2017-01-21

Users' guide for 2D full wave code TASK/WF2

Contents

1 Structure

1.1 Source program

Header	common variables	wfcomm.inc
Function	global control	wfmain.f
	element data generation	wfdiv.f
	zone data generation	wfzone.f
	antenna data generation	wfant.f
	wave analysis	wfwave.f
	transport analysis	wfevol.f
	graphics	wfgout.f
	dispersion relation	wffreq.f
Library	profile setting	wfprof.f
	file I/O	wffile.f
	common subroutines	wfsub.f
	graphic subroutines	wfgsub.f
	common library	wflib.f

- wfsub.f and wfgsub.f depends on wfcomm.inc.
- wflib.f is independent of wfcomm.inc.

1.2 Execution procedure

1. Element definition	Define node points in computation area and generate triangular elements.
2. Zone definition	Define plasma, dielectric, and vacuum zones and boundary attributes,
3. Antenna definition	Define antenna shape and position.
4. Wave analysis	Calculate wave field excited by antenna and absorbed power density.
5. Transport analysis	Calculate time evolution of density and temperature of electrons and ions,
6. Graphic display	Indicate spatial profiles and time evolution,

- For simulation of plasma production by waves, steps 4 and 5 should be repeated to analyze time evoluton.
- For simulation of plasma production without waves, step 5 should be repeated to analyze time evoluton.
- Defined element data, zone data, and antenna data can be saved in files and loaded for new and continuation simulations.
- Calculated spatial profiles will be saved in a file and loaded for continuation simulations (not yet implemented).

1.3 How to install

- Download gsaf, and task.
- Install gsaf library.
- cd to task directory
- Copy make.header.org to make.header
- Edit make.header for you computational environment.
- `make`

1.4 Coordinates

- Cartesian coordinates (`MODELS=0`)
  horizontal: x, vertical: y, near side: z
- Cylindrical coordinates (`MODELS=1`)
  horizontal: R, vertical: Z, near side: θ
- Toroidal coordinates: (`MODELS=2`)
  horizontal: $R - R_0$, vertical: Z, near side: θ

1.5 Compile parameter

- The size of arrays are defined in `wfcomm.inc` as `paremter` sentences. If the file is modified, all depending files will be recompiled ed by `make`.

Variables	Default values	Explanation
NAM	8	maximum number of antenna
NFM	2	maximum number of particle species in TR
NSM	3	maximum number of particle species in WF
NXM	200	maximum number of division in X direction
NYM	200	maximum number of division in Y direction
JNUMM	800	maximum number of antenna elements
NBDYM	500	maximum number of boundary nodes
NNODM	2200	maximum number of nodes
NELMM	4000	maximum number of elements
MBNDM	400	maximum number of width of the band matrix
MLENM	12000	maximum number of length of the band maxrix
NCNM	36	
NRM	101	maximum number of radial division for absorbed power density
NDM	20	maximum number of element attribute data
NBM	50	maximum number of boundary attribute data
NMM	8	maximum number of dielectric attribute data
NVM	2	maximum number of electric potential data
NGTM	1001	maximum number of time evolution data
NZLM	5	log_2 of maximum number of fourier modes in Z direction
NWDM	12	maximum number of graphs on a page
NCHM	10	maximum character number of a graph attribute variable
NCM	3	maximum number of static magnetic field coil

- Parameters defined in a specific file

File name	Variables	Default values	Explanation
wfdiv.f	NXQM	11	maximum number of horizontal number of rectangulars
wfdiv.f	NYQM	11	maximum number of vertical number of rectangulars
wffreq.f	NNXM	201	maximum number of horizontal division in 1D plot
wfgsub.f	NGXM	101	maximum number of horizontal division in contour plots
wfgsub.f	NGYM	101	maximum number of vertical division in contour plots
wfgsub.f	NSTEPM	101	maximum number of contours in contour plots
libspl.f	NMAX	1001	maximum number of data for spline interpolation

