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Charlottesville, Virginia

September 1969

USERS' GUIDE TO THE SYNTHESIS PROGRAM SYSTEM

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OUTLINE

There are two sets of programs in the synthesis program system, one set produces a map of the unpolarized brightness distribution and the other set a map of the polarized distribution. There are three programs in each set: PREP, MAP and PLOTMAP in set 1 and PREP, POLMAP and POLPLOT in set 2. The PREP program is identical in the two sets. It takes as input the calibrated and corrected interferometer data in the 'tape 3' form and prepares the data for a given source for input to the MAP or POLMAP programs. These programs perform the Fourier inversion and output the synthesized map onto tape ready for PLOTMAP or POLPLOT which plot the map with the Calcomp plotter.

All five programs except POLMAP will run in a small partition. In synthesizing an unpolarized map therefore the three programs may conveniently be run together as a single job which outputs an automatically plotted map from the input tape 3 data. For an automatic contour map, however, a large partition program, 'CONTOUR' must be run as a separate job.

Figure 1 is a flow diagram of the synthesis programming system.

The programs have been filed in a library on disk so that relatively few cards are required to run a job.

PROGRAM PREP

Operation. Program PREP itself comprises three job steps. In step 1 the appropriate tape 3's and any data for the desired source found on them is transferred to a scratch tape (# 1236) in the form of 7-word records. The words in each record are

1. RE - Real amplitude of visibility (in flux units).
2. IM - Imaginary amplitude of visibility (in flux units).
3. WT - Weight, which is the number of 15-second samples averaged in 1 and 2.
4. KU } - Coordinates of a unit cell in the u-v plane with cell size for
5. KV } field of view specified, and centered on cell 129, 129 so that $129 \leq KU \leq 256$, $1 \leq KV \leq 256$.
6. KPOL - Polarization index such that LL ≡ 0, LR ≡ 1, RL ≡ 2, RR ≡ 3.
7. KBASE - Baseline length rounded to the nearest 100 meters.

The output from step 1 is a listing of scan numbers transferred from the tape 3's, with a note of the baselines and number of records for that scan.

Step 2 uses the IBM Sort-Merge facility for sorting all the 7-word records accumulated on the scratch tape. The sort is made on 4 of the words only, in ascending order for each word with the hierarchy KPOL (0→3), KV (1→256), KU (129→256), KBASE (100→2700). This sorting job is a vital part of the synthesis programming system since it enables the disk transfer time required to set up the u-v matrix to be drastically reduced. The sorted records are output to a second scratch tape (# 1543) ready for input to the MAP program.

Step 3 simply gives a print-out of the first 500 records on this tape as a check that the transfer and sorting of data has been performed correctly.

Dummy data for a point source at some specified declination and for given baselines can readily be generated in step 1. A subroutine can be called which computes the u-v sampling and sets RE = 1, IM = 0, WT = 1 in each 7-word record. This facility is useful in producing model beams with the MAP program or for generating the sampling distribution for some given declination and baseline configurations. This can be used later in the MAP program for producing a map of some model source for this sampling distribution.

Data required. One data card at least is required, giving the source name as it is written on tape 3 (columns 1-10), the field of view in minutes of arc (columns 14-15, I2 format). To generate dummy data put a 1 in column 20. In this case, additional data cards are needed, the first giving declination (columns 1-14, S14.1 format) and number of baselines (columns 19-20, I2 format) and the subsequent cards giving the baselines in meters with a 10 F 8.2 format.

Data sets:

Step 1

Input: Data set 9 is 'tape 3'. If there is more than one physical tape 3, they may be concatenated into a single data set as follows:

```
First tape:    //GO.FT09F001   DD   UNIT = SYSSQ, DSNAME = TAPE 3,
               DISP = OLD, VOLUME = SER = XXXX
Second tape:   //              DD   UNIT = AFF = FT09F001,
               DSNAME = TAPE3, DISP = OLD, VOLUME = SER = XXXX
```

and so on.

