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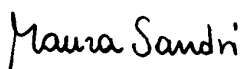
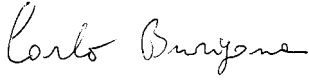
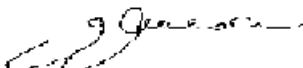
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1 Introduction

This note is to describe the data format in which LFI beams are delivered from the LFI System Team to the DPC. Essentially, the format is the GRASP8 one [1]. In this framework not all possible values for the involved GRASP8 variables are explained. Only the useful values for PLANCK/LFI beam simulations are discussed. In the original GRASP8 ASCII output file (**.grd** or **.cut**, as explained in the sections 2 and 3) a header is added, in which the relevant beam simulation characteristics are reported.

LFI main beams are computed in spherical UV-grids whereas intermediate and full beams are computed in spherical polar cuts. Each beam, both UV-grid or cuts, is computed with respect its own coordinate system – identified by the three angles θ_{MB} , ϕ_{MB} , ψ_{MB} , in the LOS frame [2] – in which the beam power peak falls in the centre of the UV-grid ($U_p = V_p = 0$) or at $\theta = 0$ for each cut [3].

Far fields are computed in the co- and x- polar basis according to the Ludwig's third definition [4]. A detailed description of simulation methods applied to the PLANCK/LFI case is reported in [5], whereas the transformation rules between the LOS frame and the beam frame are explicitly given in [6].

2 FIELD DATA IN RECTANGULAR UV- GRID

This format is used for storing the main beam field values in a rectangular UV- grid. The file extension is **grd**. Data points are located on a sphere and the direction to a field point **r** is related to the polar angles θ and ϕ by

$$\mathbf{r} = x \sin\theta \cos\phi + y \sin\theta \sin\phi + z \cos\theta.$$

The field points are parametrised by two variables which are generally denoted X and Y and which run from XMIN to XMAX and from YMIN to YMAX, respectively. The file is organised so that X is varying faster than Y. The variables X and Y should be considered as general names for the actual variables which are ϕ and θ , in this case. The file format is:

Line Contents Format

0 **HEADER** (characters)

BEAM TYPE - Main Beam
FEED NUMBER - From 18 to 27
FEED TYPE - GAU (Gaussian) or SWE (Spherical Wave Expansion) or TAB (tabulated pattern)
FEED POLARIZATION - X or Y
FEED DESIGN - QM (Qualification Model) or FM (Flight Model) or ID (from 00 to 99). In all cases the Edge Taper is specified between brackets
U V - power peak location with respect to the LOS
THETA PHI PSI - angles defining the MB frame with respect to the LOS, according to the GRASP8 convention
THETA PHI PSI - angles defining the MB frame with respect to the LOS, according to the LFI flight simulator convention
SIMULATION METHODS - GO/GTD+PO or FPO
SOFTWARE - GRASP8
ORIGINATOR - Institution and Name
DATE - dd/mm/yy

1 **TEXT** (characters)



TEXT - Line with comments

A line containing ++++ as the first 4 characters ends these two sections.

2 **KTYPE** (integer)

KTYPE = 1 - standard format for 2D grid

3 **NSET, ICOMP, NCOMP, IGRID** (4 integers)

NSET = 1 - Number of field sets or beams

ICOMP = 3 - Linear co and cx components (Ludwig's third definition)

NCOMP = 2 - The file contains two field components for each point

IGRID = 1 - uv-grid type: $(X,Y) = (u,v)$ where u and v are the two first coordinates of the unit vector to the field point. Hence, $\mathbf{r}(u,v,\sqrt{1-u^2-v^2})$. u and v are related to the spherical angles by $u = \sin\theta \cdot \cos\phi$ and $v = \sin\theta \cdot \sin\phi$

4 **IX, IY** (2 integers)

IX = 0 - Beam centre in u

IY = 0 - Beam centre in v

5 **XS, YS, XE, YE** (4 real numbers)

Limits of 2D grid. The grid points (X,Y) run through the values

$X = XCEN + XS + DX \cdot (I-1)$ and $Y = YCEN + YS + DY \cdot (J-1)$ where

$DX = (XE-XS)/(NX-1)$, $DY = (YE-YS)/(NY-1)$ and $XCEN = DX \cdot IX$, $YCEN = DY \cdot IY$.

The number of grid values NX and NY and the range of the index I and J are defined in the following lines.

6 **NX, NY, KLIMIT** (3 integers)

NX - Number of columns

NY - Number of rows

KLIMIT = 0 - Each row contains data for all NX columns

7 **F1, F2** (4 real numbers on each line)

F1, F2 - Complex field with two components. Since **ICOMP** = 3, **F1** and **F2** contain the real and imaginary parts of the field in linear scale.

