139613

p-27

NASA
Technical
Paper
3251

December 1992

User's Guide for a Large-Signal Computer Model of the Helical Traveling Wave Tube

Raymond W. Palmer

(NASA-TP-3251) USER'S GUIDE FOR A LARGE SIGNAL COMPUTER MODEL OF THE HELICAL TRAVELING WAVE TUBE (NASA) 27 p

N93-15531

Unclas

H1/33 0139613

NASA

NASA
Technical
Paper
3251

1992

User's Guide for a Large-Signal Computer Model of the Helical Traveling Wave Tube

Raymond W. Palmer
Lewis Research Center
Cleveland, Ohio

National Aeronautics and
Space Administration
Office of Management
Scientific and Technical
Information Program

Summary

We describe the use of a successful large-signal, two-dimensional (axisymmetric), deformable disk computer model of the helical traveling wave tube amplifier, an extensively revised and operationally simplified version of the one originally developed by Detweiler. We also discuss program input and output and the auxiliary files necessary for operation. Included is a sample problem and its input data and output results.

Interested parties may now obtain from the author the FORTRAN source code, auxiliary files, and sample input data on a standard floppy diskette, the contents of which are described herein. All requests should be submitted in writing.

Introduction

The Electron Beam Technology Branch of the NASA Lewis Research Center has a successful history of improving the performance of helical traveling wave tubes (TWT's). Achievements include the computer-aided designs of refocuser-collector combinations (refs. 1 to 4) and velocity-tapered output helices using the dynamic velocity taper (DVT) prescription of Kosmahl (refs. 5 and 6). The principal tool in these design procedures is a large-signal helical TWT program which accurately models the electron beam and the amplification process that results from beam-circuit interaction.

The code used at NASA Lewis is a large-signal, two-dimensional (axisymmetric), deformable disk model developed originally by Detweiler (ref. 7). This model chops an electronic wavelength of the beam entering the helical circuit into a row of charge disks. It follows these disks through the tube as they interact with the circuit and with each other, ultimately converting their kinetic energy to enhanced, radiofrequency (rf) field energy. That is, the system of coupled integro-differential equations of motion and disk-circuit interaction is solved, and results are reported at predetermined periodic axial locations. Space-charge forces are formulated such that the disks can overtake and even travel through each other. Also, although each disk retains a constant thickness, it can expand or contract radially. Azimuthal quantities are solved for by preserving each disk's angular momentum in the imposed sinusoidally periodic or solenoidal magnetic field.

The original Detweiler model was acquired and revised extensively by NASA Lewis personnel. Improvements to the original included an accurate solution of the expanded equation set, relativistic effects, a reduced potential due to imposed magnetic field (ref. 8), attenuation, and circuit severing with an automatic program restart. Perhaps the most significant improvement was making the data input procedure easier. Most of the data are now physically meaningful (dimensional) parameters. With the revised model the user no longer has to precalculate dimensionless inputs, a tedious and possibly error-prone process; the revised program consistently and transparently performs these tasks.

The source code is written in ANSI-compatible FORTRAN and requires no special function libraries. At NASA Lewis, it runs on a Cray X-MP supercomputer which produces 64-bit precision and has great speed. Typically, a case using a moderate number of simulated charge disks, such as the one shown in the SAMPLE CASE section of this user's guide, takes less than 1 min of central processor time. The storage requirement for the executable module (absolute element) is less than 0.8 megabyte.

The success of the program and the ease of its use, coupled with the relative stasis it has achieved, prompt us to release the program to users. Interested parties may write to the author to obtain the source program, auxiliary files, and sample input on a standard floppy diskette.

The user's guide includes a description of the diskette contents as well as the program input, file attachment, and output. The guide also analyzes the sample case whose input data are given on the diskette and it gives a complete presentation of the resultant output. The descriptions assume that the user is familiar with both large- and small-signal TWT theories (refs. 7 and 9 to 11). For those who wish to delve more deeply into the model or the code, Detweiler's thesis (ref. 7) is indispensable.

The Diskette

The diskette is a standard, double-sided, 80-track, high-density, 5¼-in. floppy disk. The four text files it contains were copied to it with an AT-compatible personal computer operating under MS-DOS, version 5.0.

The files all have the same name (TWT_HMOD); their identity comes from their extensions (FOR, BSØ, SCT, and INP). TWT_HMOD.FOR (116 112 bytes written from 1416 card images) is the FORTRAN source code. TWT_HMOD.BSØ (24 641 bytes from 302 card images) and .SCT (215 241 bytes from 2714 card images) are two data files that must be attached to the operating module in order to compute space-charge forces. TWT_HMOD.INP (860 bytes from 22 card images) is a sample input data file.

Input Data

A sample input file (TWT_HMOD.INP) is included on the diskette and is printed out in appendix A. This file is read on FORTRAN logical I/O unit 5.

The data entrance process begins when we divide the TWT into logical break points (e.g., where attenuation changes or the tube is severed). Then we define each section by three packets of information:

The first packet is simply a title, up to 80 characters in length. If the first four characters are the word "STOP", the program terminates.

The second and third information packets are the NAMELIST's &IN1 and &IN2.

&IN1 contains the important physical parameters. All FORTRAN variable names therein, except for ZTYPE, are real. &IN1 includes the following (*Those parameters marked with an asterisk should be entered in the first section and not changed thereafter):

- GHZ*—the operating frequency, GHz
- RADA—mean helix radius, in.
- BOVERA*—ratio of entering beam radius to mean helix radius
- TESLA—peak magnetic flux density on helix centerline, T
- VKV*—the helix voltage (i.e., the net accelerating voltage applied to the electron beam), kV
- IMA*—electron beam current, mA
- OHMS—interaction impedance, ohm
- ZTYPE—a character indicator

  ZTYPE='C' if the interaction impedance value given in OHMS is centerline impedance

  ZTYPE='A' if it is the impedance value at the mean helix radius

  ZTYPE='P' if the impedance value is the Pierce, or integrated impedance

  Note: the character must be embedded between two single quotation marks. (The impedances are defined in, or can be deduced from, the material of ref. 10, ch. 10.)
- VOVERC—the ratio of the helix phase velocity to the speed of light, dimensionless
- LMAG—the magnetic period, in. (Note: one may simulate a solenoidal field by making LMAG > >TWT length.)
- RATB*—the ratio of the magnetic flux density at the cathode to the magnetic flux density at the beam entrance to the helix, dimensionless. When RATB=0., the value or RATR (see below) is irrelevant. Typically, magnetic stack-cathode flux linkage in space tubes is quite small, and analyses with RATB set to zero are quite acceptable.
- RATR*—the ratio of the radius of the cathode to the radius of the entering beam, dimensionless. When the value of RATB (see above) is zero, the value of RATR is irrelevant.
- ZEND—the end point of this segment, in.
- ATTEN1, ATTEN2—attenuation at the beginning of this section and at the end, respectively, dB/in. Over the course of the section then, attenuation varies linearly between ATTEN1 and ATTEN2.
- DZ—step size for integrating the differential equations of motion of the charge disks with an internal Runge-Kutta scheme, in. One may increase the accuracy of the solution by choosing a very small value of DZ, but at the expense of increased central processor time.
- PINDBM—the input drive power, dBm. In all sections beyond the first, PINDBM serves as a program flag: if PINDBM is positive, the calculation continues normally; if it is zero, a sever section is indicated; if it is negative, a section immediately following a sever section is indicated. Thus, the values 0., 1., and −1. are all that are needed beyond the first section.
- URATIO*—the ratio of the input electron radial disk edge velocity to the input axial velocity, dimensionless. URATIO is thus negative for a converging beam and positive for an expanding beam.
- ALPHA, TAUZ—DVT parameters. The Pierce velocity parameter b (ref. 10, ch. 10) is modelled as

$$b = b_0 + \alpha\left(\frac{Z_a}{Z_p}\right)^{1/3}\left\{\exp[\tau_z(z - z_0)] - 1\right\}$$

  Here b_0 is the value of this parameter at the beginning of the section (at $z = z_0$); ALPHA corresponds to α and is dimensionless; Z_a is the interaction impedance evaluated at the mean helix radius; Z_p is the Pierce interaction impedance; and TAUZ corresponds to τ_z and is in in.$^{-1}$. Note that the ratio of the local phase velocity to the phase velocity at the beginning of the section is

$$\frac{v}{v_0} = \frac{1 + b_0C}{1 + bC}$$

  where C is the Pierce interaction parameter.

The NAMELIST &IN2 contains parameters that are more administrative in nature. The variables are integers and logical switches. &IN2 includes the following:

- RUN*—an integer run identifier for record keeping convenience
- IPRNT—an integer output control. Program information is put out every IPRNT steps (i.e., at IPRNT*DZ inch intervals).

- PLOTT—logical switch that, when .TRUE., causes beam trajectory information to be saved in a file on FORTRAN logical I/O unit 14 every IPRNT steps. From the saved file, one can later plot the disk edge trajectories.
- PLOTE—logical switch that, when .TRUE., causes beam energy information at the end of the section to be saved on FORTRAN logical I/O unit 15. As with trajectories, this information can be plotted later.