Output: Data set 8 is scratch tape 1236.

Step 2

Input: ('//SORTIN') is scratch tape 1236

Output: ('//SORTOUT') is scratch tape 1543

Step 3

Input: Data set 10 is scratch tape 1543.

PROGRAM MAP

Operation. The sorted 7-word data records are read off tape 1543 and the RE and IM words are added into the cell specified by KU, KV with the appropriate weighting WT. The conjugate cells are also set up at this stage.

Various facilities are available for treating the data in the u-v matrix before Fourier inversion. These are:

(a) Weighting to give an improved sidelobe level. A radial gaussian weighting can be requested which falls to 30% at the largest spacing used.

(b) Shifting of map center. Normally the output map will be centered on the 1950.0 phase reference position assumed in making the observations. A different map center can be requested by specifying the new position as a shift in R.A. and Dec. from the assumed position.

(c) Gaussian components can be added or subtracted from the map before Fourier inversion. Up to 10 components can be specified, each with an independent amplitude, position, half-width in two directions, and position angle of maximum extent.

A picture of the u-v plane is produced by subroutine DISPL1 showing the distribution of sampled cells. The Fourier transform is performed in subroutine COOLEY and the output map is displayed by subroutine DISPL2. This is shown in three ways. First the whole map is printed in one width of the paper in a coded format, with a peak of 10 coded as an asterisk, positive amplitudes as numbers 1 to 9 and negative amplitudes as letters A to I and zero as a blank. In the second and third displays the whole map is divided into two parts, the left- and right-hand sides being printed separately. The format is such that this map has equal angular scales N-S and E-W, with the width of the map in R.A. being the field of view specified in PREP. The second display has a maximum number normalized to 10 and the third display to 100, to give an amplitude scale with 1% precision. The normalization factor involved is printed out.

If requested, the whole program will be repeated to produce the synthesized beam for the same sampling and weighting as specified for the source.

Finally, the source and beam maps are output by subroutine WRITUP to a magnetic tape with the appropriate header information. This includes: Source number, R.A. and Dec. of 1950.0 map center position, field of view, normalization factor and map number. The map number can be any number 1 to 98. The beam will be written with a map number greater than this by unity.

Data required. Normally, only one data card is required. If you wish to add or subtract components from the map, however, two or more additional data cards will be needed.

The first card contains, on columns

 1-10: Source name
14-15: Field of view in arc min (I2)
16-29: R.A. of map center, 1950.0 coords (R14.1)
30-43: Dec. of map center, 1950.0 coords (S14.1)
 45 : 0 if source map and beam both required
       1 if source map only required
       2 if beam map only required
 50 : 1 if 30% radial gaussian weighting required
 55 : 1 if map to be output on magnetic tape
59-60: Map number to be put on header (I2)
61-64: Cutoff value for effective baseline in meter (I4)
 65 : 1 if the data is for more than one polarization mode
66-70: delta R.A.-shift of map center in arc sec from 1950.0 position
       positive to right of map (decreasing R.A.) (F5.0)
71-75: delta Dec.-shift of map center in arc sec from 1950.0 position
       positive to top of map (increasing Dec.) (F5.0)
 76 : 1 if only data from baselines shorter than the cutoff to be used
       else if baselines larger than the cutoff to be used
 77 : 1 add gaussian components
       2 subtract gaussian components
 78 : 1 if after subtraction new source normalization factor required
        or if for adding output the given source normalization factor req.
79-80: Number of gaussian components (.LE.10) (I2)

If column 77 contains 1 or 2, further cards must follow, one for each gaussian component. Each card contains on column

 1- 6: Amplitude or flux of component (F6.1)
 7-12: Half-power width of major axis in arc sec (F6.1)
13-18: Half-power width of minor axis in arc sec (F6.1)
19-24: Position angle of major axis in °, from north over east
       (counterclockwise on the map) (F6.1)
25-30: x-coordinate of component center in arc sec relative to 1950.0
       position, positive to right of map (west,decreasing R.A.) (F6.1)
31-36: y-coordinate of component center in arc sec relative to 1950.0
       position, positive to top of map (north,increasing Dec.) (F6.1)
37-42: Sum over the beam in the 10-contour map. (F6.1)
 45 : 1 if the flux of component is given

