPOL(NCVSP1,L,WOUPMM*FRIO,WOUPM)
CALL AINTER(NCVSP1,L,POPOS*FRIO,POPOS)
CALL AINTER(NCVSP1,L,ZETAPP*FRIO,ZETAP)
CALL AINTER(NCVSP1,L,YOGOPP*FRIO,YOGOP)
CALL AINTER(NCVSP1,L,BMINN*FRIO,BMIN)
CALL AINTER(NCVSP1,L,3QPOS*FRIO,3QPOS)
CALL AINTER(NCVSP1,L,ZETAMP*FRIO,ZETAM)
CALL AINTER(NCVSP1,L,YOGOMM*FRIO,YOGOM)
CALL TERPOL(NCVSP1,L,GELGOO*FRIO,GELGO)
CALL TERPOL(NCVS=L,EPOSS=EPOSS,FRIQ=EPOSS)
CALL TERPOL(NCVS=L,EPOSS=EPOSS,FRIQ=EPOSS)
CALL TERPOL(NCVS=L,EPOSS=EPOSS,FRIQ=EPOSS)
CALL TERPOL(NCVS=L,EPOSS=EPOSS,FRIQ=EPOSS)
CALL AINTER(NCVS=L,EPOSS=EPOSS,FRIQ=EPOSS)
CALL AINTER(NCVS=L,EPOSS=EPOSS,FRIQ=EPOSS)
CALL AINTER(NCVS=L,EPOSS=EPOSS,FRIQ=EPOSS)
CALL AINTER(NCVS=L,EPOSS=EPOSS,FRIQ=EPOSS)
CALL AINTER(NCVS=L,EPOSS=EPOSS,FRIQ=EPOSS)
GO TO 351

324 DO 349 I=1,NCVSP1
BE(I)=BEE(I*L+I)
FK(I)=FKK(I*L+I)
GPOS(I)=GPOSS(I*L+I)
BPOS(I)=BPOSS(I*L+I)
TPOS(I)=TPOSS(I*L+I)
WQP(I)=WQWP(I*L+I)
WQM(I)=WQWM(I*L+I)
WQPP(I)=WQPPP(I*L+I)
GMINS(I)=GMINSS(I*L+I)
BMINS(I)=BMINSS(I*L+I)
TMINS(I)=TMINSS(I*L+I)
WQPMM(I)=WQPM(I*L+I)
BOPOS(I)=BOPOSS(I*L+I)
ZETAP(I)=ZETAPP(I*L+I)
YOGOP(I)=YOGOPP(I*L+I)
BOMIN(I)=BOMINN(I*L+I)
ZETAM(I)=ZETAMM(I*L+I)
YOGOM(I)=YOGOMM(I*L+I)

349 CONTINUE
DO 350 I=1,NCVS
GELGO(I)=GELGOD(I*L+I)
EPOS(I)=EPOSS(I*L+I)
FPOS(I)=FPOSS(I*L+I)
EMIN(I)=EMINN(I*L+I)
FMN(I)=FMINN(I*L+I)
CKP(I*L+I)=CKPP(I*L+I)
FMP(I*L+I)=FMPP(I*L+I)
FHP(I*L+I)=FHP(I*L+I)
CKM(I*L+I)=CKMM(I*L+I)
FMM(I*L+I)=FMM(I*L+I)

350 CONTINUE
351 DO 183 I=1,NCVS
GELGOD(I)=GELGOD(I*L+I)
EPOS(I)=EPOSS(I*L+I)
FPOS(I)=FPOSS(I*L+I)
EMIN(I)=EMINN(I*L+I)
FMN(I)=FMINN(I*L+I)
CKP(I*L+I)=CKPP(I*L+I)
FMP(I*L+I)=FMPP(I*L+I)
FHP(I*L+I)=FHP(I*L+I)
CKM(I*L+I)=CKMM(I*L+I)
FMM(I*L+I)=FMM(I*L+I)