M*—the number of model charge disks used in the simulation of the electron beam. Permissible values are 2, 4, 8, 16, 20, 32, 64, 80, and 160. One may increase the accuracy of the simulation by choosing a large number of disks, but at the expense of increased central processor time. Setting M = 32 serves well for preliminary design studies.

Auxiliary File Attachments

Disk trajectory and energy distribution information can be saved in files for later plotting (see INPUT DATA). These two files are written to FORTRAN logical I/O units 14 and 15, respectively. Their contents are described later in the PROGRAM OUTPUT section.

In addition to these two files, the program module requires two more for operation. These files are used for the computation of space-charge forces between charge disks.

The first file (TWT_HMOD.BSØ on the diskette) consists of the first 750 zeros of the zeroth-order Bessel function of the first kind J_0, followed by the 750 squares of the J_1 function evaluated at these zeroes. These tabular values are used in the construction of the dimensionless space-charge-weighting function tables, from which radial and axial space-charge forces between adjacent disks are interpolated.

These data are read on FORTRAN logical I/O unit 7 when the program requires new tables to accommodate the input parameters. Before each segment of 750 data words is an information record (not to be erased). The data follow in 5E16.7 format written to 302 card images.

The second file (TWT_HMOD.SCT on the diskette) consists mainly of the space-charge-weighting-function tables. If the input parameters require, these data must be recomputed and the file overwritten before the problem can continue. Overwriting occurs if one changes the ratio of mean helix radius to electronic wavelength or if one starts the run with a new number of charge disks in the simulation. The user must allow for this possible occurrence in any job control command stream that runs the program in either the interactive or batch mode of operation.

The space-charge file is read on FORTRAN logical I/O unit 4. The first record is informational but must not be erased. The tables follow in 1P5E16.7 format. After the tabular data is another informational record (also not to be erased). Finally, there are 57 data words, which are the distances apart, in terms of phase space (ref. 7, ch. 2), at which the tables are evaluated. These data words are also in 1P5E16.7 format. Excluding the data on the informational record, there are a total of 13 107 data words. The whole file is contained on 2714 card images.

Program Output

In appendix B, a complete specimen program output is presented exactly as printed by the computer. This output results from the input file given in appendix A.

The output is directed to FORTRAN logical I/O unit 6. This information is divided into sections corresponding to the input data. Following is a description of those quantities that are reported.

First, at the beginning of each section, the program prints an echo of the section title and the two input NAMELIST's (see INPUT DATA). Then follows another NAMELIST, &OUT. &OUT contains some parameters of interest to those familiar with the Pierce, or small-signal theory of amplification (ref. 10, ch. 10):

- RELFAC—the square of the ratio of the input velocity to the speed of light, dimensionless. (Note: relativistic effects are retained in all calculations of axial velocity but not for radial or azimuthal velocities, which are generally nonrelativistic.)
- VEFF—the ratio of the centerline (reduced voltage) to the applied voltage, dimensionless. The voltage reduction arises because of the magnetic containment of the beam. (Note: this reduced voltage is used in the calculation of the axial entrance velocity and, where applicable, in the calculation of the following Pierce parameters.)
- WP—the ratio of the plasma frequency to the frequency of operation, ω_p/ω, dimensionless
- BCPRCE—the product of the electronic wave number and the Pierce interaction parameter, $\beta_e C$, in.$^{-1}$
- CPRCE—the Pierce interaction parameter C, dimensionless
- BPRCE—the Pierce velocity parameter b, dimensionless
- QCPRCE—the Pierce space-charge parameter QC, dimensionless
- D1PRCE, D2PRCE—the Pierce attenuation factors d, at the beginning and at the end of the section, respectively, dimensionless
- ZRATH—the cube root of the ratio of the interaction impedance evaluated at the mean helix radius to the Pierce interaction impedance, $(Z_a/Z_p)^{1/3}$, dimensionless. This parameter is used in the prescription of the DVT (see INPUT DATA).

After the printout of &OUT is completed, the code then determines from the section input if new space-change tables are required. Recall that the tables must be recomputed if the ratio of mean helix radius to electronic wavelength changes or if one starts a run with a new number of charge disks in the simulation. If new tables are computed, the program prints a message to inform the user.

These preliminary tasks performed, the program now labels a page heading with RUN and section number and marches through the section DZ inch per step. It prints results every IPRNT steps or IPRNT*DZ inch intervals (see INPUT DATA). Thirteen quantities are printed out at each print step:

- Z—the axial location, in.
- GAIN—the tube gain, dB
- EFF—the beam efficiency, or 100 times the ratio of rf output power to the beam power (the product of helix voltage and beam current), percent
- PHASE—the rf signal phase, θ_v, rad. The growing voltage wave on the helix is of the form

  $$Re\left\{V\exp[-j(\beta_e Z - \omega t - \theta_v)]\right\}$$

  where V is the (real) voltage. θ_v is PHASE and is an angular measure of the time difference between the arrival of the rf signal at Z to the arrival of an idealized hypothetical charge disk that moves through the TWT at the injection velocity. A negative value of PHASE means that the signal lags this reference trajectory.
- HLOSS, SLOSS, ILOSS—normalized beam power lost to the helix in ohmic heating, lost to the sever, and lost through beam interception on the helix, respectively, percent of beam power
- FAMP, FPHS, HAMP, HPHS—normalized fundamental current amplitude (i_1/i_0), fundamental current phase, (θ_1), normalized first harmonic current amplitude (i_2/i_0), and first harmonic current phase, (θ_2) respectively. Current is normalized via division by the beam current. Phase is given in degrees. These quantities constitute the first two terms of the Fourier decomposition of the modulated beam current that is of the form

  $$\sum \frac{i_n}{i_0}\cos(n\Phi - \theta_n)$$

  where Φ is the angle of the circuit voltage.
- WVSPD—ratio of the helix phase velocity to the value at the start of the section, dimensionless. This ratio is given by $(1 + b_0C)/(1 + bC)$, where b is the Pierce velocity parameter, b_0 is its value at the beginning of the section, and C is the Pierce interaction parameter.
- MGFLD—ratio of on-axis magnetic flux density to the peak value for the section, dimensionless

During the process of stepping through the section, the code will send printed notifications whenever the edge of a charge disk contacts the helix (at the average helix radius RADA). The user will also be informed the first time that the integration process drives a disk trajectory negative in the r-coordinate. Internally the model "reflects" the trajectory through the axis by changing the sign of r. The calculation then continues with this positive value as the new starting condition. We have noticed no adverse effects when only a small number of the trajectories is reflected during a run.

Finally, when the end of the section is reached, the code produces an energy and trajectory "snapshot" at ZEND. Printed out for each disk are the total kinetic energy, the (combined) kinetic energy in the z- and r-directions, the kinetic energy in the azimuthal direction only (energies in eV); the normalized radius (normalized to the average helix radius RADA); the angle at which each disk is expanding or contracting (convergence/divergence angles in deg); and the normalized position of the disk in the phase space of an electronic wavelength (normalized to pi radians). The disks are ordered in ascending total kinetic energy so that the user can get a quick idea of the energy distribution.

Following the snapshot, the program concludes the printed information of the section by giving some disk statistics. Printed out are the average and standard deviations of the sample (see eq. (10-2), ref. 12) for the normalized radii, the convergence/divergence angles, and the total kinetic energies.

The user may optionally request information to be saved for plotting later (see INPUT DATA section), trajectory information being written to FORTRAN logical I/O unit 14, and beam energy distribution information to unit 15.

Two records of the trajectory file are written every IPRNT steps. The first record consists of the single integer variable M, the number of charge disks, written in I12 format. The second record consists of the location Z, the radius RADA, a quantity proportional to the magnetic field, and these followed by M values of disk radius. Z, RADA, and the disk radii are in inches. The dimensionless magnetic quantity is $(\omega_c/\omega)(B/B_0)$, where ω_c is the cyclotron frequency, ω is the angular frequency of operation, B is the local field, and B_0 is the peak field for the section. The format of this second record is 6E12.5.

The energy distribution file is written at the end of the section (at ZEND). The first record, written in 2I12 format, consists of M and the section number. The second record gives M values of the ratio of charge disk total kinetic energy (in eV) to the helix voltage. These are sorted and written in ascending order. The format is 6E12.5. The third record gives M values of $1 - (i - 1)/M$ for i from 1 to M, also in 6E12.5 format.

These latter two records give the normalized energy distribution plot abscissa-ordinate pairs: the first record is M ordered values of the abscissa, the second is the corresponding values of the ordinate. An ordinate value on the curve represents the fraction of the total beam having normalized total kinetic energy greater than or equal to its corresponding abscissa value.

Sample Case

Our sample case is a preliminary attempt to design a nominal 5- to 7-W, Ka-Band (GHz, 32) TWT which might have application in a deep space mission. The input data are given in appendix A and the resulting output in appendix B.