If a gaussian component is to be added or subtracted, a final card must follow in 2F10.2 FORMAT with

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NOTICE: The cell size in Dec. is 5/6 the cell size in R.A., which is field of view in arc sec divided by the number of points (=60*FLDVU/128)

These changes are applied in the modification MAPPE of the program MAP. MAPPE is available in the INTERFEROMETER JOBLIBRARY

MENTOR3 is essentially MAPPE. The only modification is that the cell sizes in R.A. and in Dec. are the same.

(a) Normalization factor for source map.

(b) Normalization factor for beam map.

These numbers are taken from the output of the original map and are used in the program to ensure that a gaussian component of amplitude 100 units will give a peak number on the map equal to the largest number present on the original, so that source subtraction may be fairly precise.

Data sets. Input: Data set 8 is the output tape from 'PREP' containing the sorted 7-word data records (tape 1543 if the standard set of tapes are used. Some other tape if a soft copy is to be preserved).

Output: Data set 11 is the tape on which the output map is written, complete with its header information. This tape serves as input to the 'PLOTMAP' program.

PROGRAM POLMAP

Operation. POLMAP is very similar in operation to program MAP but will run only in a large partition. Note that this should be a 180 K partition and not a 210 K partition. In setting up the u-v data matrix the LR (KPOL = 1) samples are set up in one-half of the u-v plane and RL* (KPOL = 2) samples in the conjugate cells. The map obtained by Fourier inversion is now complex. The real map is a map of the Q Stokes parameter distribution and the imaginary map is of the U Stokes parameter. The intensity I_{pol} and position angle ϕ of the linearly polarized radiation are recovered by use of the relations

$$I_{pol} = \sqrt{Q^2 + U^2}$$

$$\phi = 1/2 \tan^{-1} U/Q$$

Subroutine DISPL2 now outputs two maps, the first showing the position angle distribution across the source with a coding in units of 10° so that, for example, 2 applies to the range 20°→30° and B the range -20°→-30°. A blank is output for the range -10°→+10°. The second shows the polarized intensity again with a coding which is printed above the map. The peak is normalized to a value of 14 using normalization factors for the real and

imaginary maps which are printed separately. This map is then printed on an angular scale in two halves as in MAP. If requested, the beam will also be computed and output as it was for MAP. Likewise a 30% radial gaussian weighting can be applied. The map may be output to magnetic tape by subroutine RYTPOL which also writes the usual header information for the map, including in this case the normalization factors for the real and imaginary maps. This tape provides the input to the POLPLOT program.

Data required. One data card only is needed, giving in columns

1 - 10 : Source name.
14 - 15: Field of view (I2 format).
16 - 29: R.A. (1950.0) (R14.1 format).
30 - 43: Dec. (1950.0) (S14.1 format).
45 : 0 for map and beam.
1 for map only.
2 for beam only.
50 : 1 for 30% radial gaussian weighting.
55 : 1 for output on magnetic tape.
59 - 60: Map number (I2 format).

Data sets. Input: Data set 8 is the tape output by PREP (1543).
Output: Data set 11 is the tape on which the polarized map is stored.

PROGRAM PLOTMAP

Operation. Three styles of plotted output can be produced:

(i) Profile cuts in right ascension.
(ii) Two-dimensional contouring.
(iii) A perspective three-dimensional view.

The output for styles (i) and (ii) are produced by subroutines 'CUTS' and 'PRECTR' in the PLOTMAP program. Since in general the 3-D perspective view is of less interest than (i) or (ii), the output for the plotter is generated, in a separate program called 'DTHREE'. This program could have been incorporated into PLOTMAP as a third subroutine but would have caused PLOTMAP to be a large partition job, which was undesirable.