2 Input parameters

```
C
C     *** DEFAULT FILE NAME ***
C
C        KFNAME: File name of element data
C        KFNAMA: File name of antenna data
C        KFNAMF: File name of field data
C        KFNAMZ: File name of zone data
C
      KFNAME = 'elm-data'
      KFNAMA = 'ant-data'
      KFNAMF = 'fld-data'
      KFNAMZ = 'zone-data'
C
C     *** CONFIGURATION PARAMETERS ***
C
C        BB    : Magnetic field at center                         (T)
C        RA    : Plasma minor radius                               (m)
C
      BB     = 0.08D0
      RA     = 0.08D0
C
C     *** CONFIGURATION PARAMETERS (MIRROR: MODELB=3,4) ***
C
C        RMIR  : Mirror ratio
C        ZBB   : Periodic length along magnetic axis             (m)
C
      RMIR   = 2.0D0
      ZBB    = 0.15D0
C
C     *** CONFIGURATION PARAMETERS (TOKAMAK: MODELB=5) ***
C
C        RR    : Plasma major radius                               (m)
C        Q0    : Safety factor at center
C        QA    : Safety factor on plasma surface
C        RKAP  : Plasma shape elongation
C        RDEL  : Plasma shape triangularity *
C
      RR     = 3.D0
      Q0     = 1.D0
      QA     = 3.D0
      RKAP   = 1.D0
      RDEL   = 0.D0
C
C     *** CONFIGURATION PARAMETERS (HELICAL: MODELB=6) ***
C
C        H1    : Helical pitch (2*pi/L) for B profile
C        H2    : Helical pitch (2*pi/L) for metric
C        RRC   : Coil radius                                     (m)
C
      H1     = 1.25D0
      H2     = 1.25D0
      RRC    = 0.95D0
C
C     *** CIRCULAR COIL PARAMETERS (MODELB=7) ***
C
C        NCMAX : Number of coil
C        RC    : Radial position of coil current                 (m)
C        ZC    : Axial position of coil current                  (m)
C        B2    : Magnetic filed on axis, center of coil          (T)
C
      NCMAX  = 3
      RC(1)  = 0.35D0
      ZC(1)  = 0.D0
      BC(1)  = 0.001D0
      RC(2)  = 0.35D0
      ZC(2)  = 0.05D0
      BC(2)  =-0.001D0
      RC(3)  = 0.35D0
```

```
      ZC(3)  =-0.05D0
      BC(3)  =-0.001D0
C
C     *** RF PARAMETERS ***
C
C        RF    : Wave frequency                               (MHz)
C        RKZ   : Wave number in (z or Z) direction          (m**-1)
C        NPHI  : Mode number in (phi) direction
C        NZMAX : Number of Fourier modes in (z, phi or Z) direction
C        RZ    : Periodic length in (z or Z) direction          (m)
C
      RF     = 2450.D0
      RKZ    = 2.5D0
      NPHI   = -1
C
      NZMAX  = 1
      RZ     = 1.D0
C
C     *** ANTENNA PARAMETERS ***
C
C        NAMAX : Number of antennae
C        AJ    : Antenna current density                       (A/m)
C        APH   : Antenna phase                              (degree)
C        AWD   : Antenna width in (z, phi, Z) direction     (degree)
C        APOS  : Antenna position in (z, phi, Z) direction  (degree)
C        APOS  : Antenna position in (z, phi, Z) direction  (degree)
C
      NAMAX=0
      DO 10 NA=1,NAM
         AJ(NA)   = 1.D0
         IF(MOD(NA,2).EQ.1) THEN
            APH(NA)  = 0.D0
         ELSE
            APH(NA)  = 180.D0
         ENDIF
         AWD(NA)  = 0.D0
         APOS(NA) = 0.D0
   10 CONTINUE
C
C     *** PLASMA PARAMETERS ***
C
C        NSMAX : Number of particle species
C        PA    : Mass number
C        PZ    : Charge number
C        PN    : Density at center                     (1.0E20/Mm*3)
C        PNS   : Density on plasma surface             (1.0E20/m**3)
C        PTPR  : Parallel temperature at center                (keV)
C        PTPP  : Perpendicular temperature at center           (keV)
C        PTS   : Temperature on surface                        (keV)
C        PZCL  : Ratio of collision frequency to wave frequency
C
      NSMAX= 2
      IF(NSMAX.GT.NSM) NSMAX=NSM
C
         PA(1)= AME/AMP
         PZ(1)=-1.0D0
         PN(1)= 0.0002D0
         PNS(1)= 0.D0
         PTPR(1)=0.01D0
         PTPP(1)=0.01D0
         PTS(1)=0.D0
         PZCL(1)= 0.02D0
C
      IF(NSM.GE.2) THEN
         PA(2)= 39.9480D0
         PZ(2)= 1.0D0
         PN(2)= 0.0002D0
         PNS(2)= 0.0D0
         PTPR(2)=0.01D0
```

```
         PTPP(2)=0.01D0
         PTS(2)=0.D0
         PZCL(2)= 0.02D0
      ENDIF
C
      IF(NSM.GE.3) THEN
         PA(3)= 1.0D0
         PZ(3)= 1.0D0
         PN(3)= 0.0D0
         PNS(3)= 0.0D0
         PTPR(3)=0.1D0
         PTPP(3)=0.1D0
         PTS(3)=0.D0
         PZCL(3)= 0.001D0
      ENDIF
C
C     *** CONTROL PARAMETERS ***
C
C        MODELS: 0 : No symmetry
C                1 : Axial symmetry (Y axis)
C                2 : Axial symmetry (Y axis -RR)
C                3 : Helical symmetry (Z axis)
C        MODELB: 0 : X axis
C                1 : Y axis
C                2 : Z axis
C                3 : Axisymmetric mirror
C                4 : Translational mirror
C                5 : Tokamak
C                6 : Helical
C                7 : Circular coils
C        MODELD: 0 : Cold plasma model
C                1 : Warm plasma model
C                2 : Hot plasma model
C        MODELP: 0 : Flat profile
C                1 : Radially parabolic profile
C                2 : Axially exponential profile
C                3 : Radially and axially parabolic profile
C                4 : Temporal use
C                5 : Radially parabolic and axially quartic profile
C
C        MODELW: 0 : Fixed density and fixed temperature on boundary
C                1 : Free density and fixed temperature on boundary
C                2 : Free Density and free temperature on boundary
C        MODELT: 0 : Fixed temperature model
C                1 : Density gradient model
C                2 : Pressure gradient model
C
C        MODELN: 0 : Fixed crosssection for electron collision with neutrals
C                1 : Mometum transder collision data
C
C        MODELV:   : Type of divide model
C
         MODELS = 1
         MODELB = 3
         MODELD = 0
         MODELP = 1
         MODELW = 0
         MODELT = 2
         MODELN = 0
         MODELV = 0
C
C     *** OUTPUT PARAMETERS ***
C
C        NPRINT: Print output parameter
