JLAB-TN-02-043

TDBBU *and* MATBBU
Input File Format

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The tdbbu[1] and matbbu[2] codes used to estimate the transverse beam breakup thresholds have recently been improved and are being used for the 10 KW FEL[3] and the 12 GeV upgrade. Both `tdbbu` and `matbbu` use a common input file format to describe an accelerator. Both also allow an auxiliary input file (called a CAVMAT or CECAV file) to to describe a CEBAF or other cavity, but this feature is often not used , as a generic cavity is available inside `tdbbu` and `matbbu`.

The input file consists of lines (cards) containing keywords and values describing the accelerator as a collection of lenses, drift spaces, cavities, etc., followed by various matrices in FORTRAN free format. The order of the cards will determine how the matrices are interpreted. Some cards (`BEAM, TITLE`) are used to provide general information and others (`CMPNT, REF, APRTR, XPRTR, YPRNT, PXPRNT, PYPRNT, CVPRNT`) to direct the program; these are not accelerator elements.

The time step unit in these codes is ½ of an RF period. Each element is counted as one time step toward the total recirculation time. This even holds true for the `CAVITY` statements describing higher order modes (HOMs) on the axis not under consideration. For example, if a `CAVITY` statement about an HOM on the Y axis is added, the phase slip specified with the recirculation matrix must be reduced to keep the total recirculation time constant even if one is only considering the X axis.

This format is **very specific** and is **very sensitive to the spacing**. The FORTRAN free format used for arrays is sometimes compiler and platform dependent. When using a new input file, it is wise to examine the `tdbbu` and `matbbu` output carefully to ensure that the input was read correctly.

It should be noted that the *R/Q* commonly reported is in units of (Ω/cm^2), while matbbu and tdbbu expect units of (Ω), so it is neccesary to convert using:

$$R_\Omega = (R/Q) * \left(c/2\pi f\right)^2$$

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1 JLAB-TN-02-045, *tdbbu 1.6: Another Tool for Estimating Beam Breakup due to Higher Order Modes*, K.B.Beard, L.Merminga, B.Yunn

2 JLAB-TN-02-044, matbbu 2.4: *A Tool for Estimating Beam Breakup due to Higher Order Modes* K.B.Beard, L.Merminga, B.Yunn

3 JLAB-TN-02-042**,** *Estimates of the Beam Breakup Thresholds in the 10KW FEL due to HOMs,* K.B.Beard, L.Merminga, B.Yunn

The input is case sensitive ("TITLE" is not the same as "title") and blank numeric fields are treated as zeros.

The first line (TITLE) is a comment; only the first 79 characters are retained.

```
      character*8 INFO(10)
      ...
   16 READ(7,50)(INFO(i),i=1,10)
   50 FORMAT (1X,9A8,A7)
```

```
1TITLE    12 GeV UPGRADE BASED ON ORIGINAL 5 PASS MACHINE-NEW MODULES ONLY
_1111111122222223333333344444444555555556666666677777777888888899999999000000
```

The following lines up to and including the $CALC line are of the following FORTRAN format. They are all read in and then processed sequentially:

```
      character*1 LBL(MELM)
      character*8 ITYP(MELM)
      real*8 DTA(MELM,8)
      ...
      READ(7,50,ERR=250) LBL(I),ITYP(I),(DTA(I,J), J=1,8)
 50   FORMAT(A1,A6,F3.0,7e10.4)
```

```
6LENS   1.-551.4
6CAVITY   166.00    1.0E+08   1874.43   .0
1aaaaaaFFF1111111111222222222233333333333444444444455555555556666666666777777777
```

where the first column identifies the reinjection point with a ">", and anything else in that column is ignored. Only versions of matbbu newer than 2.4i5g3 and tdbbu newer than 1.6h2f2 allow the use of **inline** comments beginning with a "!" or "#" in column 3 or higher.

The next field is a keyword from the following table:

internal id		element keyword	printing							
	LBL	**ITYP**	**DTA1**	**DTA2**	**DTA3**	**DTA4**	**DTA5**	**DTA6**	**DTA7**	**DTA8**
reinjection point	>									
1		CMPNT		current in mA; threshold current is this current divided by the subharmonic of bunching frequency	X OFFSET (cm)	PX OFFSET (MeV/c)	Y OFFSET (cm)	PY OFFSET (MeV/c)	ISTART (.NE.0=>use offsets)	
2-10		Z								
11		CAVITY	NPR	$(z^{"} T2/Q) * 1/k^2 * L$ in ohms *(note:* **doubled** *for ganged cavities)*	Q of HOM	HOM frequency in MHz	DEG (0 for X axis, 90. for Y axis)	OFFSET	F0	G0
12		DRIFT	NPR	DZ	DKE					