-----end of data file-----

2.1 Example of a GRD file

The first part of a **grd** file storing a LFI main beam is reported, as example.

Main Beam

27

SWE

X

FM (ET 30dB@22°)

-0.06789 0.03369

4.3466 153.6074 -22.5

4.3466 153.6074 337.5

GO/GTD + PO

GRASP8

IASF/CNR Sezione di Bologna (Italy) - M.Sandri

10/04/03

Main Beam LFI27 SWE X-POL FM

++++



```

1
1 3 2 1
0 0
-0.2600000000E-01 -0.2600000000E-01 0.2600000000E-01 0.2600000000E-01
301 301 0
0.266168536E+00 -0.188242461E+00 -0.118328029E+00 0.804270343E-01
0.250234160E+00 -0.183469660E+00 -0.121881117E+00 0.906006049E-01
0.232528869E+00 -0.178177050E+00 -0.124944119E+00 0.100390631E+00
.....
[cut of 90596 lines]

```

3 FIELD DATA IN POLAR CUTS

This format is used for storing the intermediate and far beam field values in spherical cuts. The file extension is **cut**. A cut consists of the records 1, 2 and 3 as described below. Since more than one cut is contained in a file all lines (except the header) are repeated for each cut.

Line Contents Format

0 **HEADER** (characters)

BEAM TYPE - Intermediate Beam or Full Beam
FEED NUMBER - From 18 to 27
FEED TYPE - GAU (Gaussian), SWE (Spherical Wave Expansion), TAB (tabulated pattern)
FEED POLARIZATION - X or Y
FEED DESIGN - QM (Qualification Model) or FM (Flight Model) or ID (from 00 to 99). In all cases the Edge Taper is specified between brackets
U V - power peak location with respect to the LOS
THETA PHI PSI - angles defining the MB frame with respect to the LOS, according to the GRASP8 convention
THETA PHI PSI - angles defining the MB frame with respect to the LOS, according to the LFI flight simulator convention
SIMULATION METHODS - MrGTD or FPO
SOFTWARE - GRASP8
ORIGINATOR - Institution and Name
DATE - dd/mm/yy

The following lines are repeated for each cut stored in the CUT file.

1 **TEXT** (characters)

TEXT - Line with comments

2 **V_INI, V_INC, V_NUM, C, ICOMP, ICUT, NCOMP** (2 real numbers, 1 integer, 1 real number, 3 integers)

V_INI - Initial value of θ
V_INC - Increment in θ
V_NUM - Number of values in cut
C - Constant angle (ϕ in degrees)
ICOMP = 3 - Linear co and cx components (Ludwig's third definition)
ICUT = 1 - standard polar cut where ϕ is fixed (C) and θ is the varying (V_)
NCOMP = 2 - The file contains two field components for each point

3 **(F1(I), F2(I), I = 1, V_NUM)** (4 real numbers on each line)



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`F1, F2` - Complex arrays containing the two components of the field for the
I'th data point. $V = V_INI + V_INC * (I-1)$

-----end of data file-----



3.1 Example of a CUT File

The first part of the first three cuts included in a CUT file storing a LFI full beam are reported, as example.

```
Full Beam
27
SWE
X
FM (ET 30dB@22°)
-0.06789 0.03369
4.3466 153.6074 -22.5
4.3466 153.6074 337.5
MrGTD
GRASP8
IASF/CNR Sezione di Bologna (Italy) - M.Sandri
16/04/03
Full Beam LFI27 SWE X-POL FM
++++
-0.1800000000E+03 0.2000000000E+01 181 0.0000000000E+00 3 1 2
0.255416704E-02 -0.450266894E-02 -0.989735312E-03 0.469252023E-03
0.500849070E-02 -0.434351666E-03 0.122292814E-03 0.690814680E-04
.....
[cut of 179 lines]
Full Beam LFI27 SWE X-POL FM
-0.1800000000E+03 0.2000000000E+01 181 0.2000000000E+01 3 1 2
0.265234509E-02 -0.452665368E-02 -0.684405339E-03 -0.602623128E-04
0.500660719E-02 -0.859806843E-03 0.113539829E-02 -0.684379231E-04
.....
[cut of 179 lines]
Full Beam LFI27 SWE X-POL FM
-0.1800000000E+03 0.2000000000E+01 181 0.4000000000E+01 3 1 2
0.265234509E-02 -0.452665368E-02 -0.684405339E-03 -0.602623128E-04
0.451212091E-02 -0.115271066E-02 0.116218865E-02 -0.314941344E-03
.....
[cut]
```



4 FILE NAME SPECIFICATION

In order to univocally identify a beam file by its name a standard labelling is adopted. File names meet the follows rule:

"beam type" + "feed label" + "feed type" + "feed polarization" + "feed design"

where,

- beam type - MB (Main Beam) or IB (Intermediate Beam) or FB (Full Beam)
- feed label - LFI# (#=18÷27)
- feed type - GAU (Gaussian) or SWE (Spherical Wave Expansion) or TAB (tabulated pattern)
- feed polarization - X or Y
- feed design - QM (Qualification Model) or FM (Flight Model) or ID (from 00 to 99)

For example, this is the complete set of simulations done for the LFI27 at 30 GHz:

- MB_LFI27_SWE_X_FM.grd
- IB_LFI27_SWE_X_FM.cut
- FB_LFI27_SWE_X_FM.cut

while files corresponding to analogous simulations done for the LFI23 at 70 GHz are:

- MB_LFI23_TAB_Y_QM.cut
- IB_LFI23_TAB_Y_QM.cut
- FB_LFI23_TAB_Y_QM.cut

5 REFERENCES

- [1] K. Pontoppidan, *Technical Description of GRASP8*, TICRA, Doc.No.S-894-02, 1999.
- [2] FIRST/PLANCK Project, *PLANCK Telescope Design Specification*, SCI-PT-RS-07024.
- [3] M. Sandri and F. Villa, *PLANCK/LFI: Main Beam Locations and Polarization Alignment for the LFI baseline FPU*, PL-LFI-ST-TN-027, 2001.
- [4] C. Ludwig, *The Definition of Cross Polarization*, IEEE Transactions on Antennas and Propagation, pp.116-119, Jan 1973.
- [5] M. Sandri, F. Villa, R. Nesti, C. Burigana, M. Bersanelli, N. Mandolesi, *Trade-off between angular resolution and straylight contamination in CMB anisotropy experiments. Paper I. Pattern Simulations*, submitted to A&A, 2003.
- [6] C. Burigana, M. Sandri, F. Villa, D. Maino, R. Paladini, C. Baccigalupi, M. Bersanelli, N. Mandolesi, *Trade-off between angular resolution and straylight contamination in CMB anisotropy experiments. Paper II. Straylight evaluation*, submitted to A&A, astro-ph/0303645, 2003.



6 APPENDIX

6.1 F90 routine for reading GRD files

Example of routine for reading a grid file generated by GRASP8 [1], written in F90.

```
SUBROUTINE READ_FIELD_GRID
! Example of reading field data from a 2D-grid file
! declarations
REAL :: &
XS, YS, XE, YE, & ! Grid limits
A1, A2, A3, A4, A5, A6 ! Temporary variables
INTEGER :: &
UNIT_NO=15, & ! Unit no of open input file
IER, & ! Error code
KTYPE, & ! Type of file format
NSET, & ! Number of data sets
ICOMP, & ! Control of field components
NCOMP, & ! Number of field components
IGRID, & ! Control of grid type
I_SET, & ! Index of data set
NX, NY, & ! Number of grid points
KLIMIT, & ! Limits of 2D grid
IS, IN, IE, & ! Limits and number of points in row
I, J ! Loop index
CHARACTER(LEN=72) :: &
MESS, & ! message
TEXT, & ! File header
FILE_FORM ! Format of file
COMPLEX :: AJ = (0.,1.)
COMPLEX, POINTER, SAVE :: &
F1(:, :), & ! Array for storing first component of field data
F2(:, :), & ! Array for storing second component of field data
F3(:, :), & ! Array for storing third component of field data
INTEGER, POINTER, SAVE :: &
I_X(:), I_Y(:) ! Beam centers
LOGICAL :: INIT=.TRUE. ! Initialisation flag
! Initialisation
IF (INIT) THEN
NULLIFY( &
I_X, I_Y, &
F1, F2, F3)
INIT = .FALSE.
ENDIF

IF (FILE_FORM == 'formatted') THEN
! Formatted input
DO
READ(UNIT_NO, '(A)', ERR=9990, END=9990) TEXT
IF (TEXT(1:4) == '++++') EXIT
END DO
READ(UNIT_NO, *, ERR=9990, END=9990) KTYPE
READ(UNIT_NO, *, ERR=9990, END=9990) NSET, ICOMP, NCOMP, IGRID
ELSE
! Unformatted data
DO
READ(UNIT_NO, ERR=9990, END=9990) TEXT
IF (TEXT(1:4) == '++++') EXIT
ENDDO
READ(UNIT_NO, ERR=9990, END=9990) KTYPE
READ(UNIT_NO, ERR=9990, END=9990) NSET, ICOMP, NCOMP, IGRID
ENDIF
! storage allocation
IF (ASSOCIATED(I_X)) DEALLOCATE(I_X)
IF (ASSOCIATED(I_Y)) DEALLOCATE(I_Y)
ALLOCATE(I_X(NSET), I_Y(NSET))
```