C                0 - No output
C              * 1 - Parameter and global field data
C                2 - Local field data
C                3 - Element data
C        NDRAWD: Drawing parameter for elemendt divider
C                0 : Boundary shape
C              * 1 : Element shape
```

```
C                 2 : Element shape + Element number
C                 3 : Element shape + Element number + Node number
C         NDRAWA: Drawing parameter for antenna generater
C                 0 : Antenna primary data
C                 1 : Antenna secondary data
C               * 2 : Antenna secondary data + Element shape
C         NRMAX : Number of radial mesh points
C
      NPRINT = 1
      NDRAWD = 1
      NDRAWA = 2
      NRMAX  = 101
C
C     *** DIVIDER PARAMETERS ***
C
C        BXMIN : Minimum x (m)
C        BXMAX : Maximum x (m)
C        BYMIN : Minimum y (m)
C        BYMAX : Maximum y (m)
C        RB    : Boundary radius (m)
C        BKAP  : Boundary elongation
C        BDEL  : Boundary triangularity *
C        DELX  : Typical element size in x direction (m)
C        DELY  : Typical element size in y direction (m)
C
      BXMIN  = 0.0D0
      BXMAX  = 0.1D0
      BYMIN  =-0.15D0
      BYMAX  = 0.15D0
      RB     = 0.25D0
      BKAP   = 1.D0
      BDEL   = 0.D0
      DELX   = 0.01D0
      DELY   = 0.01D0
C
C     *** ANTENNA SHAPE PARAMETERS ***
C
C        PIN   : Input Power (W); Set 0.0 to calculate from antenna current
C        PHIW  : Potential of wave electrode                    (V)
C        RD    : Antenna radius (m)
C        THETJ1: Start angle of arc antenna (degree)
C        THETJ2: End angle of arc antenna (degree)
C        ZJH1  : Axial start position of helical antenna (m)
C        ZJH2  : Axial end position of helical antenna (m)
C        PHJH  : Rotation angle of helical antenna (degree)
C        NTYPJH: Type of helical antenna
C                0 : Loop antenas on both ends
C                1 : Loop antena on the second end
C                2 : Loop antena on the first end
C                3 : No loop antena
C        NJMAX : Number of primary grid points of antenna
C
      PIN    = 0.D0
      PHIW   = 0.D0
      RD     = 0.22D0
      THETJ1 = 40.D0
      THETJ2 =-40.D0
      ZJH1   = 0.01D0
      ZJH2   = 0.19D0
      PHJH   = 360.D0
      NTYPJH = 0
      NJMAX  = 41
C
C     *** TRANSPORT PARAMETERS ***
C
C     DT     : Time step size
C     NTMAX  : Iteration number
C     NSTEP  : Number of transport calculations after one wave calculation
C     NFMAX  : Number of particle species in transport calculation
C
```

```
      DT     = 1.D-6
      NTMAX  = 1
      NTSTEP = 10
      NFMAX  = 2
C
C     *** TRANSPORT PLASMA PARAMETERS ***
C
C     PPN0   : Neutral pressure (Pa)
C                 1 torr = 133.322 Pa
C     PTN0   : Initial neutral temperarure (eV)
C     PNE0   : Initial electron density (1.D20/m^3)
C     PTE0   : Initial electron temperature (eV)
C     PTI0   : Initial ion temperature (eV)
C     PNES   : Edge electron density (1.D20/m^3)
C     PTES   : Edge electron temperature (eV)
C     PTIS   : Edge ion temperature (eV)
C
      PPN0   = 1.D0
      PTN0   = 0.03D0
      PNE0   = 1.D-6
      PTE0   = 0.03D0
      PTI0   = 0.03D0
      PNES   = 1.D-6
      PTES   = 0.03D0
      PTIS   = 0.03D0
C
C     *** BOHM DIFFUSION ***
C
C     DC     : FACTOR OF BOHM DIFFUSION COEFFICIENT
C
      DC     = 1.D0
C
C     *** COMPUTATION PARAMETERS ***
C
C     EPSIMP : CONVERGENCE CRITERION FOR IMPLICIT TIME EVOLUTION
C     EPSSUM : BOUNDARY BETWEEN RELATIVE ERROR AND ABSOLUTE ERROR
C     MAXIMP : MAXIMUM LOOP COUNT FOR IMPLICIT TIME EVOLUTION
C     FACIMP : IMPLICIT FACTOR
C
      EPSIMP = 1.D-4
      EPSSUM = 1.D0
      MAXIMP = 1
      FACIMP = 1.D0
C
C     *** ARTIFICAL SOURCE ***
C
C     PGIVEN : MAXIMUM POWER DENSITY
C     SGIVEN : MAXIMUM PLASMA SOURCE DENSITY
C     XGIVEN : X COORDINATE OF THE CENTER OF THE SOURCE
C     YGIVEN : Y COORDINATE OF THE CENTER OF THE SOURCE
C     RGIVEN : DECAY LENGTH OF THE SOURCE
C
      PGIVEN = 0.D0
      SGIVEN = 0.D0
      XGIVEN = 0.05D0
      YGIVEN = 0.D0
      RGIVEN = 0.05D0
C
C     *** ELECTRODE PARAMETERS ***
C
C     RFES   : FREQUENCY OF ELECTRODE POTENTIAL
C     PHIES  : AMPLITUDE OF ELECTRODE POTENTIAL
C
      RFES   = 13.56D0
      PHIES  = 0.D0
C
C     *** GRAPHICS CONTROL PARAMETERS ***
C
C     KGINX : GRAPHIC CONTROL STRINGS
C     KGINV : GRAPHIC CONTROL STRINGS
```

```
C
      KGINX(0)='EXI EYI EZR PP1C'
      KGINX(1)='EXR EXI EYR EYI'
      KGINX(2)='EZR EZI PP1C PP2C'
      KGINX(3)='EXR EXI EYR EYI EZR EZI PP1C PP2C'
      KGINX(4)='AXR AXI AYR AYI AZR AZI AFR AFI'
      KGINX(5)='PF0C PNEC PTEC PTIC PIOC PC0C'
      KGINX(6)='PF0Y0 PF0Y0.03 PF0X0 PF0X0.05'
      KGINX(7)='PNEY0 PNEY0.03 PNEX0 PNEX0.05'
      KGINX(8)='PTEY0 PTEY0.03 PTEX0 PTEX0.05'
      KGINX(9)='L2 TF0 TNE TTE TTI'
C
      KGINV(0)='EXR,EXI,EYR,EYI,EZR,EZI,PP1C,PP2C,PNEC,PTEC,TNE,TTE'
      KGINV(1)='PC1C PC2C PR1C PR2C'
      KGINV(2)='PU1C PU2C PV1C PV2C'
      KGINV(3)='PD1C PD2C PE1C PE2C'
      KGINV(4)='PH1C PH2C PK1C PK2C'
      KGINV(5)='PIOC'
      KGINV(6)='PIOC'
      KGINV(7)='PIOC'
      KGINV(8)='PIOC'
      KGINV(9)='PIOC'
C
C     *** GRAPHICS CONTROL PARAMETERS ***
C
C     NGRAPH: Type of 1D graphic output
C             1 : Autoscale plot
C             2 : Symmetric scale plot
C             3 : Amplitude and phase plot
C     NGRAPH: Type of 2D graphic output
C             1 : Contour plot (in element mesh)
C             2 : Color-painted contour plot (in rectangular mesh)
C             3 : Bird's eye view
C             4 : Contour plot (in rectangular mesh)
C     FRATIO: Horizontal expansion factor for 2D graphics
C
      NGRAPH=1
      FRATIO=1.D0
      NGXORG=1
C
C     *** 3D GRAPHICS CONTROL PARAMETERS ***
C
      GA=-25.0
      GB=  0.0
      GC=-30.0
      GD=  0.0
      GE= 1000.0
      GXN= 6.0
      GYN= 9.0
      GZN= 3.0
      GXN1=-5.0
      GXN2= 5.0
      GYN1= 0.0
      GYN2=10.0
      IXY= 3
      IDN=-3
C
      MODIFY=0
```