183 CONTINUE
IF (WOT) 178,172,178
178 IF (MM) 172,402,178
402 WRITE OUTPUT TAPE 3,11,L
WRITE OUTPUT TAPE 3,26,(BE(I),I=1,NCVSP1)
WRITE OUTPUT TAPE 3,7,(BPOS(I),I=1,NCVSP1)
WRITE OUTPUT TAPE 3,8,(EMIN(I),I=1,NCVSP1)
WRITE OUTPUT TAPE 3,21,(GPOS(I),I=1,NCVSP1)
WRITE OUTPUT TAPE 3,22,(GMIN(I),I=1,NCVSP1)
WRITE OUTPUT TAPE 3,23,(TPOS(I),I=1,NCVSP1)
WRITE OUTPUT TAPE 3,24,(TMINS(I),I=1,NCVSP1)
WRITE OUTPUT TAPE 3,66,(BOPOS(L,I),I=1,NCVSP1)
WRITE OUTPUT TAPE 3, 67, (BQMIN (L, I), I = 1, NCVS P1)
WRITE OUTPUT TAPE 3, 25, (WQWP (I), I = 1, NCVS P1)
WRITE OUTPUT TAPE 3, 27, (WQWP (I), I = 1, NCVS P1)
WRITE OUTPUT TAPE 3, 28, (WQWP (I), I = 1, NCVS P1)
WRITE OUTPUT TAPE 3, 29, (WQWP (I), I = 1, NCVS P1)
WRITE OUTPUT TAPE 3, 30, (ZETAP (L, I), I = 1, NCVS P1)
WRITE OUTPUT TAPE 3, 31, (ZETAM (L, I), I = 1, NCVS P1)
WRITE OUTPUT TAPE 3, 32, (YOGOP (L, I), I = 1, NCVS P1)
WRITE OUTPUT TAPE 3, 33, (YOGOM (L, I), I = 1, NCVS P1)
WRITE OUTPUT TAPE 3, 34, (EPOS (I), I = 1, NCVS)
WRITE OUTPUT TAPE 3, 35, (EMIN (I), I = 1, NCVS)
WRITE OUTPUT TAPE 3, 36, (FPOS (I), I = 1, NCVS)
WRITE OUTPUT TAPE 3, 37, (FMIN (I), I = 1, NCVS)
WRITE OUTPUT TAPE 3, 38, (CKP (L, I), I = 1, NCVS)
WRITE OUTPUT TAPE 3, 39, (CKM (L, I), I = 1, NCVS)
WRITE OUTPUT TAPE 3, 40, (FMP (L, I), I = 1, NCVS)
WRITE OUTPUT TAPE 3, 41, (FMP (L, I), I = 1, NCVS)
WRITE OUTPUT TAPE 3, 42, (FHP (L, I), I = 1, NCVS)
WRITE OUTPUT TAPE 3, 43, (FHM (L, I), I = 1, NCVS)
WRITE OUTPUT TAPE 3, 44, (GELGO (I), I = 1, NCVS)