13		LENS	NPR	*(k_q^2 not 0):* lens strength in DIMAD units ($1/m^2$) **or** *($k_q^2 = 0$):* focal length in cm (DIMAD units) (negative defocusing horizontally,just like DIMAD)	k_q^2 of quad ($B'/_{dp}$ in $1/_m{}^2$) **Note:** one can also use thin lens here by setting $k_q^2=0$ and then specifying the focal length in cm instead of the quad length					
14		MATRIX	*(read in phase slip & matrix)*							
15		RECIRC	*(read in phase slip & recirculation matrix)*							
16		CECAV	NPR	DELTAE *(read auxiliary file & ignore value)*	PHI0 (ignored)					
17-20		Z								
21		REF		time at which to turn on beam in uSec	time at which to turn off beam in uSec	total time to run simulation in uSec	MOD TIME FOR A BUNCH PRINT CYCLE	MOD TIME FOR A CAVITY PRINT	print interval in uSec	
22		BEAM		injection energy in MeV	bunching frequency (2 x RF frequency) in MHz	subharmonic of bunching frequency	fraction	of	current	(4)
23		CALC		KSTART *(read in injector noise)*	duration that beam is ON (pulsed beam only) uSec	duration that beam is OFF (pulsed beam only) uSec				
24		APRTR		APERTURE	IRECOV *(pam?)#* ar the start of energy recovery					
25		XPRNT		PASS NUMBER	LOCATION NUMBER	FREQUENCY OF PRINT				
26		PXPRNT		PASS NUMBER	LOCATION NUMBER	FREQUENCY OF PRINT				
27		YPRNT		PASS NUMBER	LOCATION NUMBER	FREQUENCY OF PRINT				
28		PYPRNT		PASS NUMBER	LOCATION NUMBER	FREQUENCY OF PRINT				
29		CVPRNT		PASS NUMBER	LOCATION NUMBER	FREQUENCY OF PRINT				
30		Z								

The REF card specifies the time during the simulation that the beam is turned on, the time it may be turned off, and the total time of simulation. Typically, the beam turns on at time 0, and off at the same time the simulation ends. Typically, the time of interest is about ~ 2*Q/ω of the HOMs, so for f=2 GHz, $Q=10^5$, T~150 uS, and for $Q=10^6$, T~1500 uS.

Starting with tdbbu 1.6h, the CALC card can specify a pulsed beam with an on and off time in uS; if the on time is zero, the beam is assumed to be continuous. The REF and CALC card times are ignored by matbbu.

After the CALC card comes various FORTRAN free format data. It should be the injector noise followed by the phase slip and recirculation matrix for each pass.

First, the **injector noise in x and Px**; its format is the FORTRAN free format:

```
      real*8 AMPX(MPAS),FREQX(MPAS),AMPPX(MPAS),FREQPX(MPAS)
      integer*8 IRANDX(MPAS),IRANDPX(MPAS)
      ...
      READ(7,*,ERR=25) AMPX(1),FREQX(1),IRANDX(1),
     &     AMPPX(1),FREQPX(1),IRANDPX(1)
```

```
0.1,0.,0,0.,0.,0
```

then **injector noise in y and Py**:

```
      real*8 AMPY(MPAS),FREQY(MPAS),AMPPY(MPAS),FREQPY(MPAS)
      integer*8 IRANDY(MPAS),IRANDPY(MPAS)
      ...
      READ(7,*,ERR=25) AMPY(1),FREQY(1),IRANDY(1),
     &     AMPPY(1),FREQPY(1),IRANDPY(1)
```

```
0.1,0.,0,0.,0.,0
```

Next follows (a list of) the phase slip and matrix corresponding to the `MATRIX` and `RECIR` lines. The first line contains the 180deg phase slip w.r.t RF, followed by the matrix. Both are in FORTRAN free format. For the `MATRIX` card:

```
      integer*8 ITD(MMAT,MPAS)
      real*8 RTM(MPAS,MMAT,16)
      ...
      READ(7,*) ITD(NMAT,NPASS)
      READ(7,*) (RTM(NPASS,NMAT,jk),jk=1,16)
```

```
100
1.,0.,0.,0.,0.,1.,0.,0.,0.,0.,1.,0.,0.,0.,0.,1.
```

The units of the matrix are unspecified within the file. Earlier versions of tdbbu and matbbu used "**STANDARD**" (cm-MeV/c) units, while later versions used "**DIMAD**" (m-radian) units. Versions `tdbbu 1.6` and `matbbu 2.4f` forward require the user to specify the input units on the command line (either --STANDARD or --DIMAD).

If the `RECIR` line was used, there is also data corresponding to **input recirculation noise aspects**:

```
      READ(7,*) ITD(NMAT,NPASS)
      READ(7,*) (RTM(NPASS,NMAT,jk),jk=1,16)
      READ(7,*,END=25) AMPX(NPASS),FREQX(NPASS),IRANDX(NPASS),
     1  AMPPX(NPASS),FREQPX(NPASS),IRANDPX(NPASS)
      READ(7,*,END=25) AMPY(NPASS),FREQY(NPASS),IRANDY(NPASS),
     1  AMPPY(NPASS),FREQPY(NPASS),IRANDPY(NPASS)
```

```
6036
1.3353676,0.0,0.0,0.0
0.01933465,0.748857463,0.0,0.0
0.0,0.0,5.066133,0.0
0.0,0.0,0.16944319,0.1973892
0.,0.,0,0.,0.,0
0.,0.,0,0.,0.,0
```

The CECAV card directs the programs to read the (**CE**baf **CAV**ity) auxiliary input file describing the CEBAF cavity.