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```
IF (FILE_FORM == 'formatted') THEN
! Formatted input
DO I = 1, NSET
READ(UNIT_NO, *, ERR=9990, END=9990) I_X(I), I_Y(I)
END DO
ELSE
! Unformatted data
DO I = 1, NSET
READ(UNIT_NO, ERR=9990, END=9990) I_X(I), I_Y(I)
END DO
END IF
! Loop through data sets. The following lines are read NSET times
sets_loop: &
DO I_SET = 1, NSET
IF (FILE_FORM == 'formatted') THEN
! Formatted input
READ(UNIT_NO, *, ERR=9990, END=9990) XS, YS, XE, YE
READ(UNIT_NO, *, ERR=9990, END=9990) NX, NY, KLIMIT
ELSE
! Unformatted data
READ(UNIT_NO, ERR=9990, END=9990) XS, YS, XE, YE
READ(UNIT_NO, ERR=9990, END=9990) NX, NY, KLIMIT
END IF
! storage allocation
IF (ASSOCIATED(F1)) DEALLOCATE(F1)
IF (ASSOCIATED(F2)) DEALLOCATE(F2)
IF (ASSOCIATED(F3)) DEALLOCATE(F3)
ALLOCATE(F1(NX,NY), F2(NX,NY), F3(NX,NY), STAT=IER)
IF (IER /= 0) THEN
MESS = 'Could not allocate enough memory'; GO TO 9998
END IF
! Loop through columns
column_loop: &
DO J = 1, NY
IF (KLIMIT == 1) THEN
IF (FILE_FORM == 'formatted') THEN
! Formatted input
READ(UNIT_NO, *, ERR=9990, END=9990) IS, IN
ELSE
! Unformatted data
READ(UNIT_NO, ERR=9990, END=9990) IS, IN
END IF
IE = IS + NX - 1 ELSE
IS = 1
IE = NX
END IF
(FILE_FORM == 'formatted') THEN
! Formatted input
IF (NCOMP == 2) THEN
DO I = IS, IE
READ(UNIT_NO, *, ERR=9990, END=9990) A1, A2, A3, A4
F1(I,J) = A1+AJ*A2; F2(I,J) = A3+AJ*A4
END DO
ELSE
DO I = IS, IE
READ(UNIT_NO, *, ERR=9990, END=9990) A1, A2, A3, A4, A5, A6
F1(I,J)=A1+AJ*A2; F2(I,J)=A3+AJ*A4; F3(I,J)=A5+AJ*A6
END DO
END IF
ELSE
! unformatted
IF (NCOMP == 2) THEN
READ(UNIT_NO, ERR=9990, END=9990) &
(F1(I,J), F2(I,J), I=IS,IE)
ELSE
READ(UNIT_NO, ERR=9990, END=9990) &
(F1(I,J), F2(I,J), F3(I,J), I=IS,IE)
END IF
END IF
```



```
ENDDO column_loop
ENDDO sets_loop
GO TO 9999
! Errors
9990 CONTINUE; MESS='Error in field data file'
9998 CONTINUE; IER=1
CALL OM_ERROR('READ_FIELD_GRID' , 'FATAL' , MESS)
9999 CONTINUE
END SUBROUTINE READ_FIELD_GRID
```

6.2 C routine for reading GRD files

Example of routine for reading a LFI main beam stored in a grid file, written in C.

```
#include <stdlib.h>
#include <stdio.h>
#include <string.h>

void main(int argc, char *argv[])
{
    int i,j;
    char str[80]="\0";
    int KTYPE;
    int NSET,KCOMP,NCOMP,KGRID;
    int IX,IY;
    int NX,NY,KLIMIT;
    double XS,YS,XE,YE;
    double XR,XI,YR,YI;
    char grdfile[80];
    FILE *grd;

    if (argc != 2) {
        printf("Insert filename.grd \n");
        exit(1);
    }

    strcpy(grdfile,argv[1]);
    grd=fopen(grdfile,"r");

    while (strstr(str,"++++") == NULL) {
        fgets(str,80,grd);
    }

    fscanf(grd,"%d",&KTYPE);
    fscanf(grd,"%d %d %d",&NSET,&KCOMP,&NCOMP,&KGRID);
    fscanf(grd,"%d %d",&IX,&IY);
    fscanf(grd,"%lf %lf %lf %lf",&XS,&YS,&XE,&YE);
    fscanf(grd,"%d %d %d",&NX,&NY,&KLIMIT);

    for(j=0;j<NY;j++) {
        for(i=0;i<NX;i++) {
            fscanf(grd,"%lf %lf %lf %lf",&XR,&XI,&YR,&YI);
        }
    }

    fclose(grd);
}
```