The tube uses a 14-mA electron beam accelerated to 5.255 kV. This beam has quite low perveance and, consequently, high thermal effects (refs. 13 and 14) which the model cannot simulate. Therefore, the size of the beam used in the input data (beam radius, BOVERA*RADA = 0.03013 in.) is determined by a parametric analysis beyond the scope of this document. The peak magnetic flux density (TESLA = 0.21 T) is $\sqrt{2}$ times the solenoidal Brillouin field necessary to contain the beam. At the TWT entrance, the beam is expanding at an angle of ½ deg (URATIO = 0.00873). Approximately 5 G leaks back from the entrance to link the cathode (RATB = 2.381×10^{-3}), which has 25 times the area of the beam (RATR = 5.0).

The TWT consists of four sections: an input helix, a sever, and an output helix which is divided into a constant-pitch section and a dynamically tapered section. All have the same radius (RADA = 0.0131 in.), the same peak field (TESLA = 0.21 T), the same magnetic period (LMAG = 0.2025 in.), and the same centerline (ZTYPE = 'C') impedance (OHMS = 28.84 ohms). The active helices have the same attenuation (ATTEN1 = ATTEN2 = 2.35 dB/in.). The sever, into which is dumped the power from the previous section, is given the artificial attenuation values of 99 dB/in. (merely as a reminder to the user that this section is indeed the sever).

The input helix is 1.616 in. long, the sever is 0.560 in. long, and the output helix is 2.079 in. long, the last 1.099 in. being dynamically tapered. The input helix is wound such that the normalized phase velocity is 0.1353, corresponding to a Pierce velocity parameter of approximately 1.79. The output helix has a normalized phase velocity of 0.1426, which results in a Pierce velocity parameter slightly less than synchronous ($b = -0.19$). The tapered section (TAUZ = 4.3, ALPHA = 0.045) reduces this velocity to about 83 percent of its input value over the last 1.099 in.

The equations of motion are integrated every 5×10^{-4} in. in this problem whose run number is 1234. A moderate number of disks (M = 32) is used in this simulation. In three of the four sections, we call for output every 0.1 in. (IPRNT = 100); in the tapered section, we want five times more detail (IPRNT = 20). We save no plot data. Each section is labeled, and the problem is halted when the last label is the word "STOP".

The drive power is nearly 2 mW (PINDBM = 2.75 dBm). Note that the nature of PINDBM changes in sections 2 to 4. In the second section, the program recognizes that PINDBM = 0. corresponds to a sever section. PINDBM = −1. in the third section causes recovery (auto restart) of the solution. The value of 1. in the last section means problem continuation.

In appendix A, we note that the signal is amplified by 17.3 dB in the input helix. That power is dumped into the sever where the signal phase is maintained constant while the gain and efficiency calculations are terminated, but their values are arbitrarily reported as zero.

In the output helix the problem is restarted; here the product of the fundamental current amplitude times a coupling factor results in a new starting condition for the current-circuit interaction.

The rf efficiency grows to nearly 0.8 percent by the time the charge disks enter the tapered section where the phase velocity is continuously reduced in order to maintain an efficient disk-circuit reaction. The result is an rf efficiency of more than 9 percent (6.6 W output power). The combination circuit and sever loss is 1.9 W. The output kinetic energy of the charge disks varies from a minimum of 4069 to 5397 eV.

Concluding Remarks

We describe the operation of a large-signal, two-dimensional (axisymmetric), deformable disk computer model of the helical traveling wave tube amplifier.

This FORTRAN program is a modified version of the one developed originally by Detweiler. It was greatly expanded and improved by NASA Lewis Research Center Personnel. In particular, the data input procedure was significantly simplified. This revised code was used successfully in a variety of analytical and design tasks.

We describe the program input process, the output, and the auxiliary files that must be attached to the operating module. Included and discussed is a sample problem, the input data and output results for which are provided in the appendices.

Since the program is successful, easy to use, and in relative stasis, we can now release it to potential users. Interested parties may obtain the source code, auxiliary files, and the sample input data file on a standard floppy diskette by writing the author. The contents of the diskette are described herein.

Lewis Research Center
National Aeronautics and Space Administration
Cleveland, Ohio, March 30, 1992

Appendix A
Sample Input

```
                 INPUT HELIX
 &IN1 GHZ=32.0,RADA=.01310,BOVERA=.230,TESLA=.2100,
 VKV=5.2500,IMA=14.000,
 OHMS=28.84,VOVERC=.13530,LMAG=.2025,RATB=2.381E-03,RATR=5.0,
 ZEND=1.616,DZ=.0005,ATTEN1=2.3500,ATTEN2=2.3500,
 PINDBM= 2.750,ZTYPE='C',URATIO= 0.00873 &END
 &IN2
  RUN=1234,IPRNT=100,
  M= 32,PLOTT=F,PLOTE=F  &END
                 SEVER SECTION
 &IN1 ZEND=2.176,PINDBM=0.,TAUZ=0.000000,ALPHA=0.,ATTEN1= 99.,
 ATTEN2= 99. &END
 &IN2 IPRNT=100,PLOTT=F  &END
      CONSTANT PITCH SECTION OF THE OUTPUT HELIX
 &IN1 ZEND=3.156,PINDBM=-1.,TAUZ=0.000000,ALPHA=0.000,ATTEN1= 2.35,
 ATTEN2=2.35,VOVERC=.1426  &END
 &IN2 PLOTT=F        &END
          DVT SECTION OF THE OUTPUT HELIX
 &IN1 ZEND=4.255,ATTEN1= 2.350,ATTEN2= 2.350,PINDBM= 1.,
  TAUZ=4.3000000,ALPHA= 0.045          &END
 &IN2 IPRNT= 20,PLOTE=F,PLOTT=F              &END
STOP
```

Appendix B
Sample Output

```
***                INPUT HELIX                                                      ***
&IN1  GHZ = 32.0,  RADA = 1.31E-02,  BOVERA = 0.23,  TESLA = 0.21,  VKV = 5.25,  IMA = 14.0,  OHMS = 28.84,  VOVERC = 0.1353,
 LMAG = 0.2025,  RATB = 2.381E-03,  RATR = 5.0,  ZEND = 1.616,  DZ = 5.0E-04,  ATTEN1 = 2.35,  ATTEN2 = 2.35,  ALPHA = 0.0,
 TAUZ = 0.0,  PINDBM = 2.75,  URATIO = 8.73E-03,  ZTYPE = 'C',  &END
&IN2  RUN = 1234,  M = 32,  IPRNT = 100,  PLOTE = F,  PLOTT = F,  &END
&OUT  RELFAC = 2.012526147E-02,  VEFF = 0.995738666,  WP = 9.379711547E-02,  BCPRCE = 3.25734233,  CPRCE = 2.714512591E-02,
 BPRCE = 1.78709604,  QCPRCE = 0.196395845,  D1PRCE = 8.306001793E-02,  D2PRCE = 8.306001793E-02,  ZRATH = 1.45508064,  &END
*** NEW SPACE CHARGE TABLES HAVE BEEN COMPUTED. ***
```

RUN NO. 1234, SECTION NO. 1

Z (IN)	GAIN (DB)	EFF (%)	PHASE (RAD)	HLOSS (%)	SLOSS (%)	ILOSS (%)	FAMP (I1/I0)	FPHS (DEG)	HAMP (I2/I0)	HPHS (DEG)	WVSPD (V/V0)	MGFLD (B/B0)
0.050	-0.115	0.000	-0.292	0.000	0.000	0.000	0.001	-7.546	0.000	53.236	1.000	0.019
0.100	-0.214	0.000	-0.588	0.000	0.000	0.000	0.002	13.097	0.000	-131.837	1.000	-0.999
0.150	-0.263	0.000	-0.891	0.000	0.000	0.000	0.005	28.264	0.000	-59.542	1.000	-0.058
0.200	-0.215	0.000	-1.203	0.000	0.000	0.000	0.009	42.136	0.000	30.363	1.000	0.997
0.250	-0.024	0.000	-1.519	0.000	0.000	0.000	0.013	55.473	0.000	76.425	1.000	0.097
0.300	0.333	0.000	-1.834	0.000	0.000	0.000	0.018	68.396	0.000	103.900	1.000	-0.993
0.350	0.848	0.001	-2.141	0.000	0.000	0.000	0.023	80.306	0.000	126.982	1.000	-0.135
0.400	1.483	0.001	-2.434	0.001	0.000	0.000	0.028	91.161	0.000	142.661	1.000	0.988
0.450	2.186	0.002	-2.712	0.001	0.000	0.000	0.032	100.507	0.000	149.796	1.000	0.174
0.500	2.909	0.002	-2.975	0.001	0.000	0.000	0.036	108.275	0.001	152.520	1.000	-0.981
0.550	3.622	0.003	-3.227	0.001	0.000	0.000	0.039	114.325	0.001	173.407	1.000	-0.212
0.600	4.303	0.004	-3.469	0.001	0.000	0.000	0.041	119.128	0.001	-177.907	1.000	0.973
0.650	4.948	0.005	-3.706	0.001	0.000	0.000	0.044	122.328	0.002	-165.262	1.000	0.249
0.700	5.556	0.007	-3.941	0.001	0.000	0.000	0.045	124.437	0.002	-160.799	1.000	-0.963
0.750	6.139	0.008	-4.176	0.002	0.000	0.000	0.047	125.012	0.002	-159.065	1.000	-0.287
0.800	6.706	0.009	-4.413	0.002	0.000	0.000	0.049	124.399	0.003	-153.210	1.000	0.952
0.850	7.271	0.011	-4.652	0.002	0.000	0.000	0.052	122.903	0.004	-147.284	1.000	0.324
0.900	7.845	0.013	-4.892	0.003	0.000	0.000	0.057	121.117	0.004	-139.278	1.000	-0.940
0.950	8.439	0.015	-5.133	0.003	0.000	0.000	0.062	119.642	0.005	-132.505	1.000	-0.360
1.000	9.056	0.018	-5.374	0.004	0.000	0.000	0.069	118.861	0.006	-129.837	1.000	0.926
1.050	9.700	0.021	-5.614	0.004	0.000	0.000	0.076	118.526	0.006	-132.032	1.000	0.396
1.100	10.365	0.025	-5.853	0.005	0.000	0.000	0.085	118.896	0.007	-127.097	1.000	-0.910
1.150	11.051	0.030	-6.088	0.006	0.000	0.000	0.094	119.634	0.009	-123.685	1.000	-0.431
1.200	11.748	0.035	-6.321	0.007	0.000	0.000	0.104	120.838	0.010	-117.873	1.000	0.894
1.250	12.455	0.042	-6.552	0.008	0.000	0.000	0.114	121.988	0.011	-115.880	1.000	0.466