172 CONTINUE
IF (WOT) 184, 185, 184
184 IF (MM) 185, 403, 185
403 WRITE OUTPUT TAPE 3, 45, (GELGOP (I), I = 1, NCVS)
DO 118 I = 1, NCVS
OEL (I) = 1.0 / OQ (I) * GELGOP (I) * GO (I)
O (I) = 1.0 / (1.0 / OO (I) + 1.0 / OEL (I) + 1.0 / OEXT (I))
OOEL (I) = 1.0 / (1.0 / OQ (I) + 1.0 / OEXT (I))
GEL (I) = GELGOP (I) * GO (I)
REL (I) = 1.0 / GEL (I)
118 CONTINUE
WRITE OUTPUT TAPE 3, 46, (OEL (I), I = 1, NCVS)
WRITE OUTPUT TAPE 3, 47, (O (I), I = 1, NCVS)
WRITE OUTPUT TAPE 3, 48, (OOEL (I), I = 1, NCVS)
WRITE OUTPUT TAPE 3, 53, (GEL (I), I = 1, NCVS)
WRITE OUTPUT TAPE 3, 81, (REL (I), I = 1, NCVS)
185 IF (SKIP) 177, 186, 177
186 NN = 2 * N
DELO = (FFO (K) - FO) / FO
CALL FREO (Q, FNU, DELO, NCVS, FREAL, FIMAG)
DO 143 I = 1, NCVS
Y (I) = 0.0 / OEL (I)
ZGR (I) = Y (I) * FREAL (I) / GEL (I)
ZGI (I) = Y (I) * FIMAG (I) / GEL (I)
CALL FORMATR (N, I, NCVS, CKP, CKM, CP, CPF, FM, FHP, FHM, ZETAP, ZETAM, YOGOP, YOG
10M, PPLUSR, PPLUSI, COLMR, COLMI, FLMPR, FLMPI)
140 CALL DMATRX (NCVS P1, NN, 1, BQPOS, BQMIN, BE, BS, DR, DI, FIR, FII)
IF (I = 1) 130, 131, 132
130 PAUSE
132 IF (1 - NCVS) 133, 134, 130
131 CALL CMPD (DR, DI, NN, NN, COLMR, COLMI, 1, FMULTR, FMULTI)
GO TO 143
133 DO 170 JJ = 1, NN
DO 170 KK = 1, NN
ZGGLR (JJ, KK) = GO (I) * ZGR (I) * FLMPR (JJ, KK) - GO (I) * ZGI (I) * FLMPI (JJ, KK)
ZGGLI (JJ, KK) = GO (I) * ZGI (I) * FLMPR (JJ, KK) + GO (I) * ZGR (I) * FLMPI (JJ, KK)
170 CONTINUE
CALL CMSUBT (ZGGLR, FIR, NN, SUMR)
CALL CMSUBT(ZGRL,FI1,NN,SUMI)
CALL CMMP(SUMR,SUMI,NN,NN,FMULTR,FMULTI,1,CR,CI)
DO 141 JJ=1,NN
  FMULTR(JJ,KK)=CR(JJ,KK)
  FMULTI(JJ,KK)=CI(JJ,KK)
  CONTINUE
CALL CMMP(DR,DI,NN,NN,FMULTR,FMULTI,1,CR,CI)
DO 142 JJ=1,NN
  FMULTR(JJ,KK)=CR(JJ,KK)
  FMULTI(JJ,KK)=CI(JJ,KK)
  CONTINUE
GO TO 143
134 CALL CMMP(PPLUSR,PPLUSI,1,NN,FMULTR,FMULTI,1,CR,CI)
  FIGVGR=CR(1,1)
  FIGVGI=CI(1,1)
143 CONTINUE
EXPR=COSF(THETA)
EXPI=SINF(THETA)
FIVR=FIGVGR*GO(NCVS)
FIVI=FIGVGI*GO(NCVS)
FIVER=FREAL(NCVS)*FIGVGR*GO(NCVS)*FIGVGI*GO(NCVS)*FIVR*EXPR-FREAL(NCVS)*FIVI*EXPR-FREAL(NCVS)*FIGVGR*GO(NCVS)*FIGVGI*GO(NCVS)*FIVR*EXPR-FREAL(NCVS)*FIVI*EXPR
  GVR=(RO(NCVS)*QEXT(NCVS)*FIVER)/(1.0+QEXT(NCVS)/QOEL(NCVS))
  GVI=(RO(NCVS)*QEXT(NCVS)*FIVI)/(1.0+QEXT(NCVS)/QOEL(NCVS))
  PHASE(K)=ATANF(GVI/GVR)
  IF (GVR) 155,156,156
  155 PHASE(K)=PHASE(K)+PI
  GO TO 157
  156 IF (PHASE(K)) 158,157,157
  157 PHASE(K)=PHASE(K)+2.0*PI
  158 IF (PHASE(K)) 158,157,157
  159 FONE=FREAL(1)**2+FIMAG(1)**2
  160 FTWO=FREAL(NCVS)**2+FIMAG(NCVS)**2
  161 FIGV=FIVR**2+FIVI**2
  162 GAIN(KK)=4.0*RO(NCVS)*QEXT(NCVS)*FIVER/(1.0+QEXT(NCVS)/QOEL(NCVS))**2
  163 DBGAIN(KK)=4.3429*LOGF(GAIN(KK))
  164 IF (WOT) 173,177,173
  173 IF (MM) 177,404,177
  404 WRITE OUTPUT TAPE 3,52,(Y(I),I=1,NCVS)
  405 WRITE OUTPUT TAPE 3,54,(ZGR(I),I=1,NCVS)
  406 WRITE OUTPUT TAPE 3,55,(ZGI(I),I=1,NCVS)
  407 WRITE OUTPUT TAPE 3,70,(FIVR,FIVI,GVR,GVI)
  177 CONTINUE
  178 WRITE OUTPUT TAPE 3,50,(FNU(I),I=1,NCVS)
  179 WRITE OUTPUT TAPE 3,71,(GAIN(KK),KK=1,NKK)
  180 WRITE OUTPUT TAPE 3,72,(DBGAIN(KK),KK=1,NKK)
  181 MM=1
  182 GO TO 175
C FORMAT STATEMENTS
1 FORMAT (54H
2 FORMAT (2I5,3E8.0,3F7.4)
<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>2</td>
<td>FORMAT (7FB.4)</td>
</tr>
<tr>
<td>4</td>
<td>FORMAT (7F10.2)</td>
</tr>
<tr>
<td>5</td>
<td>FORMAT (F10.4)</td>
</tr>
<tr>
<td>6</td>
<td>FORMAT (20H NUMBER OF CAVITIES=13/17H NUMBER OF MODES=13/12H DC VO LTAGE=E10.3)</td>
</tr>
<tr>
<td>7</td>
<td>FORMAT (25H B+)</td>
</tr>
<tr>
<td>8</td>
<td>FORMAT (25H B-)</td>
</tr>
<tr>
<td>9</td>
<td>FORMAT (15+2F10.4)</td>
</tr>
<tr>
<td>10</td>
<td>FORMAT ())))/6H FDEL=F10.4/))</td>
</tr>
<tr>
<td>11</td>
<td>FORMAT ())))/3H M=15/)</td>
</tr>
<tr>
<td>12</td>
<td>FORMAT (25H DC CAVITY VOLTAGE $7E12.3)</td>
</tr>
<tr>
<td>13</td>
<td>FORMAT (7H CAVITY26X,1H111X,1H211X,1H311X,1H411X,1H511X,1H611X,1H71X,1)</td>
</tr>
<tr>
<td>14</td>
<td>FORMAT (12H DC CURRENT=F10.3/30H CENTER FREQUENCY(CYCLES/SEC)=E12. 14/3H A=F7.4/3H B=F7.4/3H C=F7.4/3H/)</td>
</tr>
<tr>
<td>15</td>
<td>FORMAT (25H D )</td>
</tr>
<tr>
<td>16</td>
<td>FORMAT (25H R/O  )</td>
</tr>
<tr>
<td>17</td>
<td>FORMAT (25H G0  )</td>
</tr>
<tr>
<td>18</td>
<td>FORMAT (25H GEXT )</td>
</tr>
<tr>
<td>19</td>
<td>FORMAT (29H CENTER GAP TO CENTER GAP $7F12.4)</td>
</tr>
<tr>
<td>20</td>
<td>FORMAT (3F10.2)</td>
</tr>
<tr>
<td>21</td>
<td>FORMAT (25H G+  )</td>
</tr>
<tr>
<td>22</td>
<td>FORMAT (25H G-  )</td>
</tr>
<tr>
<td>23</td>
<td>FORMAT (25H T+  )</td>
</tr>
<tr>
<td>24</td>
<td>FORMAT (25H T-  )</td>
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<tr>
<td>25</td>
<td>FORMAT (25H WQ+/WP  )</td>
</tr>
<tr>
<td>26</td>
<td>FORMAT (25H RE  )</td>
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<tr>
<td>27</td>
<td>FORMAT (25H WQ-/WP  )</td>
</tr>
<tr>
<td>28</td>
<td>FORMAT (25H WQ+/W  )</td>
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<tr>
<td>29</td>
<td>FORMAT (25H WQ-/W  )</td>
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<tr>
<td>30</td>
<td>FORMAT (25H ZETA+  )</td>
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<tr>
<td>31</td>
<td>FORMAT (25H ZETA-  )</td>
</tr>
<tr>
<td>32</td>
<td>FORMAT (25H Y0+/GO  )</td>
</tr>
<tr>
<td>33</td>
<td>FORMAT (25H Y0-/GO  )</td>
</tr>
<tr>
<td>34</td>
<td>FORMAT (25H E+  )</td>
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<tr>
<td>35</td>
<td>FORMAT (25H E-  )</td>
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<tr>
<td>36</td>
<td>FORMAT (25H F+  )</td>
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<tr>
<td>37</td>
<td>FORMAT (25H F-  )</td>
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<tr>
<td>38</td>
<td>FORMAT (25H C+  )</td>
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<tr>
<td>39</td>
<td>FORMAT (25H C-  )</td>
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<td>40</td>
<td>FORMAT (25H M+  )</td>
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<tr>
<td>41</td>
<td>FORMAT (25H M-  )</td>
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<tr>
<td>42</td>
<td>FORMAT (25H H+  )</td>
</tr>
<tr>
<td>43</td>
<td>FORMAT (25H H-  )</td>
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<tr>
<td>44</td>
<td>FORMAT (25H GELGO )</td>
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<tr>
<td>45</td>
<td>FORMAT ())))/25H GELGOF $7F12.6)</td>
</tr>
<tr>
<td>46</td>
<td>FORMAT (25H GEL  )</td>
</tr>
<tr>
<td>47</td>
<td>FORMAT (25H Q  )</td>
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<tr>
<td>48</td>
<td>FORMAT (25H GOEL  )</td>
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<tr>
<td>49</td>
<td>FORMAT (7F10.5)</td>
</tr>
<tr>
<td>50</td>
<td>FORMAT ())))/25H NU $7F12.6)</td>
</tr>
<tr>
<td>52</td>
<td>FORMAT (25H Y  )</td>
</tr>
<tr>
<td>53</td>
<td>FORMAT (25H GEL  )</td>
</tr>
<tr>
<td>54</td>
<td>FORMAT (25H ZGR  )</td>
</tr>
<tr>
<td>55</td>
<td>FORMAT (25H ZG1  )</td>
</tr>
<tr>
<td>56</td>
<td>FORMAT (5H NKK=15/6H FREQ=F10.4/5H DEL=F10.4/))</td>
</tr>
<tr>
<td>66</td>
<td>FORMAT (25H BOPOS $7F12.6)</td>
</tr>
<tr>
<td>67</td>
<td>FORMAT (25H BOMIN $7F12.6)</td>
</tr>
</tbody>
</table>
70 FORMAT (6H FIVR=F10.6/6H FIVI=F10.6/5H GVR=F10.6/5H GVI=F10.6)
71 FORMAT (//8E14.6/(8E14.6))
72 FORMAT (//8F14.6/(8F14.6))
81 FORMAT(25H REL 7F12.6)
END
SUBROUTINE POTDEP (NCVS, VO, FIO, A, B, C, DGAP, VPTR, RSUBD, VBAR, VSUBD)
DIMENSION VOC (10), DGAP (10), VPTR (10), VSUBD (10), VBAR (10), ROEPS (10), ODDEV (25)