3 Execution contraol (`wfmain`)

1. Function

   - Command input

P:	parameter input
V:	view parameter
D:	division of elements
Z:	zone data creation
A:	antenna data creation
W:	wave analysis
T:	tranport analysis
R:	run wave-transport coupled analysis
C:	continue wave-transport analysis
G:	graphic output
S:	save data in a file
L:	load data from a file
B:	characteristic frequencies vs density
Q:	quit

   - Parameter input in a `namelist` format
     `BB=1.2d0`
     If variable name is not diefined in `namelist`,
     a list of variables defined in `namelist` is shown.

2. Order of parameter setup

   - Initialization in `WFINIT`
   - Input from a namelist file `wfparm`
   - Input in a command line

4 Division of elements (`wfdiv`)

1. Function

   D: creation of node and element data
   G: graphic output of node and element data
   W: numerical output of node and element data
   S: save node and element data to a file
   L: load node and element data from a file
   X: exit

2. Type of division

   X: One rectangular
   BXMIN, BXMAX (minimum of x, maximum of x)
   BYMIN, BYMAX (minimum of y, maximum of y)

   R: Multi rectangular
   NYQMAX (number of YPOS data)
   YPOS (y position)
   NXQMAX (number of XPOS data for y=YPOS)
   XPOS (x position)
   Divide in rectangulars

   P: One quadrangle (oblique shape, xmin = 0)
   BXMIN, BXMAX (xmax at BYMIN, xmax at BYMAX)
   BYMIN, BYMAX (minimum of y, maximum of y)

   M: Axisymmetric mirror
   BXMIN, BXMAX, BYMIN, BYMAX
   Divide in magnetic surface shape of axisymmetric mirror

   V: Translational mirror
   BXMIN, BXMAX, BYMIN, BYMAX
   Divide in magnetic surface shape of one-dimensional mirror

   C: Circular
   RB (wall radius)

   T: Tokamak (poloidal cross section)
   RB, BKAP, BDEL (wall radius, ellipticity, triangularity)

   H: Linear helical
   RB, BXMIN, BXMAX (wall radius, minimum x, maximum x)

3. Division step

   - Divide with step less than DELX and DELY

4. Created data

   - Position of nodes: `XD(IN)`,
     - `YD(IN)IN` = node number,   maximum: `NNOD`
   - Node numbers of a triangular element: `IELM(3,IE)`
     - `IE` = Element number   maximum: `NELM`
     - anti-clock wise: 1, 2, 3

5 Creation of antena data (`wfant`)

1. Function

   A: creation of antenna data
   G: graphic output of antenna data
   W: numerical output of antenna data
   S: save antenna data to a file
   L: load antenna data from a file
   X: exit

2. Definition on antenna

   - NAMAX: maximum number of antenna
   - Shape of antenna
     C: Circular antenna: RD, RKAP, NJMAX
     (antenna radius, ellipticity, number of division)
     A: Arc antenna: THETA1, THETA2, RD, RKAP, NJMAX
     istart angle, end angle, antenna radius, ellipticity, number of division)
     P: Loop/Line antenna: NJMAX (number of antenna node)
       * NJMAX = 1: loop antenna
       * NJMAX > 1: line antenna connecting nodes (actually a plane in z direction)

     H: Helical antenna:
       * ZJH1 : Axial start position of helical antenna (m)
       * ZJH2 : Axial end position of helical antenna (m)
       * RD : antenna radius (m)
       * PHJH : Rotation angle of helical antenna (degree)
       * NTYPJH: Type of helical antenna
         · 0 : Loop antenas on both ends (NJMAX=2)
         · 1 : Loop antena on the second end (NJMAX=3)
         · 2 : Loop antena on the first end (NJMAX=3)
         · 3 : No loop antena (NJMAX=4)
         · 10 : Helicon antena (NJMAX=2)
       * NJMAX > 1: line antenna connecting nodes (actually a plane in z direction)

     H: Helicon antenna:
       * ZJH1 : Axial start position of antenna (m)
       * ZJH2 : Axial end position of antenna (m)
       * ZJH3 : Axial position of inward feeder (m)
       * ZJH4 : Axial position of outward feeder (m)
       * RTJ1 : Rotation angle of helical part at start position of antenna (degree)
       * RTJ2 : Rotation angle of helical part at end position of of antenna (degree)
       * RD : antenna radius (m)

3. created data

   - Antenna node position: `XJ0(NJ0,NA)`, `YJ0(NJ0,NA)`
   - Variables
     - `NA` = antenna number maximum: `NAMAX`
     - `NJ0` = antenna node number maximum: `NJ0MAX(NA)`

6 Creation of attribute data (`wfzone`)

1. Function

   Z: creation of attribute data

   G: graphic output of attribute data

   W: numerical output of attribute data

   S: save attribute data to a file

   L: load attribute data from a file

   X: exit

2. Creation of attribute data

   D: Definition of element attribute data

   - NDMAX: number of data
   - ND,ID,XMIN,XMAX,YMIN,YMAX: element zone number, attribute of element, zone area
   - Define element attribute of the elements in the zone
     * ID=0: plasma (default)
     * ID=1: vacuum
     * ID>1: dielectric of specified dielectric attribute

   E: Definition of dielectric attribute

   - NMMAX: number of dielectric attribute
   - NM,EPSD: dielectric attribute number, relative dielectric constant
   - Define relative dielectric constant for dielectric attribute number

   M: Definition of permitive/dielectric/resistive attribute

   - NMMAX: number of material attribute
   - NM: dielectric attribute number
   - EPSD: relative dielectric constant
   - RMUD: relative permittivity constant
   - SIGD: resisivity

   A: Definition of wave boundary attribute

   - NBMAX: number of wave boundary attributes
   - NB,ID,XMIN,XMAX,YMIN,YMAX: wave boundary attribute number, type of wave boundary attribute, zone area
   - Define wave boundary attribute of the boundary nodes in the zone
     * ID=0: in the plasma (default)
     * ID=1: boundary between plasma and conductor with potential 0
     * ID=2: boundary between plasma and conductor with potential PHIW
     * ID=3: boundary between plasma and conductor with potential continuously varying from 0 to PHIW
     *

   B: Define transport boundary attribute

   - NBMAX: number of transport boundary attributes

- NB,ID,XMIN,XMAX,YMIN,YMAX: transport boundary attribute number, transport boundary attribute, zone area
- Define transport boundary attribute of the boundary nodes in the zone
  - ID=0: in a plasma (default)
  - ID=1: boundary between plasma and conductor with potential 0
  - ID=2: boundary between plasma and conductor with potential PHIES
  - ID=3: boundary between plasma and conductor with potential continuously varying from 0 to PHIES.
  - ID=4: boundary between plasma and conductor with potential oscillating with amplitude PHIES and frequency RFES
  - ID=5: boundary between plasma and conductor with potential oscillating with amplitude varying form 0 to PHIES and frequency RFES
  - ID=8: boundary between plasma and dielectric (insulator) without surface charge
  - ID=9: boundary between plasma and dielectric (insulator) with surface charge
  - ID=10: vacuum or dielectric (default)
  - ID=11: boundary between vacuum/dielectric and conductor with potential 0
  - ID=12: boundary between vacuum/dielectric and conductor with potential PHIES
  - ID=13: boundary between vacuum/dielectric and conductor with potential continuously varying from 0 to PHIES.
  - ID=14: boundary between vacuum/dielectric and conductor with potential oscillating with amplitude PHIES and frequency RFES
  - ID=15: boundary between vacuum/dielectric and conductor with potential oscillating with amplitude varying form 0 to PHIES and frequency RFES