RUN NO. 1234, SECTION NO. 1

Z (IN)	GAIN (DB)	EFF (%)	PHASE (RAD)	HLOSS (%)	SLOSS (%)	ILOSS (%)	FAMP (I1/I0)	FPHS (DEG)	HAMP (I2/I0)	HPHS (DEG)	WVSPD (V/V0)	MGFLD (B/B0)
1.300	13.158	0.050	-6.780	0.009	0.000	0.000	0.124	123.363	0.012	-117.371	1.000	-0.876
1.350	13.854	0.059	-7.007	0.010	0.000	0.000	0.135	124.114	0.014	-121.957	1.000	-0.500
1.400	14.534	0.069	-7.233	0.012	0.000	0.000	0.145	125.076	0.017	-123.661	1.000	0.856
1.450	15.200	0.081	-7.458	0.014	0.000	0.000	0.156	125.395	0.021	-122.488	1.000	0.533
1.500	15.850	0.095	-7.684	0.017	0.000	0.000	0.166	125.774	0.025	-117.663	1.000	-0.835
1.550	16.491	0.111	-7.911	0.019	0.000	0.000	0.176	125.635	0.028	-114.903	1.000	-0.566
1.600	17.124	0.128	-8.139	0.023	0.000	0.000	0.185	125.101	0.029	-115.597	1.000	0.814
1.616	17.326	0.135	-8.213	0.024	0.000	0.000	0.189	124.749	0.031	-116.419	1.000	0.992

RUN NO. 1234, SECTION NO. 1

DISK NO.	EK(TOTAL) EV	EK(Z+R) EV	EK(PHI) EV	R/A	ANGLE DEG	PHASE/PI
3	5141.293561	5135.665739	5.627822	0.242123	0.600500	0.735161
5	5144.165586	5138.771444	5.394143	0.237569	0.539212	0.838095
4	5144.213372	5138.662243	5.551129	0.240637	0.571295	0.787273
2	5146.013174	5140.448247	5.564927	0.240905	0.626825	0.685530
1	5149.551260	5144.199216	5.352044	0.236737	0.644633	0.634032
6	5153.405859	5148.184176	5.221683	0.234147	0.514896	0.892584
7	5155.521625	5150.599597	4.922028	0.228084	0.493878	0.944659
32	5157.584472	5152.474172	5.110301	0.231911	0.660929	0.582944
31	5168.290925	5163.516134	4.774791	0.225041	0.661141	0.531404
8	5172.612400	5168.002507	4.609893	0.221585	0.485758	-0.996144
9	5178.601622	5174.325697	4.275926	0.214413	0.486208	-0.940471
30	5180.669661	5176.298559	4.371102	0.216481	0.649202	0.478186
29	5194.214708	5190.159354	4.055354	0.209537	0.641862	0.423178
10	5197.354338	5193.470577	3.883761	0.205664	0.486544	-0.878065
11	5211.003349	5207.417313	3.586036	0.198759	0.496428	-0.816254
28	5212.034929	5208.251146	3.783783	0.203369	0.618908	0.367551
27	5225.435221	5221.886084	3.549137	0.197883	0.601318	0.307580
12	5229.626733	5226.307964	3.318769	0.192343	0.488623	-0.750579
26	5243.882887	5240.479003	3.403884	0.194405	0.571094	0.247635
13	5247.104702	5243.962260	3.142442	0.187986	0.491044	-0.684027
25	5258.959051	5255.700661	3.258390	0.190857	0.539665	0.182332
14	5263.214163	5260.241543	2.972620	0.183690	0.491029	-0.614376
15	5274.943653	5271.958214	2.985439	0.184015	0.498019	-0.542937
24	5275.548236	5272.495822	3.052415	0.185717	0.532626	0.115538
16	5295.434325	5292.440712	2.993613	0.184219	0.507762	-0.469317
23	5298.706449	5295.604022	3.102427	0.186972	0.523391	0.046753
17	5299.799684	5296.821494	2.978190	0.183824	0.501415	-0.396292
21	5303.008435	5299.965872	3.042563	0.185461	0.511461	-0.101397
19	5306.792606	5303.792542	3.000064	0.184381	0.498270	-0.247283
22	5309.521586	5306.480587	3.040999	0.185420	0.499073	-0.020126
18	5313.033270	5310.047043	2.986227	0.184026	0.509739	-0.317600
20	5316.159397	5313.073334	3.086063	0.186557	0.507256	-0.165250

...STATISTICS........

R...........	0.206/	0.021
ANG.........	0.545/	0.061
EK(TOTAL)...	5223.991/	61.988

```
***                   SEVER SECTION                                                                     ***
&IN1  GHZ = 32.0,  RADA = 1.31E-02,  BOVERA = 0.23,  TESLA = 0.21,  VKV = 5.25,  IMA = 14.0,  OHMS = 28.84,  VOVERC = 0.1353,
 LMAG = 0.2025,  RATB = 2.381E-03,  RATR = 5.0,  ZEND = 2.176,  DZ = 5.0E-04,  ATTEN1 = 99.0,  ATTEN2 = 99.0,  ALPHA = 0.0,
 TAUZ = 0.0,  PINDBM = 0.0,  URATIO = 8.73E-03,  ZTYPE = 'C',  &END
&IN2  RUN = 1234,  M = 32,  IPRNT = 100,  PLOTE = F,  PLOTT = F,  &END
&OUT  RELFAC = 2.012526147E-02,  VEFF = 0.995738666,  WP = 9.379711547E-02,  BCPRCE = 3.25734233,  CPRCE = 2.714512591E-02,
 BPRCE = 1.78709604,  QCPRCE = 0.196395845,  D1PRCE = 3.49912416,  D2PRCE = 3.49912416,  ZRATH = 1.45508064,  &END
```

RUN NO. 1234, SECTION NO. 2

Z (IN)	GAIN (DB)	EFF (%)	PHASE (RAD)	HLOSS (%)	SLOSS (%)	ILOSS (%)	FAMP (I1/I0)	FPHS (DEG)	HAMP (I2/I0)	HPHS (DEG)	WVSPD (V/V0)	MGFLD (B/B0)
1.650	0.000	0.000	-8.213	0.024	0.135	0.000	0.199	115.396	0.033	-135.170	1.000	0.597
1.700	0.000	0.000	-8.213	0.024	0.135	0.000	0.218	103.717	0.039	-160.189	1.000	-0.790
1.750	0.000	0.000	-8.213	0.024	0.135	0.000	0.240	93.816	0.048	178.422	1.000	-0.628
1.800	0.000	0.000	-8.213	0.024	0.135	0.000	0.263	86.001	0.056	160.791	1.000	0.766
1.850	0.000	0.000	-8.213	0.024	0.135	0.000	0.284	79.112	0.065	144.061	1.000	0.658
1.900	0.000	0.000	-8.213	0.024	0.135	0.000	0.303	73.408	0.074	130.254	1.000	-0.741
1.950	0.000	0.000	-8.213	0.024	0.135	0.000	0.318	68.053	0.083	116.836	1.000	-0.686
2.000	0.000	0.000	-8.213	0.024	0.135	0.000	0.328	63.295	0.090	105.468	1.000	0.714
2.050	0.000	0.000	-8.213	0.024	0.135	0.000	0.332	58.557	0.094	93.664	1.000	0.714
2.100	0.000	0.000	-8.213	0.024	0.135	0.000	0.329	53.984	0.094	81.424	1.000	-0.686
2.150	0.000	0.000	-8.213	0.024	0.135	0.000	0.319	49.105	0.090	66.779	1.000	-0.741
2.176	0.000	0.000	-8.213	0.024	0.135	0.000	0.312	46.536	0.086	58.648	1.000	-0.027