The operations performed in PLOTMAP are as follows. The output tape from program 'MAP' is searched for the map of the source requested on a data card and having the map number also specified. The header information is decoded and printed out, together with a copy of the map in the "two halves" format as produced in MAP. The map is written as an array on disk.

A second data card is read giving the coordinates of the grid points at the corners of the portion of the map to be plotted (in units of one grid interval, i.e. (to 256), the styles of output desired (cuts or contour map), and the maximum amplitude of the profile cuts. The Calcomp routines are then initialized, and various parameters computed. These include the number of points on the right ascension and declination grid (NORA and NODEC), the grid increments (RAINC and DECINC) and the corner coordinates (RAMAX/RAMIN and DECMAX/DECMIN). These parameters are printed, and then the necessary subroutines (CUTS and PRECTR) are called.

'CUTS' produces profile cuts along lines of constant declination. A scale factor is chosen to be an integral multiple of ten seconds of arc/inch so that the maximum dimension of the plot is around fifteen inches. The scale factor chosen is written on the plot. The amplitude array for each line of constant declination is read from disk, scaled appropriately and the profile is drawn. The scaling is adjusted so that the difference between max. and min. numbers in the area to be plotted has an amplitude of AMPSCL inches. This number is supplied on the data card, but if omitted is set to two inches. When the profiles have been completed, a set of axes are drawn and labeled, and the heading and border drawn round the map.

'PRECTR' writes both card and tape output (tape 1164) which serves as input to program 'CONTOUR', which is a large partition job and must be run separately. Since the Calcomp contouring routine can contour at most an 85 x 85 point array, PRECTR divides the region to be mapped into units which the contouring routine can handle. The scale factor is chosen as before to be the integral multiple of ten seconds of arc per inch which makes the largest dimension of the map close to fifteen inches. The program then produces the cards and tape output necessary to produce a contour plot. The maximum amplitude on the map is 100 units and the contour interval is set at

10 units starting at level 10 with the solid lines. Level 0 and negative contours are drawn with dashed lines; depressions have tick marks on the downhill side. Finally, the axes are produced as in 'CUTS' and the plotter instructions for these filed directly on the plotter disk file. Note that the instructions for plotting the contour map which are produced in program CONTOUR are output on to a different disk file so that in the final 'PLOTOUT' program both files must be unloaded to give the map and axes together.

Data required. Two data cards must be supplied:

Card 1	:	Columns 1 - 10.	Source name
		19 - 20.	Map number (I2 format)
Card 2	:	1 - 5.	Lower left column number of portion to be plotted
		6 - 10	Upper right column number
I5 format		11 - 15	Lower left row number
		16 - 20	Upper right row number
		21 - 25	1 if profile cuts desired
		26 - 30	1 if contouring desired
		31 - 35	Maximum amplitude in inches of profile cuts. (F5.0 format). If no number is given, 2 inches is assumed.

Data sets. Input: Data set 8 is the tape produced by program MAP.

Output: Data set 12 is the card punch, producing cards for program 'CONTOUR'.

Output data set 13 is the tape (1164) on which the data in the format of ARAY cards are written to be used by program CONTOUR.

'PLOTTAPE' is the data set of plotter commands for drawing profile cuts and/or the axes for the contour map.

PROGRAM CONTOUR

Operation. 'CONTOUR' is the large partition program which produces the plotter commands required to draw the contour map. The punched card output from PLOTMAP is combined with the deck of JCL and END and STOP cards of the CONTOUR

program in the following manner:

```
(JCL cards)
  .
  .
  .
// FT05F001  DD  *
  PUNCHED
  OUTPUT
END
STØP
/*
```

The contour map will have a contour every 10 units, the first solid line being level 10. Level 0 and negative contours are drawn with dotted lines, and depressions on the map are indicated by tick marks on the downhill side.

Data required. None.