W: Definition of wave boundary potential variation

- NVMAX: number of wave boundary potential variation
- NV,XMIN,XMAX,YMIN,YMAX: wave boundary potential variation number, wave boundary potential variation, zone area
- For wave boundary attribute ID=3, define the range of wave potential varying
  only NV=1 is available at present
  wave potential = 0 at X=XMIN, Y=YMIN
  and PHIW at X=XMAX, Y=YMAX

P: Definition of transport boundary potential variation

- NVMAX: number of transport boundary potential variation
- NV,XMIN,XMAX,YMIN,YMAX: transport boundary potential variation number, transport boundary potential variation, zone area
- For wave boundary attribute ID=3, 5, 13, 15, define the range of transport potential varying
  only NV=1 is available at present
  wave potential = 0 at X=XMIN, Y=YMIN
  and PHIS at X=XMAX, Y=YMAX

V: view attributes

X: exit

7 Wave analysis (`wfwave`)

1. Functions

   - Reduce Maxwell's equation for potential $(\vec{A}, \phi)$ to a simultaneous equation $\mathbf{A} \cdot \vec{x} = \vec{b}$ with the finite element method, and calculate the wave electric field and the absorbed power density by solving the matrix equation.

2. Procedure

   1) Pre-processing
      - SETANT: Set antenna current
      - CVDBND: Set node attribute (`KBND(IN)`, `IBND(IN)`) and calculate the size of coefficient matrix.
      - CVCALC: Calculate right-hand-side vector $\vec{b}$ form the antenna current

   2) Solver
      - CVSOLV: Calculate coefficient matrix $\mathbf{A}$ for each element, translate the calculated line to a upper triangular band matrix, and obtain $\vec{x}$ by backward substitution after translation completed.
        CMCALC: Calculate coefficient matrix $\mathbf{A}$ for each element.
          DTENSR: Calculate dielectric tensor at each node

   3) Post-processing
      - CALFLD: Calculate the wave electric field from the potential
      - PWRABS: Calculate the absorbed power in each element and distribute it the nodes.
      - PWRRAD: Integrate the wave electric field along the antenna current to calculate the radiated power.

8 Transport analysis (`wffvol`)

1. Function

   - Time evolution equation for plasma density, temperature, and potential is reduced to a simultaneous equation $\mathbf{A} \cdot \vec{x} = \vec{b}$ using the finite element method, and solve it numerically

2. Procedure

   1) Pre-processing
      - DVDBND: setup attribute, `KBND(IN)` and `IBND(IN)`, and calculate the width and length of the band coefficeint matrix.
      - DVCALC: Calculate right-hand-side vector $\vec{b}$.

   2) Solver
      - DVSOLV: Calculate coefficient matrix $\mathbf{A}$ for each element, translate the calculated line to a upper triangular band matrix, and obtain $\vec{x}$ by backward substitution after translation completed.
        DMCALC: Calculate coefficient matrix $\mathbf{A}$ for each element.
          WFCOEF: Calculate diffusion coefficient on the note.

   3) Post-processing
      - DALFLD: Calculate density, temperature and eletrostatic potential from the solution vector $\vec{x}$.
      - WFEVST: Save varying variables.

9 Graphic output (`wfgout`)

Indicate graphics of spatial profile and time evolution. One graphic control command separated by a space corresponds to one figure. Multiple figures are drawn on a page by writing a number of commands in a line.

9.1 Example of input data

Example 1: `EXR EYI EZA`

- The following three figures are drawn on a page.
  Contour of the real part of the x component of the wave electric filed E_x
  Contour of the imaginary part of the x component of the wave electric filed E_x
  Contour of the absolute value of the z component of the wave electric filed E_z

Example 2: `EYX0.0 PTEC PNIY0.0`

  x dependence of the y component of the wave electric field E_y at $y = 0.0$
- Contour of electron temperature
- y dependence of the ion density at $x = 0.0$

Example.3: `TN1`

  Time dependence of the electron density (solid line: average, dashed line: maximum, broken line: minimum)

Example 4: `5`

  Profiles of electrostatic potential, density, temperature
- Character strings defined by `KGINX(5)` in `WFINIT`.

9.2 Definition of graphic control command

$\mathtt{EX}_1\mathtt{X}_2$	spatial profile of wave E
$\mathtt{BX}_1\mathtt{X}_2$	spatial profile of wave B
$\mathtt{AX}_1\mathtt{X}_2$	spatial profile of wave potential
$\mathtt{PX}_1\mathtt{X}_2\mathtt{X}_3$	spatial profile of plasma quantities
$\mathtt{TX}_1\mathtt{X}_2$	time evolution of plasma quantities
n	combination of pre-defined string in (`KGINX`)
`V`n	combination of pre-defined string in (`KGINV`)
`G`n	type of graphic output
`L`n	number of figures in horizontal direction on a page
`X`	exit

9.3 `E/B/A`

- $\mathtt{X}_1$

`X`	x
`Y`	y
`Z`	z
`+`	Eg
`-`	left-hand-side polarization component
`P`	parallel component

- $\mathtt{X}_2$ `R` Contour of real part
  `I` Contour of imaginary part
  `A` Contour of absolute value
  `Xpos` x dependence at $y =$ `pos`
  `Ypos` y dependence at $x =$ `pos`

9.4 `P`: spatial profile

- $\mathtt{X}_1$ `P` Absorbed power density
  `N` Particle number density
  `T` Temperature
  `B` Magnetic field strength and flux
  `M` Pressure
  `G` Drift velocity
  `S` Surface electric charge density
  `F` Electrostatic potential
  `C` Electrical charge density
  `R` Collision frequency
  `U` Parallel mobility: mu-para
  `V` perpendicular mobility: mu-perp
  `D` Particle diffusion coefficient: D-para
  `E` Particle diffusion coefficient: D-perp
  `H` Thermal diffusion coefficient: chi-para
  `K` Thermal diffusion coefficient: chi-perp
  `I` Ionization particle source

- $\mathtt{X}_2$ `E` Electron component
  `I` Ion component
  `1` First component (usually = electron)
  `2` Second component (usually = ion)

- $\mathtt{X}_3$ `C` Contour plot
  `Xpos` x dependence at $y =$ `pos`
  `Ypos` y dependence at $x =$ `pos`