RUN NO. 1234, SECTION NO. 2

DISK NO.	EK(TOTAL) EV	EK(Z+R) EV	EK(PHI) EV	R/A	ANGLE DEG	PHASE/PI
22	5140.704649	5140.661877	0.042772	0.233906	0.567164	-0.007408
24	5147.890018	5147.845432	0.044586	0.221542	0.357978	0.093514
27	5154.015117	5153.970047	0.045070	0.218656	0.314604	0.210983
25	5157.875694	5157.830866	0.044828	0.220088	0.331829	0.139635
29	5158.508320	5158.462104	0.046217	0.212340	0.321288	0.304471
23	5171.827148	5171.782091	0.045058	0.218741	0.457668	0.072723
19	5191.024959	5190.974332	0.050627	0.193032	0.532909	-0.158791
31	5191.028551	5190.984288	0.044263	0.223597	0.537580	0.412149
21	5193.255494	5193.211931	0.043563	0.228225	0.597515	-0.029314
26	5197.313336	5197.269669	0.043667	0.227517	0.348732	0.205015
20	5198.915064	5198.866166	0.048897	0.199853	0.542641	-0.097820
28	5205.266126	5205.219147	0.046979	0.208523	0.257021	0.293720
18	5216.271606	5216.214322	0.057284	0.172650	0.480673	-0.223170
30	5216.563566	5216.518039	0.045526	0.216103	0.432263	0.376713
17	5220.795730	5220.735451	0.060279	0.165526	0.452357	-0.292448
1	5223.196885	5223.151708	0.045177	0.218091	0.557683	0.513612
16	5241.567203	5241.508920	0.058284	0.170173	0.538700	-0.366671
3	5241.732653	5241.689023	0.043630	0.227805	0.611818	0.626528
6	5242.975191	5242.928549	0.046642	0.210219	0.505707	0.838325
32	5244.097872	5244.054133	0.043739	0.227072	0.565572	0.477145
15	5252.287351	5252.230690	0.056661	0.174279	0.570566	-0.443992
5	5258.615467	5258.571586	0.043881	0.226128	0.579170	0.757282
14	5262.019794	5261.962070	0.057724	0.171560	0.547367	-0.527389
4	5262.651656	5262.607327	0.044329	0.223232	0.550328	0.718008
8	5266.363450	5266.309593	0.053856	0.182221	0.469415	0.973041
13	5266.608885	5266.551681	0.057204	0.172876	0.551460	-0.612601
2	5268.483020	5268.439590	0.043430	0.229217	0.577653	0.599933
12	5273.360652	5273.301475	0.059176	0.168059	0.492747	-0.697352
11	5275.066150	5275.001828	0.064322	0.157277	0.392790	-0.780832
9	5278.095083	5278.039234	0.055848	0.176471	0.431587	-0.939671
10	5281.888070	5281.828930	0.059140	0.168147	0.431419	-0.863326
7	5282.643850	5282.597969	0.045881	0.214208	0.501600	0.902788

...STATISTICS........

R...........	0.202/	0.025
ANG.........	0.481/	0.095
EK(TOTAL)...	5224.466/	44.220

```
***       CONSTANT PITCH SECTION OF THE OUTPUT HELIX                                        ***
&IN1  GHZ = 32.0,  RADA = 1.31E-02,  BOVERA = 0.23,  TESLA = 0.21,  VKV = 5.25,  IMA = 14.0,  OHMS = 28.84,  VOVERC = 0.1426,
 LMAG = 0.2025,  RATB = 2.381E-03,  RATR = 5.0,  ZEND = 3.156,  DZ = 5.0E-04,  ATTEN1 = 2.35,  ATTEN2 = 2.35,  ALPHA = 0.0,
 TAUZ = 0.0,  PINDBM = -1.0,  URATIO = 8.73E-03,  ZTYPE = 'C',  &END
&IN2  RUN = 1234,  M = 32,  IPRNT = 100,  PLOTE = F,  PLOTT = F,  &END
&OUT  RELFAC = 2.012526147E-02,  VEFF = 0.995738666,  WP = 9.379711547E-02,  BCPRCE = 3.25345329,  CPRCE = 2.711271654E-02,
 BPRCE = -0.19048546,  QCPRCE = 0.196865652,  D1PRCE = 8.315930428E-02,  D2PRCE = 8.315930428E-02,  ZRATH = 1.45681998,  &END
```

RUN NO. 1234, SECTION NO. 3

Z (IN)	GAIN (DB)	EFF (%)	PHASE (RAD)	HLOSS (%)	SLOSS (%)	ILOSS (%)	FAMP (I1/I0)	FPHS (DEG)	HAMP (I2/I0)	HPHS (DEG)	WVSPD (V/V0)	MGFLD (B/B0)
2.200	-3.126	-0.001	-8.749	0.024	0.135	0.000	0.304	75.877	0.082	114.115	1.000	0.658
2.250	5.180	0.006	-8.919	0.024	0.135	0.000	0.284	79.860	0.073	113.144	1.000	0.766
2.300	9.118	0.019	-8.987	0.024	0.135	0.000	0.261	76.963	0.067	94.906	1.000	-0.628
2.350	11.573	0.035	-9.045	0.025	0.135	0.000	0.238	71.131	0.069	71.403	1.000	-0.790
2.400	13.250	0.052	-9.105	0.026	0.135	0.000	0.218	63.031	0.082	51.072	1.000	0.597
2.450	14.451	0.070	-9.172	0.028	0.135	0.000	0.207	52.103	0.101	36.219	1.000	0.814
2.500	15.324	0.086	-9.249	0.030	0.135	0.000	0.211	40.516	0.124	27.393	1.000	-0.566
2.550	15.977	0.101	-9.338	0.033	0.135	0.000	0.229	30.130	0.146	22.296	1.000	-0.835
2.600	16.486	0.114	-9.442	0.036	0.135	0.000	0.261	23.295	0.168	20.246	1.000	0.533
2.650	16.926	0.127	-9.561	0.039	0.135	0.000	0.301	19.920	0.190	20.671	1.000	0.856
2.700	17.360	0.141	-9.693	0.042	0.135	0.000	0.344	19.619	0.211	23.773	1.000	-0.500
2.750	17.847	0.158	-9.838	0.047	0.135	0.000	0.389	21.348	0.233	28.403	1.000	-0.876
2.800	18.430	0.181	-9.989	0.051	0.135	0.000	0.434	24.542	0.257	35.353	1.000	0.466
2.850	19.134	0.214	-10.142	0.056	0.135	0.000	0.479	28.168	0.281	42.883	1.000	0.894
2.900	19.951	0.258	-10.292	0.063	0.135	0.000	0.524	32.078	0.305	51.484	1.000	-0.431
2.950	20.862	0.319	-10.432	0.070	0.135	0.000	0.568	35.309	0.324	58.781	1.000	-0.910
3.000	21.818	0.397	-10.562	0.080	0.135	0.000	0.613	38.119	0.340	65.190	1.000	0.396
3.050	22.785	0.496	-10.680	0.092	0.135	0.000	0.658	39.862	0.349	69.030	1.000	0.926
3.100	23.726	0.615	-10.788	0.107	0.135	0.000	0.701	40.968	0.352	70.762	1.000	-0.360
3.150	24.624	0.757	-10.888	0.125	0.135	0.000	0.742	41.133	0.348	69.173	1.000	-0.940
3.156	24.728	0.775	-10.899	0.127	0.135	0.000	0.746	41.100	0.347	68.759	1.000	-0.860