Example input files are included in the distributions of both the tdbbu and matbbu programs, and one is included in the matbbu tech note.[4]

4 JLAB-TN-02-044, matbbu 2.4: *A Tool for Estimating Beam Breakup due to Higher Order Modes* K.B.Beard, L.Merminga, B.Yunn

CAVMAT file

In place of a DRIFT statement with an energy gain, which tells the codes to use a generic cavity, it is possible to use a CECAV statement. Each time a CECAV statement is encountered in the main program and for each pass, one cavity's transport matrix is read from the CAVMAT file. The subsequent fields in the CECAV statement are ignored.

The original CAVMAT format, call CEBAF style, was only used to describe the CEBAF cavities. The format for the CEBAF style is:

```
Energy
x*x  x*x'  x'*x  x'*x'  y*y  y*y'  y'*y  y'*y'
```

Where Energy is the kinetic energy in MeV and the matrix elements are in either DIMAD or STANDARD units. When using the CEBAF style, the length of a CEBAF cavity is fixed at **70.0 cm** within the code.

The Cornell style has only a single line per cavity:

```
dE L x*x  x*x'  x'*x  x'*x'  y*y  y*y'  y'*y  y'*y'
```

Where dE is the energy gain in MeV, L is the length in cm, and the matrix elements are either in DIMAD or STANDARD units.

In both cases, comments may be inserted using a "#" or "!" character (except between the two data lines of the CEBAF style), and are in free format. The numbers may be separated by ","s and /or whitespace; the values are extracted and the format determined using KBB library routines.[5]

In both cases and similar to the input file format, the format does **not** include a specification of the units. The units for the CAVMAT file must be specified on the tdbbu or matbbu command line. An example of a CAVMAT file using DIMAD units with 4 cavities, one pass up and one pass down:[6]

```
#cavmat file - 4/17/03
# dE-MeV              L-cm   x.x        x.x'       x'.x        x'.x'      y.y        y.y'       y'.y        y'.y'
13.100000000000000    106   0.590438   0.670771   -0.110131   0.620768   0.590438   0.670771   -0.110131   0.620768
13.100000000000000    106   0.777919   0.825888   -0.0382953  0.78369    0.777919   0.825888   -0.0382953  0.78369
13.100000000000000    106   0.846759   0.888673   -0.0194486  0.848785   0.846759   0.888673   -0.0194486  0.848785
13.100000000000000    106   0.846759   0.888673   -0.0194486  0.848785   0.846759   0.888673   -0.0194486  0.848785
-13.10000000000000    106   1.15324    1.20744    -0.0264247  1.15049    1.15324    1.20744    -0.0264247  1.15049
-13.10000000000000    106   1.22208    1.28788    -0.0597174  1.21308    1.22208    1.28788    -0.0597174  1.21308
-13.10000000000000    106   1.40956    1.5231     -0.250072   1.34069    1.40956    1.5231     -0.250072   1.34069
-13.10000000000000    106   1.40956    1.5231     -0.250072   1.34069    1.40956    1.5231     -0.250072   1.34069
#
```

Typical CAVMAT file.

5 KBB 7.5g Library, K.Beard, http://casa.jlab.org/internal/code_library/casa_lib/KBB/DOC/

6 R.Calaga, private communication

Automatic Generation of Input Files

Often, rather than modify files by hand, it is convenient to allow matbbu to generate new files automatically using the `-MO`, `+MO`, `-MI`, or `+MI` options in combination with the `-g`, `-u`, `+CR`, `+CQ`, `+CF`, `-OL`, and `-LO` options from an already existing input file.

For example, if one wanted to only create (but not run) input files for 3 accelerators "as built" (**-R 3**), with only the HOMs in lines 91-129 (**-OL 91,129**) reset to having R/Q 's of 86 Ω (**+CR 86.0**), Q's of 2.6E4 (**+CQ 2.6E4**), a central frequency of 1871.4 MHz (**+CF 1871.4**), and a gaussian spread of frequencies of 5 MHz sigma (**-g 5.**):

```
$> matbbu -i generic.mode --DIMAD -o tmp -R 3 -OL 91,129 \
     +CR 86.0 +CQ 2.6E4 +CF 1871.4 -g 5. -MO case -f 0:9999
```

A frequency range (-f 0:9999) is required for matbbu to consider all the HOMs to be within the range of interest. The input files created would be "case.1", "case.2", and "case.3". The "tmp.*" output files may be ignored except for debugging.

These input files may be used by either tdbbu or matbbu..