9.5 `T`: time evolution

- $\mathtt{X}_1$ `N` particle density
  `T` temperature
  `F` electrostatic potential
  `P` absorbed power

- $\mathtt{X}_2$ `E` Electron component
  `I` Ion component
  `0` not relevant (e.g. electrostatic potential)
  `1` First component (usually = electron component)
  `2` Second component (usually = ion component)

10 List of subroutines

```
MAIN (wfmain.f)               main program

   WFINIT (wfmain.f)          initialization of input parameters
   WFPLST (wfmain.f)          show input parameter list
   WFPARM (wfmain.f)          read input parameters
   WFVIEW (wfmain.f)          view input parameters

   WFDIV  (wfdiv.f)           division of element
      DFNODX (wfdiv.f)        division of a rectangular
      DFNODP (wfdiv.f)        division of a parallelogram
      DFNODR (wfdiv.f)        division of multiple rectangulars
      DFNODM (wfdiv.f)        division of axisymmetric mirror
         BOUNDM (wfdiv.f)     definition of axisymmetric mirror
      DFNODV (wfdiv.f)        division of translational mirror
         BOUNDV (wfdiv.f)     definition of translational mirror
      DFNODC (wfdiv.f)        division of arbitrary shaped region (simply connected)
         BOUNDX (wfdiv.f)     definition of x-direction boundary
         BOUNDY (wfdiv.f)     definition of y-direction boundary
         BOUNDF (wfdiv.f)     definition of boundaries
      SETNOD (wfdiv.f)        define node from division data
      SETELM (wfdiv.f)        define element from division data
      WFLDIV (wfdiv.f)        numerical output of node and element data
      WFGDIV (wfdiv.f)        graphic output of node and element data
         WFPRME (wfdiv.f)     graphic output of number of nodes and elements
      WFWELM (wffile.f)       file output of element data
      WFRELM (wffile.f)       file input of elemental data

   WFZONE (wfzone.f)          setting attribute data
      WFXZON (wfzone.f)       define attribute data
      WFGZON (wfzone.f)       graphic output of attribute data
      WFLZON (wfzone.f)       numerical output of attribute data
      WFSETZ (wfzone.f)       create attribute array from attribute data
         SETBDY (wfzone.f)    create boundary attribute array from attribute data
         EFINDK (wfzone.f)    find an element including specified two nodes
      WFWZON (wffile.f)       file output of attribute data
      WFRZON (wffile.f)       file input of attribute data

   WFANT  (wfant.f)           setting antenna data
      WFDEFA (wfant.f)        define antenna data
      WFPLTA (wfant.f)        graphic output of antenna data
         WFPRMJ (wfant.f)     graphic output of antenna parameters
      WFWANT (wffile.f)       file output of antenna data
      WFRANT (wffile.f)       file input of antenna data

   WFWAVE (wfwave.f)          wave analysis
      WFSETW (wfwave.f)       initial setup of wave analysis
      SETANT (wfwave.f)       Fourier decomposition of antenna current
      CVDBND (wfwave.f)       initializatioin of matrix solver
```

```
   CVCALC (wfwave.f)        calculation of right-hand-side vector
   CVSOLV (wfwave.f)        matrix solver
      CMCALC (wfwave.f)     calculation of matrix coefficient
         DTENSR (wfwave.f)  calculation of dielectric tensor
   CALFLD (wfwave.f)        calculation of wave E from solution vector
   PWRABS (wfwave.f)        calculation of absorbed power
   PWRRAD (wfwave.f)        calculation of radiated power from antenna
   INITEP (wfwave.f)        initialization of Fourier component of wave E
   TERMEP (wfwave.f)        Fourier composition of wave E
   LPEFLD (wfwave.f)        numerical output of wave E data
   LPELMT (wfwave.f)        numerical output of element and node data
   WFWFLD (wffile.f)        file output of wave E data
   WFRFLD (wffile.f)        file input of wave E data

WFEVIN (wfevol.f)           initialization of transport analysis
WFEVOL (wfevol.f)           one step of transport analysis
   DVDNOD (wfevol.f)        initialization of matrix solver
   DVSOLV (wfevol.f)        matrix solver
      DMCALC (wfevol.f)     calculation of matrix coefficient
      DMCALD (wfevol.f)     matrix coefficient in vaccum and dielectric
      DMCALP (wfevol.f)     matrix coefficient in  plasma
         WFCOEF (wfevol.f)  calculation of transport coefficients
   DALFLD (wfevol.f)        calculation of density and temperature from solution vector
WFEVST (wfevol.f)           save time evolution of transport data

WFGOUT (wfgout.f)           graphic output control
   WFCTOG (wfgout.f)        conversion of complex 3 data (Ex Ey Ez)
   WFATOG (wfgout.f)        conversion of complex 4 data (Ax Ay Az phi)
   WFDTOG (wfgout.f)        conversion of real data
   WFTTOG (wfgout.f)        conversion of time evolution data
   WFCALB (wfgout.f)        calculation of wave magnetic field and polarization
   WFCALD (wfgout.f)        calculation of wave dispersion relation

   WFGINI (wfgsub.f)        initialization of plot size
      WFGWIN (wfgsub.f)     determinatioin of plot size
      WFGVEW (wfgsub.f)     determinatioin of plot layout
      WFGPFX (wfgsub.f)     contour plot of profile data
      WFGPPR (wfgsub.f)     1D plot of profile data
      WFGPPRX(wfgsub.f)    1D plot of profile data
      WFGPFR (wfgsub.f)     1D plot of profile data
      WFGPAR (wfgsub.f)     1D plot of profile data
      WFGPFT (wfgsub.f)     1D plot of time evolution
      WFGPRM (wfgsub.f)     draw computation parameters
      WFGNOD (wfgsub.f)     draw attribute data boundary nodes
      WFGBDY (wfgsub.f)     draw computatinal boundary
      WFGPLA (wfgsub.f)     draw plasma boundary
      WFGANT (wfgsub.f)     draw antenna data
      WFGELM (wfgsub.f)     draw element and node data
         GCLIP  (wfgsub.f)  conversion from double precision to single precision
         NGVLEN (wfgsub.f)  determine number of digits of scale data
```

```
          GUSRGB (wfgsub.f)  createion of paint colour RGB data
```