NCVSP1=NCVS+1
EM=1.759E11
CL=2.998E8
EMC2=EM/CL**2
VOC (NCVSP1) = SQRTF (1.0-1.0/(1.0+EMC2*VO)**2)
ODDEV(1) = 2.0
ODDEV(2) = 2.0
DO 42 J=4, NCVS
  ODDEV(J-1) = ODDEV(J-2) + 2.0
  ODDEV(J) = ODDEV(J-1)
42 CONTINUE
PI=3.14159265
FMGO=376.7
BPC=B**2+C**2
BMC=B**2-C**2
VPTR (NCVSP1) = 1.0/(2.0*PI)*FMGO*FIO/VOC (NCVSP1) *(0.5+LOGF(A/B)-BPC/
14.0*BMC)+C**4*LOGF(B/C)/BMC**2
VSUBD (NCVSP1) = VO-VPTR (NCVSP1)/(1.0-VPTR (NCVSP1)/(2.0*VO))
I=0
RD=B
RRD=(B-C)/2.0
GO TO 31
17 RD=RD-RRD
31 I=I+1
TEST=BMC/2.0-BPC/4.0+C**4*LOGF(B/C)/BMC-BPC/4.0+C**4*LOGF(B/C)/BMC
1(B/RD)
  IF (I-1) 10,11,12
10 PAUSE
11 IF (TEST) 13,14,15
13 SIGN2=-1.0
  GO TO 16
15 SIGN2=+1.0
16 IF (SIGN+SIGN2) 17,18,17
11 IF (TEST) 19,14,20
19 SIGN=-1.0
  GO TO 17
20 SIGN=+1.0
  GO TO 17
18 RDD=1.0E-6
  IF (RDD-RDD) 14,14,21
21 RD=RD+RDD
  RRD=RRD/10.0
  GO TO 17
14 RSUBD=RD
DO 22 I=1, NCVS
  VOC(I) = SQRTF (1.0-1.0/(1.0+EMC2*VO)**2)
  ROEPS(I) = FMGO/PI*FIO/VOC(I)*1.0/(BMC)*(39.37)**2/(1.0-VPTR(I)/(2.0*VO))
M=0
27 M=M+1
  IF (FM/ODDEV(M)-1.0) 40,27,41
41 PAUSE
40 FPD=FM*PI/(2.0*DGAP(I))
  IF (I) 28,29,30
28 PAUSE
30 FI1CD=BESSELF(FPD*C,1,2)
GO TO 32
29 FI1CD=0.0
32 FK1BD=BESSELF(FPD*B,1,3)
FI0RD=BESSELF(FPD*RSUBD,0.2)
FKORD=BESSELF(FPD*RSUBD,0.3)
UM=(1.0/FPD)**2*(1.0-FPD*B*FK1BD*FI0RD-FPD*C*FKORD*FI1CD)/(39.37)**
1*2
ANR=8.0/(FM**2*PI**2)*ROEPS(I)*SINF(FM*PI/2.0)**2*UM/(1.0-ROEPS(I)
1*UM/(2.0*V0))
23 PAUSE
25 IF (ANR-CHECK) 26,38,38
24 CHE=1.0E-4
CHECK=ANR*CHE
SUM=ANR
GO TO 27
38 SUM=SUM+ANR
GO TO 27
26 VRAR(I)=VSUBD(NCVSP1)-SUM
27 CONTINUE
RETURN
END
C