RUN NO. 1234, SECTION NO. 3

DISK NO.	EK(TOTAL) EV	EK(Z+R) EV	EK(PHI) EV	R/A	ANGLE DEG	PHASE/PI
12	5046.442661	5038.515798	7.926864	0.301460	-0.452395	0.118756
10	5050.971129	5042.007046	8.964084	0.322123	-0.468135	0.082188
8	5077.047973	5070.542838	6.505135	0.270548	-0.215109	0.036545
11	5087.618870	5078.435412	9.183458	0.326307	-0.354008	0.134869
23	5088.712572	5084.683291	4.029282	0.205782	-0.512314	0.598491
24	5090.066132	5086.349906	3.716226	0.196037	-0.457557	0.573142
13	5094.021663	5087.112016	6.909647	0.279682	-0.525047	0.165815
19	5094.340939	5090.219902	4.121037	0.208547	-0.440591	0.315489
21	5095.642741	5090.784773	4.857967	0.229537	-0.343605	0.484060
22	5095.838585	5091.369827	4.468758	0.218708	-0.591376	0.400051
9	5110.205692	5101.930655	8.275037	0.308521	-0.262269	0.100253
17	5117.669475	5111.814651	5.854824	0.255142	-0.501637	0.231178
15	5130.509259	5124.634652	5.874607	0.255618	-0.528414	0.210759
25	5138.014569	5134.681870	3.332699	0.183349	-0.732004	0.672857
14	5143.220575	5137.534161	5.686414	0.250990	-0.515363	0.205084
16	5144.003392	5139.276388	4.727003	0.225934	-0.714465	0.321927
27	5152.143801	5149.507781	2.636020	0.157586	-0.541383	0.749862
26	5152.383356	5150.039140	2.344215	0.145324	-0.610887	0.840326
18	5155.751237	5151.984780	3.766456	0.197611	-0.342176	0.391574
20	5164.264258	5160.188685	4.075573	0.207156	-0.466878	0.492224
6	5167.497384	5163.115388	4.381996	0.216192	-0.205092	-0.000949
7	5173.495156	5169.061338	4.433817	0.217681	-0.130423	0.050619
29	5192.374043	5189.482497	2.891546	0.167512	-0.640707	0.954385
28	5198.432099	5195.337007	3.095092	0.174997	-0.597501	-0.939779
5	5222.112959	5219.143840	2.969118	0.170398	-0.009295	-0.048705
31	5291.323051	5289.560653	1.762398	0.116356	-0.032594	-0.817631
30	5319.074978	5316.873459	2.201518	0.138836	0.193920	-0.640717
1	5365.583179	5363.373580	2.209600	0.139196	0.040452	-0.511563
3	5377.701755	5375.767145	1.934609	0.125738	0.403936	-0.352145
2	5392.861765	5390.818298	2.043467	0.131255	0.406375	-0.211332
4	5400.644923	5398.030395	2.614528	0.156642	-0.003152	-0.124211
32	5423.264199	5421.037331	2.226868	0.139973	-0.014942	-0.480270

...STATISTICS........
R.......... 0.208/ 0.060
ANG......... -0.318/ 0.305
EK(TOTAL)... 5179.789/ 110.404

```
***          DVT SECTION OF THE OUTPUT HELIX                                                  ***
&IN1  GHZ = 32.0,  RADA = 1.31E-02,  BOVERA = 0.23,  TESLA = 0.21,  VKV = 5.25,  IMA = 14.0,  OHMS = 28.84,  VOVERC = 0.1426,
 LMAG = 0.2025,  RATB = 2.381E-03,  RATR = 5.0,  ZEND = 4.255,  DZ = 5.0E-04,  ATTEN1 = 2.35,  ATTEN2 = 2.35,  ALPHA = 4.5E-02,
 TAUZ = 4.3,  PINDBM = 1.0,  URATIO = 8.73E-03,  ZTYPE = 'C',  &END
&IN2  RUN = 1234,  M = 32,  IPRNT = 20,  PLOTE = F,  PLOTT = F,  &END
&OUT  RELFAC = 2.012526147E-02,  VEFF = 0.995738666,  WP = 9.379711547E-02,  BCPRCE = 3.25345329,  CPRCE = 2.711271654E-02,
 BPRCE = -0.19048546,  QCPRCE = 0.196865652,  D1PRCE = 8.315930428E-02,  D2PRCE = 8.315930428E-02,  ZRATH = 1.45681998,  &END
```

RUN NO. 1234, SECTION NO. 4

Z (IN)	GAIN (DB)	EFF (%)	PHASE (RAD)	HLOSS (%)	SLOSS (%)	ILOSS (%)	FAMP (I1/I0)	FPHS (DEG)	HAMP (I2/I0)	HPHS (DEG)	WVSPD (V/V0)	MGFLD (B/B0)
3.160	24.798	0.787	-10.907	0.129	0.135	0.000	0.750	41.072	0.346	68.460	1.000	-0.790
3.170	24.967	0.819	-10.926	0.134	0.135	0.000	0.757	40.996	0.345	67.651	1.000	-0.566
3.180	25.135	0.851	-10.945	0.138	0.135	0.000	0.765	40.921	0.343	66.774	1.000	-0.287
3.190	25.301	0.884	-10.964	0.143	0.135	0.000	0.772	40.823	0.341	65.773	1.000	0.019
3.200	25.463	0.918	-10.983	0.148	0.135	0.000	0.779	40.706	0.339	64.636	1.000	0.324
3.210	25.624	0.952	-11.002	0.153	0.135	0.000	0.786	40.560	0.337	63.327	1.000	0.597
3.220	25.782	0.988	-11.021	0.158	0.135	0.000	0.793	40.370	0.335	61.813	0.999	0.814
3.230	25.937	1.024	-11.040	0.163	0.135	0.000	0.800	40.151	0.333	60.138	0.999	0.952
3.240	26.091	1.060	-11.058	0.169	0.135	0.000	0.806	39.896	0.331	58.302	0.999	1.000
3.250	26.241	1.098	-11.077	0.174	0.135	0.000	0.812	39.620	0.330	56.354	0.999	0.952
3.260	26.389	1.136	-11.096	0.180	0.135	0.000	0.819	39.340	0.330	54.356	0.999	0.814
3.270	26.534	1.174	-11.115	0.187	0.135	0.000	0.825	39.052	0.330	52.327	0.999	0.597
3.280	26.677	1.214	-11.134	0.193	0.135	0.000	0.832	38.774	0.331	50.331	0.999	0.324
3.290	26.818	1.253	-11.153	0.200	0.135	0.000	0.838	38.4[illegible]	0.333	48.366	0.999	0.019
3.300	26.955	1.294	-11.173	0.206	0.135	0.000	0.844	38.206	0.336	46.428	0.998	-0.287
3.310	27.091	1.335	-11.192	0.214	0.135	0.000	0.851	37.905	0.339	44.523	0.998	-0.566
3.320	27.225	1.377	-11.211	0.221	0.135	0.000	0.857	37.570	0.343	42.632	0.998	-0.790
3.330	27.356	1.419	-11.231	0.228	0.135	0.000	0.863	37.209	0.347	40.791	0.998	-0.940
3.340	27.486	1.462	-11.251	0.236	0.135	0.000	0.869	36.825	0.353	39.036	0.998	-0.999
3.350	27.613	1.506	-11.271	0.244	0.135	0.000	0.876	36.429	0.359	37.419	0.998	-0.963
3.360	27.737	1.550	-11.291	0.252	0.135	0.000	0.882	36.048	0.365	36.018	0.997	-0.835
3.370	27.860	1.594	-11.312	0.261	0.135	0.000	0.889	35.688	0.372	34.851	0.997	-0.628
3.380	27.981	1.639	-11.332	0.269	0.135	0.000	0.896	35.359	0.379	33.932	0.997	-0.360
3.390	28.099	1.684	-11.353	0.278	0.135	0.000	0.903	35.056	0.387	33.236	0.997	-0.058
3.400	28.216	1.730	-11.374	0.287	0.135	0.000	0.910	34.759	0.394	32.700	0.997	0.249

RUN NO. 1234, SECTION NO. 4

Z (IN)	GAIN (DB)	EFF (%)	PHASE (RAD)	HLOSS (%)	SLOSS (%)	ILOSS (%)	FAMP (I1/I0)	FPHS (DEG)	HAMP (I2/I0)	HPHS (DEG)	WVSPD (V/V0)	MGFLD (B/B0)
3.410	28.331	1.777	-11.395	0.297	0.135	0.000	0.918	34.458	0.401	32.287	0.996	0.533
3.420	28.445	1.824	-11.417	0.306	0.135	0.000	0.925	34.133	0.408	31.943	0.996	0.766
3.430	28.557	1.872	-11.439	0.316	0.135	0.000	0.932	33.780	0.415	31.655	0.996	0.926
3.440	28.667	1.920	-11.461	0.326	0.135	0.000	0.940	33.412	0.423	31.452	0.996	0.997
3.450	28.776	1.969	-11.484	0.337	0.135	0.000	0.948	33.041	0.430	31.369	0.995	0.973
3.460	28.882	2.018	-11.506	0.347	0.135	0.000	0.956	32.698	0.437	31.476	0.995	0.856
3.470	28.988	2.067	-11.530	0.358	0.135	0.000	0.964	32.398	0.444	31.798	0.995	0.658
3.480	29.091	2.117	-11.553	0.370	0.135	0.000	0.972	32.146	0.452	32.338	0.995	0.396
3.490	29.193	2.167	-11.577	0.381	0.135	0.000	0.981	31.939	0.459	33.074	0.994	0.097
3.500	29.294	2.218	-11.601	0.393	0.135	0.000	0.990	31.752	0.465	33.940	0.994	-0.212
3.510	29.393	2.269	-11.625	0.405	0.135	0.000	0.998	31.571	0.472	34.890	0.994	-0.500
3.520	29.492	2.321	-11.650	0.417	0.135	0.000	1.006	31.379	0.479	35.879	0.993	-0.741
3.530	29.589	2.374	-11.675	0.430	0.135	0.000	1.015	31.166	0.485	36.887	0.993	-0.910
3.540	29.685	2.427	-11.701	0.443	0.135	0.000	1.023	30.947	0.492	37.940	0.993	-0.993
3.550	29.780	2.480	-11.727	0.456	0.135	0.000	1.032	30.733	0.498	39.060	0.992	-0.981
3.560	29.874	2.534	-11.754	0.469	0.135	0.000	1.040	30.548	0.505	40.290	0.992	-0.876
3.570	29.966	2.589	-11.781	0.483	0.135	0.000	1.049	30.407	0.511	41.651	0.991	-0.686
3.580	30.058	2.644	-11.808	0.497	0.135	0.000	1.057	30.310	0.518	43.134	0.991	-0.431
3.590	30.148	2.699	-11.836	0.511	0.135	0.000	1.066	30.257	0.524	44.722	0.990	-0.135
3.600	30.238	2.755	-11.864	0.526	0.135	0.000	1.074	30.229	0.531	46.368	0.990	0.174
3.610	30.327	2.812	-11.893	0.541	0.135	0.000	1.082	30.213	0.537	48.031	0.989	0.466
3.620	30.415	2.870	-11.923	0.556	0.135	0.000	1.089	30.198	0.543	49.677	0.989	0.714
3.630	30.503	2.928	-11.953	0.571	0.135	0.000	1.097	30.174	0.548	51.280	0.988	0.894
3.640	30.590	2.987	-11.984	0.587	0.135	0.000	1.104	30.152	0.554	52.858	0.988	0.988
3.650	30.676	3.047	-12.015	0.603	0.135	0.000	1.111	30.141	0.559	54.434	0.987	0.988