Common routines

```
   WFSPSI (wfprof.f)          calculation of magnetic flux
      WFBPSI (wfprof.f)          calculation of magnetic flux
   WFBMAG (wfprof.f)          calculation of magnetic field
      WFCOIL (wfprof.f)       calculation of magnetic field by circular current
      APSI   (wfprof.f)       calculation of vector potential by circular current
   WFSDEN (wfprof.f)          calculation of density and temperature
      CALRNU (wfprof.f)       calculation of collsion frequency
         ATINIT (wfatmd.f)    initializatin of collsion cross section
         ATSIGV (wfatmd.f)    calculation of collision data
         ATSIGM (wfatmd.f)    calculation of collisional cross section
            DATAAR (wfatmd.f) collisional cross section data for Ar
            DATAH2 (wfatmd.f) collisional cross eection data for H
            DATACA4(wfatmd.f) collisional cross section data for CF4

   WFVNOD (wfsub.f)           calculation of element volume
   MODANT (wfsub.f)           division of antenna data accordint element
   CROS   (wfsub.f)           calculation of crossing point of two line element
   EFINDL (wfsub.f)           find an element including two specified nodes
   WFFEPI (wfsub.f)           initializatioin of element find routine
   WFFEP  (wfsub.f)           find an element including specified position
   WFABC  (wfsub.f)           calculation of linear interporlate function and area
   WFSELM (wfsub.f)           calculation of element area
   WFNPOS (wfsub.f)           obtain node positons of an element
   FIELDE (wfsub.f)           interpolation of wave E at given position
   FIELDC (wfsub.f)           interpolation of complex data at given position
   FIELDD (wfsub.f)           interpolation of real data at given position
   SETAIF (wfsub.f)           calculation of integral in normalized element
      AI2    (wfsub.f)        integral of 2 variable integral
      AI3    (wfsub.f)        integral of 3 variable integral

   FRGFLS (wflib.f)           Solution of nonlinear equation (Regula Falsi)
   SPL1DX (atomic.f)          1D spline interporlation (non-even grid)
   DEFIFE (atomic.f)          Half infinite integral by double-exponential formula

   DSPFN  (lib/libdsp.f90)    Plasma dispersion function
   FFT2L  (lib/libfft.f90)    Fast Fourier transform
   BESIN  (lib/libbes.f90)    First kind of modified Bessel function
   BESKN  (lib/libbes.f90)    Second kind of modified Bessel function
   ELLFC  (lib/libell.f90)    First kind of complete elliptic integral
   ELLEC  (lib/libell.f90)    Second kind of complete elliptic integral

   SPL1D  (lib/libspl.f90)    calculation of 1D spline coeffficients
   SPL1DF (lib/libspl.f90)    interpolation by 1D spline (function only)
   SPL1DD (lib/libspl.f90)    interpolation by 1D spline (function, derivative)
   SPL2D  (lib/libspl.f90)    calculation of 2D spline coeffficients
   SPL2DF (lib/libspl.f90)    interpolation by 2D spline (function only)
```

```
SPL2DD (lib/libspl.f90)     interpolation by 1D spline (function, derivative)
CSPL1D (lib/libspl.f90)     calculation of 1D complex spline coeffficients
CSPL1DF(lib/libspl.f90)     interpolation by 1D complex spline (function only)
```

11 List of COMMON variables

At present, this list is based on an old version of WF2.
It will be updated later

WFCNS1

CI	imaginary unit
PI	pi
AEE	elementary charge
AME	electron mass
AMP	proton mass
VC	light velocity in vacuum
RMU0	permeability constant in vacuum
EPS0	dielectric constant in vacuum

WFPRM1

BB	central magnetic field
RA	plasma minor radius

WFPRM2

RR	plasma major radius (m)
QA	safety factor on axis
Q0	safety factor on surface
RKAP	ellipticity of plasma cross section
RDEL	triangularity of plasma cross section
RMIR	mirror ratio
ZBB	periodic length along magnetic axis (m)
H1	helical pitch of magnetic field $2\pi/L$
H2	helical pitch of distance $2\pi/L$
RRC	coil radius in linear helical system (m)

WFPRM3

RF	wave frequency (MHz)
RKZ	wave number in z direction (m^{-1})
RZ	periodic length in z direction (m)
NPHI	mode number in azimuthal direction ϕ

WFPRM4

PA(NSM)	mass number
PZ(NSM)	charge number
PN(NSM)	particle density on axis ($10^{20}/\mathrm{m}^3$)
PNS(NSM)	particle density on surface ($10^{20}/\mathrm{m}^3$)
PZCL(NSM)	ratio of collision frequency and wave frequency

WFPRM5

PTPR(NSM)	parallel component of central temperature (keV)

PTPP(NSM)	perpendicular component of central density (keV)
PTS(NSM)	surface temperature (keV)

WFPRM6

NSMAX	number of particle species
NAMAX	number of antenna
NRMAX	number of radial mesh point for 1D plot
NZMAX	number of Fourier modes in z direction

WFPRM7

NPRINT	control ID of print output
NDRAWD	control parameter for element plot
NDRAWA	control parameter for antenna plot

WFPRM8

PNE0	initial electron density ($10^{20}/\mathrm{m}^3$)
PTE0	initial electron temperature (eV)
PTI0	initial ion temperature (eV)
PPN0	initial neutral pressure (Pa)
PTN0	initial neutral temperature (eV)

WFPRM9

PIN	(W)

WFPRK1

KIDSYS	KID1/KID2/KID3/KID4
KIDPOS	
KID1	magnetic field configuration
KID2	element configuration
KID3	dielectric tensor model
KID4	radial profile

WFPRK2

KFNAME	file name of element data
KFNAMA	file name of antenna data
KFNAMF	file name of field data

WFPRD1

BXMIN	minimum value of x (m)
BXMAX	maximum value of x (m)
BYMIN	minimum value of y (m)
BYMAX	maximum value of y (m)
RB	boundary radius (m)
BKAP	boundary ellipticity
BDEL	boundary triangularity

WFPRD2

DELX	typical element size in x direction (m)
DELY	typical element size in y direction (m)

WFPRA1

RD	antenna radius (m)
THETJ1	initial angle of arc antenna (degree)
THETJ2	end angle of arc antenna (degree)
NJMAX	original number of antenna grid points

WFPRA2

AJ(NAM)	antenna current (loop) / current density (line)
APH(NAM)	antenna phase
APOS(NAM)	antenna position in (z, ϕ, Z) direction (degree)
AWD(NAM)	antenna width in (z, ϕ, Z) direction (degree)

WFDIV1

XL(NYM)	left end position
XR(NYM)	right end position
NYMAX	number of division in y direction

WFDIV2

NXA(NYM)	number of nodes in x direction

WFDIV3

XDA(NXM,NYM)	x coordinates of the node (NX,NY)
YDA(NXM,NYM)	y coordinates of the node (NX,NY)
NDA(NXM,NYM)	node number of the node (NX,NY)