SPACE CHARGE REDUCTION FACTOR

SUBROUTINE SPCRDG(I,A,B,C,DDG,BP,BE,FK,GG,BB,T)
DIMENSION GP(10),BP(10),BE(10),FK(10)
G=GP(I)
J=0
DG=DDG
20 G=G+DG
TTT=G**2*(BP(I)**2/((SORTF(G**2+FK(I)**2)-BE(I)**2)-1.0)
IF (TTT) 20,20,12
12 TT=SORTF(TTT)
J=J+1
IF (C) 1.3.2
1 PAUSE 11111
2 FJ0TC=BESSELF(TT*C,0.1)
FJ1TC=BESSELF(TT*C,1.1)
FIOGC=BESSELF(G*C,0.2)
FI1GC=BESSELF(G*C,1.2)
FN0TB=BESSELF(TTB*0.4)
FN1TB=BESSELF(TTB*1.4)
FN0TC=BESSELF(TTC*0.4)
FN1TC=BESSELF(TTC*1.4)
3 FI0GA=BESSELF(G*A,0.2)
FI0GB=BESSELF(G*B,0.2)
FI1GB=BESSELF(G*B,1.2)
FK0GA=BESSELF(G*A,0.3)
FK0GB=BESSELF(G*B,0.3)
FK1GB=BESSELF(G*B,1.3)
FJ0TB=BESSELF(TTB,0.1)
FJ1TB=BESSELF(TTB,1.1)
BCOTH=(FK0GA+F11GB+FK1GB*FI0GA)/(FK0GB*FI0GA-FK0GA*FI0GB)
IF (C) 4.5.6
4 PAUSE 44444
5 FOFI=TTB*FJ1TB-G*B*BCOTH*FJ0TB
GO TO 7
6 FOFI=(TTB)**2*(FJ1TB*FN1TC-FJ1TC*FN1TB)-TTB*G*B*BCOTH*(FJ0TB*FN1
ITC-FJ1TC*FN0TB)+TTB*G*B**2*FI1GC/FI0GC*(FJ1TB*FN0TC-FJ0TC*FN1TB)-(G
2*B)**2*BCOTH*FI1GC/FI0GC*(FJ0TB*FN0TC-FJ0TC*FN0TB)
7 IF (J-1) 4.70.69
69 IF (FOFI) 80.10.82
80 SIGN2=-1.0
GO TO 83
82 SIGN2=+1.0
83 IF (SIGN+SIGN2) 20.8.20
70 IF (FOFI) 64.10.66
64 SIGN=-1.0
GO TO 20
66 SIGN=+1.0
GO TO 20
8 DG=1.0E-6
IF (DG=DGG) 10.10.9
9 G=G-DG
DG=DG/10.0
GO TO 20
10 T=TT
GG=G
BB=SORTF(GG**2+FK(I)**2)
RETURN
END
SUBROUTINE SPCRDM(I, A, B, C, DDG, GM, BP, BE, FK, GG, BB, T)
DIMENSION GM(10), BP(10), BE(10), FK(10)
G = GM(I)
J = 0
DG = DDG