RUN NO. 1234, SECTION NO. 4

Z (IN)	GAIN (DB)	EFF (%)	PHASE (RAD)	HLOSS (%)	SLOSS (%)	ILOSS (%)	FAMP (I1/I0)	FPHS (DEG)	HAMP (I2/I0)	HPHS (DEG)	WVSPD (V/V0)	MGFLD (B/B0)
3.660	30.762	3.107	-12.047	0.620	0.135	0.000	1.118	30.156	0.563	56.038	0.986	0.894
3.670	30.847	3.168	-12.080	0.637	0.135	0.000	1.124	30.210	0.567	57.699	0.986	0.714
3.680	30.931	3.230	-12.113	0.654	0.135	0.000	1.130	30.301	0.570	59.411	0.985	0.466
3.690	31.015	3.293	-12.147	0.671	0.135	0.000	1.136	30.431	0.572	61.174	0.984	0.174
3.700	31.099	3.356	-12.182	0.689	0.135	0.000	1.141	30.589	0.573	62.952	0.984	-0.135
3.710	31.182	3.421	-12.217	0.707	0.135	0.000	1.146	30.761	0.574	64.706	0.983	-0.431
3.720	31.265	3.486	-12.254	0.726	0.135	0.000	1.151	30.940	0.573	66.413	0.982	-0.686
3.730	31.348	3.553	-12.291	0.745	0.135	0.000	1.155	31.119	0.571	68.048	0.981	-0.876
3.740	31.430	3.621	-12.330	0.764	0.135	0.000	1.159	31.303	0.568	69.627	0.980	-0.981
3.750	31.513	3.690	-12.369	0.784	0.135	0.000	1.162	31.501	0.564	71.184	0.979	-0.993
3.760	31.595	3.760	-12.409	0.804	0.135	0.000	1.165	31.727	0.559	72.767	0.978	-0.910
3.770	31.677	3.831	-12.450	0.824	0.135	0.000	1.168	31.997	0.552	74.427	0.977	-0.741
3.780	31.759	3.903	-12.493	0.845	0.135	0.000	1.170	32.312	0.545	76.178	0.976	-0.500
3.790	31.840	3.976	-12.536	0.866	0.135	0.000	1.173	32.674	0.537	78.022	0.975	-0.212
3.800	31.922	4.051	-12.581	0.887	0.135	0.000	1.174	33.074	0.527	79.928	0.974	0.097
3.810	32.004	4.127	-12.627	0.909	0.135	0.000	1.175	33.496	0.517	81.842	0.973	0.396
3.820	32.086	4.205	-12.674	0.932	0.135	0.000	1.176	33.932	0.504	83.725	0.972	0.658
3.830	32.169	4.285	-12.723	0.955	0.135	0.000	1.177	34.373	0.491	85.547	0.970	0.856
3.840	32.251	4.367	-12.773	0.978	0.135	0.000	1.177	34.823	0.477	87.306	0.969	0.973
3.850	32.334	4.450	-12.824	1.002	0.135	0.000	1.177	35.296	0.461	89.031	0.968	0.997
3.860	32.417	4.535	-12.877	1.026	0.135	0.000	1.177	35.811	0.445	90.770	0.966	0.926
3.870	32.501	4.621	-12.932	1.050	0.135	0.000	1.177	36.388	0.428	92.585	0.965	0.766
3.880	32.584	4.710	-12.989	1.075	0.135	0.000	1.177	37.037	0.410	94.505	0.963	0.533
3.890	32.668	4.800	-13.047	1.101	0.135	0.000	1.176	37.758	0.391	96.534	0.961	0.249
3.900	32.752	4.893	-13.107	1.127	0.135	0.000	1.175	38.540	0.372	98.626	0.960	-0.058

RUN NO. 1234, SECTION NO. 4

Z (IN)	GAIN (DB)	EFF (%)	PHASE (RAD)	HLOSS (%)	SLOSS (%)	ILOSS (%)	FAMP (I1/I0)	FPHS (DEG)	HAMP (I2/I0)	HPHS (DEG)	WVSPD (V/V0)	MGFLD (B/B0)
3.910	32.837	4.988	-13.169	1.154	0.135	0.000	1.174	39.364	0.352	100.694	0.958	-0.360
3.920	32.922	5.086	-13.232	1.181	0.135	0.000	1.172	40.215	0.331	102.653	0.956	-0.628
3.930	33.009	5.186	-13.298	1.208	0.135	0.000	1.171	41.081	0.310	104.408	0.954	-0.835
3.940	33.095	5.289	-13.367	1.237	0.135	0.000	1.169	41.965	0.288	105.914	0.952	-0.963
3.950	33.183	5.395	-13.437	1.265	0.135	0.000	1.167	42.887	0.266	107.163	0.950	-0.999
3.960	33.271	5.504	-13.510	1.295	0.135	0.000	1.166	43.872	0.244	108.182	0.948	-0.940
3.970	33.359	5.614	-13.585	1.325	0.135	0.000	1.164	44.947	0.222	108.993	0.946	-0.790
3.980	33.448	5.728	-13.663	1.355	0.135	0.000	1.162	46.126	0.199	109.506	0.943	-0.566
3.990	33.536	5.844	-13.744	1.387	0.135	0.000	1.159	47.412	0.177	109.461	0.941	-0.287
4.000	33.626	5.963	-13.827	1.418	0.135	0.000	1.157	48.793	0.154	108.317	0.938	0.019
4.010	33.715	6.085	-13.914	1.451	0.135	0.000	1.154	50.247	0.132	105.134	0.936	0.324
4.020	33.806	6.210	-14.003	1.484	0.135	0.000	1.151	51.758	0.113	98.554	0.933	0.597
4.030	33.897	6.338	-14.096	1.518	0.135	0.000	1.147	53.313	0.100	87.260	0.930	0.814
4.040	33.988	6.470	-14.192	1.553	0.135	0.000	1.143	54.920	0.097	72.136	0.927	0.952
4.050	34.079	6.604	-14.291	1.588	0.135	0.000	1.139	56.597	0.108	57.796	0.924	1.000
4.060	34.170	6.741	-14.394	1.624	0.135	0.000	1.134	58.371	0.130	48.224	0.921	0.952
4.070	34.261	6.879	-14.502	1.661	0.135	0.000	1.129	60.273	0.160	43.679	0.918	0.814
4.080	34.351	7.020	-14.613	1.699	0.135	0.000	1.123	62.318	0.195	42.873	0.915	0.597
4.090	34.440	7.161	-14.728	1.737	0.135	0.000	1.116	64.512	0.234	44.644	0.911	0.324
4.100	34.528	7.304	-14.848	1.777	0.135	0.000	1.108	66.844	0.274	48.226	0.908	0.019
4.110	34.615	7.448	-14.972	1.817	0.135	0.000	1.099	69.299	0.317	53.128	0.904	-0.287
4.120	34.701	7.593	-15.101	1.857	0.135	0.000	1.088	71.861	0.359	59.007	0.900	-0.566
4.130	34.785	7.737	-15.235	1.899	0.135	0.000	1.076	74.512	0.401	65.630	0.896	-0.790
4.140	34.868	7.880	-15.374	1.942	0.135	0.000	1.061	77.250	0.442	72.844	0.892	-0.940
4.150	34.947	8.022	-15.519	1.985	0.135	0.000	1.045	80.072	0.481	80.558	0.888	-0.999