WFDIV4

XDW(NXM,NYM)	weight center position in x direction
YDW(NXM,NYM)	weight center position in y direction

WFDIV5

XF	fixed x coordinates to find boundary
YF	fixed y coordinates to fine boundary

WFDIV6

VNOD(NNODM)	volume around a node

WFELM1

NNOD	total number of nodes
NELM	total number of elements
NBDY	total number of boundary nodes

MBND	width of coefficient matrix
MLEN	length of coefficient matrix

WFELM2

XD(NNODM)	x coordinates of a node
YD(NNODM)	y coordinates of a node
IELM(3,NELMM)	node numbers belonging to an element

WFELM3

IBND(NNODM)	minimum line number in the coefficient matrix for a node
KBND(NNODM)	number of equations for a node
IBDY(NBDYM)	node number of boundary nodes

WFSLV1

KELM(3,NELMM)	work area for matrix solver
JBND(NNODM)	work area for matrix solver

WFSLV2

CM(4,4,3,3)	coefficient matrix for an element for wave analysis
CRV(MLENM)	right-hand-side vector for wave analysis
CSV(MLENM)	solution vector for wave analysis

WFSLV3

LDEST(NCNM)	work area for matrix solver
NK(NCNM)	work area for matrix solver
NFLG(NNODM)	work area for matrix solver

WFSLV4

CEQ(MBNDM,MBNDM)	work area for wave matrix solver

WFSLV5

LHED(MBNDM)	work area for matrix solver
LPIV(MBNDM)	work area for matrix solver
CQQ(MBNDM)	work area for wave matrix solver

WFSLV6

MLCO(MLENM)	work area for matrix solver
MCOL(MLENM)	work area for matrix solver
MPOS(MLENM)	work area for matrix solver

WFSLV7

MHED(MBUFM)	work area for matrix solver
CBUF(MBUFM)	work area for wave matrix solver
DBUF(MBUFM)	work area for transport matrix solver

WFAIF1

AIF3(3,3,3)	integral of three interpolation functions
AIF2(3,3)	integral of two interpolation functions
AIF1(3)	integral of an interpolation function

WFEVO1

DT	time step width
T	time
NTMAX	number of time step
NTSTEP	number of transport steps for one wave step
NEVOL	0: fixed density@1: time evolution

WFEVO2

PNE(NNODM)	electron density at a node ($10^{20}/\mathrm{m}^3$)
PPE(NNODM)	electron pressure at a node (Pa)
PTE(NNODM)	electron temperature at a node (eV)

WFEVO3

PNI(NNODM)	ion density at a node ($10^{20}/\mathrm{m}^3$)
PPI(NNODM)	ion pressure at a node (Pa)
PTI(NNODM)	ion temperature (eV)

WFEVO4

PHI(NNODM)	scalar potential

WFEVO5

DEQ(MBNDM,MBNDM)	work area for transport matrix solver
DQQ(MBNDM)	work area for transport matrix solver

WFEVO6

DM(5,5,3,3)	coefficient matrix for an element for transport analysis
DRV(MLENM)	right-hand-size vector for transport analysis
DSV(MLENM)	solution vector for transport analysis

WFEVO7

PNET(NGTM,3)	time evolution of average electron number
PTET(NGTM,3)	time evolution of average electron temperature

WFEVO8

PNIT(NGTM,3)	time evolution of average ion number
PTIT(NGTM,3)	time evolution of average ion temperature

WFEVO9

PHIT(NGTM,3)	time evolution of Φ

TG(NGTM)	sampling time for time evolution plot
NGTMAX	number of time evolution data

WFCAL1

HA1	work variable for linear helical analysis

WFFEP1

FMAX(NYM)	maximum y belonging to NEY
FMIN(NYM)	minimum y belonging to NEY

WFFEP2

NEMAX(NYM)	maximum element number belonging to NEY
NEMIN(NYM)	minimum element number belonging to NEY
NEYMAX	maximum of NEY

WFFLD1

CAF(4,NNODM)	wave vector and scalar potential on a node

WFFLD2

CEF(3,NNODM)	wave electric field (x, y, z)
CEP(3,NNODM)	wave electric field (RHS, LHS, parallel)
CEFK(3,NNODM)	wave electric field for a single Fourier mode

WFFLD3

CBF(3,NNODM)	magnetic died (x, y, z)
CBP(3,NNODM)	magnetic fieldiRHS, LHS, parallel)
SA(NNODM)	area belonging an element

WFFLD4

EMAX(4)	maximum value of wave E field component
ETMAX	maximum value of wave E
PNMAX	maximum value of density

WFPWR1

TSPWR	total absorbed power
PWR(NNODM)	absorbed power for a node

WFPWR2

TPWR(NSM)	total absorbed power for a particle species
SPWR(NNODM,NSM)	absorbed power for a particle species at a node

WFPWR3

RPWR(NRM)	absorbed power at a node
RSPWR(NRM,NSM)	absorbed power for particle species at a node
DR	number of division in radial direction

WFANT1

CIMP(NAM)	loading impedance of each antenna
CTIMP	total loading impedance

WFANT2

XJ(JNUMM,NAM)	x coordinates of antenna nodes after breakup
YJ(JNUMM,NAM)	y coordinates of antenna nodes after breakup
CAJ(NAM)	complex antenna current of each antenna

WFANT3

XJ0(JNUMM,NAM)	x coordinates of antenna nodes before breakup
YJ0(JNUMM,NAM)	y coordinates of antenna nodes before breakup
JNUM0(NAM)	number of antenna nodes before breakup

WFANT4

JELMT(JNUMM,NAM)	element number of the element in which a part of antenna belongs
JNUM(NAM)	number of antenna nodes after breakup

WFPWK1

RKZF(NZM)	wave number of the Fourier component
CAJF(NZM,NAM)	Fourier components of antenna current

WFPWK2

TSPWRF(NZM)	Fourier components of absorbed power
TPWRF(NZM,NSM)	Fourier components of absorbed power for each particle species.

WFWIN1

XDMIN	work area for screen division
XDMAX	work area for screen division
YDMIN	work area for screen division
YDMAX	work area for screen division

WFWIN2

GXD(NNODM)	work area for screen division
GYD(NNODM)	work area for screen division

WFWIN3

NFOPEN	work area for screen division

FFTWRK

CT(NZM*NZLM/2,2)	work area for fast Fourier transform
LIST(NZM*NZLM)	work area for fast Fourier transform
IFFT	work area for fast Fourier transform
LP	work area for fast Fourier transform