20 G = G - DG
TTT = G**2 * (BP(I)**2 / (SORTF(G**2 + FK(I)**2) - BE(I)**2) - 1.0)
IF (TTT) 20, 20, 12

12 TT = SQRIF(TTT)
J = J + 1
IF (C) 1, 3, 2
1 PAUSE 11111
2 FJOTC = BESSELF(TT*C, 0, 1)
FJ1TC = BESSELF(TT*C, 1, 1)
FIOGC = BESSELF(G*C, 0, 2)
FI1GC = BESSELF(G*C, 1, 2)
FNOOC = BESSELF(TT*B, 0, 4)
FN1TB = BESSELF(TT*B, 1, 4)
FNOOC = BESSELF(TT*C, 0, 4)
FN1TC = BESSELF(TT*C, 1, 4)
3 FIOGA = BESSELF(G*A, 0, 2)
FI0GB = BESSELF(G*B, 0, 2)
FI1GB = BESSELF(G*B, 1, 2)
FK0GA = BESSELF(G*A, 0, 3)
FK0GB = BESSELF(G*B, 0, 3)
FK1GB = BESSELF(G*B, 1, 3)
FJ0TB = BESSELF(TT*B, 0, 1)
FJ1TB = BESSELF(TT*B, 1, 1)
BCOTH = (FK0GA*FI1GB + FK1GB*FI0GA)/(FK0GB*FI0GA - FK0GA*FI0GB)
IF (C) 4, 5, 6
4 PAUSE 44444
5 FOFI = TT*B*FJ1TB - G*B*BCOTH*FJ0TB
GO TO 7
6 FOFI = (TT*B)**2 * (FJ1TB*FN1TC - FJ1TC*FN1TB) - TT*B*G*B*BCOTH*(FJ0TB*FN1TC - FJ1TC*FN0TC + TT*G*B**2 * FIOGC*FI0GC - (FJ1TB*FN0TC - FJ0TC*FN1TB) - (G**2*B)**2 * BCOTH*FI1GC*FI0GC*FJ0TB*FN0TC - FJ0TC*FN0TB)
7 IF (J-1) 4, 70, 69
69 IF (FOFI) 80, 10, 82
80 SIGN2 = -1.0
GO TO 83
82 SIGN2 = +1.0
83 IF (SIGN + SIGN2) 20, 8, 20
70 IF (FOFI) 64, 10, 66
64 SIGN = -1.0
GO TO 20
66 SIGN = +1.0
GO TO 20
8 DGG = 1.0E-6
IF (DG - DGG) 10, 10, 9
9 G = G + DG
DG = DG/10.0
GO TO 20
10 T = TT
GG = G
BB = SQRIF(G**2 + FK(I)**2)
RETURN
END
SUBROUTINE EFCHM(L,A,B,C,NCSV,VI,X,Y,ZZ,EE,FF,CCK,DUM1,DUM2,DUM3)
DIMENSION X(10),Y(10),ZZ(10),EE(10),FF(10),CCK(10,10),VI(10)
DIM DUM1,DUM2,DUM3
DO 10 I=1,NCSV
IF (I-1) 15,11,12
10 PAUSE
11 T=X(I)
G=Y(I)
BT=ZZ(I)
IF (C) 1,2,3
1 PAUSE 11111
2 FJOTB=BESEL{T+B,0,4) FJOTC=BESEL{T+C,0,1)} FJC=BESEL{T+C,1,1)
FJOTC=BESEL{T+C,0,4)
FN1TC=BESELF{T+C,1,4)
F10GC=BESELF{G+C,0,2)
F11GC=BESELF{G+C,1,2)
2 FJOTB=BESEL{T+B,0,1}
FJOTC=BESEL{T+C,0,1)
F10GA=BESELF{G*A,0,2)
F10GB=BESELF{G*B,0,0)
F10GC=BESELF{G+C,0,2)
F11GB=BESELF{G+B,1,2)
IF (C) 4,5,6
4 PAUSE 4444
5 E=FJOTB**2+FJ1TB**2 F=FJOTB**2*(1.0+G**2/T**2+1.0/(T*B*(F10GB*F10GB+F10GB*F10GB)))**2)
1)
CK=2.0*(T*B*F10GB+FJ1TB+G*B*F11GB*FJOTB)/(G**2*B**2+T**2*B**2)*F1
10GA*(FJOTB**2+FJ1TB**2))
GO TO 7
6 BB=-(T*B+FJ1TC+G*F11GC/F10GC)/(T*FN1TC+G*F11GC*FN0TC/F10GC)
E=(T*B**2+(FJOTB**2+FJ1TB**2)+2.0*B*(FJOTB*F10TB+FJ1TB*FN1TB)+BB**
12*(FN0TB**2+FN1TB**2)-C**2*{(FJOTC**2+F11TC**2)+2.0*B*(FJOTC*FN0
2TC+F11TC*FN1TC)+BB**2*(FN0TC**2+FN1TC**2)}/(BB**2-C**2)
F=(1.0+G**2/T**2)*(B**2*(FJOTB*BB*FN0TB)**2-C**2*(FJOTC*BB*FN0TC)*
1*2)/(T**2*(B**2-C**2)*(FJOTB*BB*FN0TB)**2/(T**2*(B**2-C**2)*(F10GB*F10GB
1-F10GA*F00GB)**2)
CK=2.0*(T*B*F10GB+(FJ1TB+G*B*F11GB*FJOTB)-(T
1*C*F10GC*(FJ1TC+BB*FN1TC)+G*C*F11GC*(FJOTC+BB*FN0TC))/(E*F10GA*(B
2**2-C**2)*(G**2+T**2))
7 EE(I)=E
FF(I)=F
CCK(L+I)=CK
GO TO 10
14 EE(I)=EE(I)
FF(I)=FF(I)
CCK(L+I)=CCK(L+I)
10 CONTINUE
RETURN
END
C FREQUENCY FUNCTION SUBROUTINE
SUBROUTINE FREQ(Q,TU,DEL0,NCVS,FREAL,FIMAG)
DIMENSION Q(10),TU(10),FREAL(10),FIMAG(10)
DO 10 I=1,NCVS
   CFCTR = (Q(I)**2.+DEL0+TU(I))*DELO-TU(I))/((1.+DEL0)**(1.+TU(I)))
   FREAL(I) = 1./(1.+CFCTR**2)
10  FIMAG(I) = -CFCTR*FREAL(I)
RETURN
END