RUN NO. 1234, SECTION NO. 4

Z (IN)	GAIN (DB)	EFF (%)	PHASE (RAD)	HLOSS (%)	SLOSS (%)	ILOSS (%)	FAMP (I1/I0)	FPHS (DEG)	HAMP (I2/I0)	HPHS (DEG)	WVSPD (V/V0)	MGFLD (B/B0)
4.160	35.024	8.160	-15.670	2.029	0.135	0.000	1.027	82.989	0.517	88.729	0.883	-0.963
4.170	35.098	8.295	-15.827	2.074	0.135	0.000	1.007	86.005	0.549	97.329	0.879	-0.835
4.180	35.167	8.424	-15.990	2.119	0.135	0.000	0.986	89.122	0.576	106.341	0.874	-0.628
4.190	35.232	8.547	-16.160	2.165	0.135	0.000	0.963	92.332	0.598	115.731	0.869	-0.360
4.200	35.293	8.663	-16.337	2.212	0.135	0.000	0.938	95.614	0.614	125.448	0.864	-0.058
4.210	35.349	8.771	-16.522	2.260	0.135	0.000	0.912	98.944	0.624	135.423	0.859	0.249
4.220	35.399	8.870	-16.715	2.308	0.135	0.000	0.885	102.289	0.627	145.572	0.854	0.533
4.230	35.445	8.959	-16.915	2.357	0.135	0.000	0.857	105.628	0.623	155.823	0.848	0.766
4.240	35.485	9.038	-17.125	2.406	0.135	0.000	0.830	108.944	0.613	166.122	0.842	0.926
4.250	35.519	9.107	-17.344	2.456	0.135	0.000	0.804	112.244	0.598	176.447	0.836	0.997
4.255	35.534	9.137	-17.457	2.481	0.135	0.000	0.792	113.899	0.590	-178.380	0.833	0.997

RUN NO. 1234, SECTION NO. 4

DISK NO.	EK(TOTAL) EV	EK(Z+R) EV	EK(PHI) EV	R/A	ANGLE DEG	PHASE/PI
7	4069.122377	4051.532992	17.589385	0.411281	0.107521	0.333469
17	4102.462425	4093.338416	9.124008	0.301157	0.286142	0.396110
9	4107.263410	4100.750306	6.513104	0.257832	-0.426043	0.268587
22	4107.619668	4102.483222	5.136446	0.231720	-0.340433	0.546093
16	4120.013488	4116.683370	3.330118	0.192046	-0.097722	0.661325
11	4124.914158	4119.473767	5.440391	0.237729	0.273193	0.409029
13	4129.559780	4124.340373	5.219407	0.233370	0.520795	0.410017
14	4169.467542	4164.033970	5.433572	0.237582	0.152250	0.527056
15	4180.185217	4175.320782	4.864435	0.226178	0.173941	0.515946
19	4190.688156	4187.228845	3.459311	0.195141	-0.497642	0.708623
1	4200.457467	4200.395373	0.062094	0.069452	0.713173	0.692286
4	4233.777140	4224.640788	9.136352	0.301293	0.327280	0.521808
12	4258.533712	4235.674985	22.858727	0.466742	0.020487	0.427258
21	4290.895459	4289.369226	1.526233	0.141215	-0.524270	0.865681
6	4336.794666	4322.770820	14.023846	0.368804	-0.226469	0.397583
30	4341.118498	4340.513271	0.605228	0.104935	2.081292	0.847735
10	4342.107370	4322.892829	19.214541	0.429030	0.046951	0.468248
2	4355.314559	4333.102103	22.212455	0.460225	0.348553	0.516839
18	4367.560254	4365.046806	2.513447	0.170974	-0.956886	0.966008
31	4510.101719	4509.952227	0.149492	0.040603	0.419252	-0.926990
5	4542.366788	4524.510883	17.855905	0.413998	-1.697020	0.703688
8	4615.452916	4603.649999	11.802917	0.339652	0.051028	0.561029
20	4660.569507	4656.997825	3.571681	0.197691	-0.549036	-0.821999
24	4712.292754	4710.037904	2.254850	0.163669	0.033065	-0.793577
3	4754.535307	4752.494528	2.040779	0.157404	0.999679	-0.801785
23	4990.027363	4989.151264	0.876099	0.116959	0.517630	-0.474169
27	5214.489066	5209.892132	4.596934	0.220322	1.030740	0.772334
29	5315.596109	5315.043744	0.552365	0.102274	-2.195347	-0.490228
25	5329.728783	5328.094531	1.634251	0.144635	0.652117	0.025116
26	5338.114450	5328.612168	9.502282	0.306410	-1.221093	-0.707925
28	5391.612277	5391.089332	0.522945	0.031335	-0.093591	-0.339601
32	5397.077846	5387.715688	9.362158	0.304267	0.805445	-0.105661

...STATISTICS.........		
R...........	0.237/	0.120
ANG.........	0.023/	0.812
EK(TOTAL)...	4524.994/	450.685

References

1. Dayton, J.A., Jr., et al.: Analytical Prediction and Experimental Verification of TWT and Depressed Collector Performance Using Multidimensional Computer Programs. IEEE Trans. Electron Devices, vol. ED-26, no. 10, Oct. 1979, pp. 1589-1598.
2. Dayton, J.A., Jr., et al.: Experimental Verification of a Computational Procedure for the Design of TWT-Refocuser-MDC Systems. IEEE Trans. Electron Devices, vol. ED-28, no. 12, Dec. 1981, pp. 1480-1489.
3. Ramins, P. et al.: Verification of an Improved Computational Design Procedure for TWT-Dynamic Refocuser-MDC Systems with Secondary Electron Emission Losses. IEEE Trans. Electron Devices, vol. ED-33, Jan. 1986, pp. 85-90.
4. Ramins, P.; Force, D.A.; and Kosmahl, H.G.: Analytical and Experimental Performance of a Dual-Mode Traveling-Wave Tube and Multistage Depressed Collector. NASA TP-2752, 1987.
5. Kosmahl, H.G.; and Peterson, J.C.: A TWT Amplifier with a Linear Power Transfer Characteristic and Improved Efficiency. NASA TM-83477, 1984.
6. Curren, A.N. et al.: High-Efficiency Helical Traveling-Wave Tube with Dynamic Velocity Taper and Advanced Multistage Depressed Collector. IEDM-International Electron Devices Meeting, Dec. 1987, Proceedings, IEEE, 1987, pp. 473-476.
7. Detweiler, H.K.: Characteristics of Magnetically Focused Large-Signal Traveling-Wave Amplifiers. Report RADC-TR-68-433, Oct. 1968.
8. Dayton, J.A. et al.: Analytical Prediction with Multi-Dimensional Programs and Experimental Verification of the Performance, at a Variety of Operating Conditions, of Two Traveling Wave Tubes with Depressed Collectors. NASA TP-1449, 1979.
9. Pierce, J.R.: Traveling Wave Tubes. Van Nostrand Company, 1950.
10. Gewartowski, J.W.; and Watson, H.A.: Principles of Electron Tubes, Including Grid-Controlled Tubes, Microwave Tubes, and Gas Tubes. Van Nostrand Company, 1965.
11. Rowe, J.E.: Nonlinear Electron-Wave Interaction Phenomena. Academic Press, 1965.
12. Herrmann, G.: Optical Theory of Thermal Velocity Effects in Cylindrical Electron Beams. J. Appl. Phys., vol. 29, no. 2, Feb., 1958, pp. 127-136.
13. Amboss, K.: Verification and Use of Herrmann's Optical Theory of Thermal Velocity Effects in Electron Beams in the Low Perveance Regime. IEEE Trans. Electron Devices, vol. ED-11, no. 10, Oct. 1964, pp. 479-485.

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	December 1992	Technical Paper

4. TITLE AND SUBTITLE
User's Guide for a Large-Signal Computer Model of the Helical Traveling Wave Tube

5. FUNDING NUMBERS
WU-506-72

6. AUTHOR(S)
Raymond W. Palmer

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135-3191

8. PERFORMING ORGANIZATION REPORT NUMBER
E-6804

9. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, D.C. 20546-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NASA TP-3251

11. SUPPLEMENTARY NOTES
Responsible person, Raymond W. Palmer, (216) 433-3518.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified - Unlimited
Subject Category 33

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 words)***

We describe the use of a successful large-signal, two-dimensional (axisymmetric), deformable disk computer model of the helical traveling wave tube amplifier, an extensively revised and operationally simplified version of the one originally developed by Detweiler. We also discuss program input and output and the auxiliary files necessary for operation. Included is a sample problem and its input data and output results. Interested parties may now obtain from the author the FORTRAN source code, auxiliary files, and sample input data on a standard floppy diskette, the contents of which are described herein. All requests should be submitted in writing.

14. SUBJECT TERMS
User's guide; Large-signal; Computer model; Helical TWT

15. NUMBER OF PAGES
28

16. PRICE CODE
A03

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	