C INTERPOLATION
SUBROUTINE TERPOL(N,L,Y,X,ANSR)
DIMENSION Y(3,10,10),ANSR(10)
DO 10 I=1,N
   A=Y(2,L,I)
   B=(Y(3,L,I)-Y(1,L,I))/0.16
   C=(Y(1,L,I)+Y(3,L,I)-2.0*Y(2,L,I))/0.0128
   ANSR(I)=A+B*X+C*X**2
10  CONTINUE
RETURN
END

C AGAIN INTERPOLATION
SUBROUTINE AINTER(N,L,Y,X,YY)
DIMENSION Y(3,10,10),YY(10,10)
DO 10 I=1,N
   A=Y(2,L,I)
   B=(Y(3,L,I)-Y(1,L,I))/0.16
   C=(Y(1,L,I)+Y(3,L,I)-2.0*Y(2,L,I))/0.0128
   YY(I,L)=A+B*X+C*X**2
10  CONTINUE
RETURN
END
SUBROUTINE FORMATR(N, I, NCVS, CKP, CKM, FMP, FMM, FHP, FHM, ZETAP, ZETAM, YOGOP, YOGOM, PPLUSR, PPLUSI, COLMR, COLMI, FLMPR, FLMPI)
DIMENSION CKP(10,10), CKM(10,10), FMP(10,10), FMM(10,10), FHP(10,10), FHM(10,10), ZETAP(10,10), ZETAM(10,10), YOGOP(10,10), YOGOM(10,10), PPLUSR(20,20), PPLUSI(20,20), COLMR(20,20), COLMI(20,20), FLMPR(20,20), FLMPI(20,20)

L = 0
NN = 2*N
DO 1 K = 1, NN, 2
  J = 1
  L = L + 1
  PPLUSR(J,K) = CKP(L,I) * FMP(L,I) * FHP(L,I) * YOGOP(L,I) / (1.0 + ZETAP(L,I))
  PPLUSR(J,K+1) = -CKM(L,I) * FMP(L,I) * FHM(L,I) * YOGOM(L,I) / (1.0 - ZETAM(L,I))
  PPLUSI(J,K) = 0.0
  PPLUSI(J,K+1) = 0.0
1 CONTINUE

L = 0
DO 2 J = 1, NN, 2
  K = 1
  L = L + 1
  COLMR(J,K) = CKP(L,I) * FMP(L,I) / (2.0 * (1.0 + ZETAP(L,I)))
  COLMR(J+1,K) = CKM(L,I) * FMM(L,I) / (2.0 * (1.0 - ZETAM(L,I)))
  COLMI(J,K) = 0.0
  COLMI(J+1,K) = 0.0
2 CONTINUE

DO 3 J = 1, NN
  DO 3 K = 1, NN
  L = 1
  FLMPR(J,K) = COLMR(J,L) * PPLUSR(L,K)
  FLMPI(J,K) = COLMI(J,L) * PPLUSI(L,K)
3 CONTINUE
RETURN
END
FORMATION OF D MATRIX

SUBROUTINE DMATRX(NCVSP1,N,BQPOS,BQMIN,BE,S,DR,DI,FIR,FII)
DIMENSION BQPOS(10,10),BQMIN(10,10),BE(10),S(10),DR(20,20),DI(20,20),FIR(20,20),FII(20,20)
DO 1 J=1,N+2
  M=0
  DO 2 K=1,N+2
    M=M+1
    IF (J-K) 3,4,3
  3   DR(J,K)=0,0
       DI(J,K)=0,0
       DR(J+1,K)=0,0
       DI(J+1,K)=0,0
       DR(J,K+1)=0,0
       DI(J,K+1)=0,0
       DR(J+1,K+1)=0,0
       DI(J+1,K+1)=0,0
       FIR(J,K)=0,0
       FII(J,K)=0,0
       FIR(J+1,K)=0,0
       FII(J+1,K)=0,0
       FIR(J,K+1)=0,0
       FII(J,K+1)=0,0
       FII(J+1,K+1)=0,0
       GO TO 2
  4   SXP=SINF(BE(NCVSP1)*S(I))
       CXP=COSF(BE(NCVSP1)*S(I))
       SYP=SINF(BQPOS(M,NCVSP1)*S(I))
       CYP=COSF(BQPOS(M,NCVSP1)*S(I))
       SYM=SINF(BQMIN(M,NCVSP1)*S(I))
       CYM=COSF(BQMIN(M,NCVSP1)*S(I))
       DR(J,K)=SXP*SYP+CXP*CYP
       DI(J,K)=SYP*CXP-SXP*CYP
       DR(J+1,K+1)=CXP*CYM-SXP*SYM
       DI(J+1,K+1)=-(SXP*CYM+SYM*CXP)
       FIR(J,K)=1,0
       FII(J,K)=0,0
       FIR(J+1,K+1)=1,0
       FII(J+1,K+1)=0,0
  13  CONTINUE
  2  CONTINUE
1 CONTINUE
RETURN
END
COMPLEX MATRIX MULTIPLICATION (UP TO 10x10)

AXB=C

N = ROWS OF A AND C
M = ROWS OF B AND COLUMNS OF A
L = COLUMNS OF B AND C

SUBROUTINE CMMP (AR, AI, N, M, BR, BI, L, CR, CI)
DIMENSION AR (20, 20), AI (20, 20), BR (20, 20), BI (20, 20), CR (20, 20), CI (20, 120), D (20, 20), E (20, 20)
CALL RMMP (AR, N, M, BR, L, D)
CALL RMMP (AI, N, M, BI, L, E)
DO 10 I = 1, N
  DO 10 J = 1, L
    10 CR (I, J) = D (I, J) - E (I, J)
CALL RMMP (AI, N, M, BR, L, D)
CALL RMMP (AR, N, M, BI, L, E)
DO 20 I = 1, N
  DO 20 J = 1, L
    20 CI (I, J) = D (I, J) + E (I, J)
RETURN
END

COMPLEX MATRIX SUBTRACTION

SUBROUTINE CMSUBT (ZGGL, FI, NN, SUM)
DIMENSION ZGGL (20, 20), FI (20, 20), SUM (20, 20)
DO 1 J = 1, NN
  DO 1 K = 1, NN
    1 SUM (J, K) = FI (J, K) - ZGGL (J, K)
CONTINUE
RETURN
END

REAL MATRIX MULTIPLICATION

SUBROUTINE RMMP (A, N, M, B, L, C)
DIMENSION A (20, 20), B (20, 20), C (20, 20)
DO 5 I = 1, N
  DO 5 J = 1, L
    5 C (I, J) = C (I, J) + A (I, K) * B (K, J)
RETURN
END
REFERENCES


2. __________, "A More Precise Analysis of Multicavity Klystrons II," To be published.