Data sets. Input: Data set 13 is the tape produced by PLOTMAP (tape 1164) containing ARAY type 3 card images and BEND card images.

Output: 'PLOTTAPE' is the disk file on which the plotter commands are stored. Data set 7 is the card punch for optional punched card output of the ARAY card.

PROGRAM DTHREE

Operation. 'DTHREE' produces a 3-dimensional perspective view of any portion of a map. When the desired map has been found on tape the header information and the map are printed out as in PLOTMAP. The portion of the map to be presented is reduced to an array of size 64 x 64 or smaller by selecting every n^{th} point, where $1 \leq n \leq 4$. The Calcomp routines for producing the 3-D view are then called.

Data required. Two data cards must be supplied:

Card 1	:	Columns 1 - 10.	Source name
		19 - 20.	Map number, I2 format.
Card 2	:	1 - 5	Lower left column number of portion to be plotted.
I5 format		6 - 10	Upper right column number.

I5 format	Columns 11 - 15	Lower left row number.
	16 - 20	Upper right row number.
F5.0 format	21 - 25	Initial viewing factor (QS).
	26 - 30	Frame height (H).
F10.0 format	31 - 40	Horizontal viewing angle in degrees (THETA)
F10.0 format	41 - 50	Vertical viewing angle, in degrees (GAMMA)
F5.0 format	51 - 55	Ratio of viewing distance to radius of sphere enclosing 3-D region (Q).
I5 format	56 - 60	Hidden line switch (IVIS). This number is 1 for the hidden lines to be removed.

These parameters are defined in the Calcomp manual on the THREED and VIEW routines.

Data sets. Input: Data set 8 is the tape containing maps output by program MAP.

Output: PLOTTAPE is the disk file containing commands for the plotter.

PROGRAM POLPLOT

Operation. POLPLOT reads the unpolarized and polarized maps from tape and sets them up on separate disk files. The program then reads both maps a point at a time and if the unpolarized brightness at that point is greater than some threshold value the amplitude and phase of the polarization vector are computed. Otherwise the amplitude is set to zero. The polarization vector computed can be either the polarized intensity or percentage polarization of the unpolarized intensity. For both forms of output, the polarization vector is normalized so that the maximum length is one inch. The normalization factor (AMPMAX) is printed. The Calcomp routines are then called to generate the plotter commands and finally the coordinate grid, labeling and header are output in the usual way.

Data required. One data card, giving in

Columns	1 - 10	Source name
I2 format	19 - 20	Map number of unpolarized map
	29 - 30	Map number of polarized map
I3 format	39 - 40	Threshold value of unpolarized map above which a polarized

vector will be drawn. This number is in the same units as that of the stored map, so that the peak value is 100.

50 0 for polarized intensity map.
1 for polarized percentage map.

Data sets. Input: Data set 8 is the tape on which polarized and unpolarized maps are stored. It is convenient to have both maps stored on the same tape, but if on separate tapes the two tapes may be concatenated into a single data set. In this case the tape containing the polarized map should be the second one so that the REWIND instruction will rewind this tape to find the polarized map.

Output: PLOTTAPE is the disk file containing plotter commands.

PROGRAM PLOTOUT

Operation. This is the two-card program which simply unloads the disk file containing plotter commands on to the plotter. The name of the disk file on the EXEC card must match that on the PLOTTAPE card in the job which produced the Calcomp commands. Note that for a contour map, two EXEC cards are required, the first for the disk file produced by PLOTMAP and the second for that produced by CONTOUR. The first file contains the border, coordinate pips, labeling and header information and the second contains the map itself.

When plotting is complete the data set will be deleted from disk. If it is to be preserved, the following cards must be used for PLOTOUT:

```
//JOB  card
//     EXEC  PGM = PLOTSER
//PLOTTER  DD  UNIT = PLOTTER
//PLOTTAPE DD DSN = PLOTTER.XXX, DISP = (OLD,KEEP)
```

A data set may be deleted without plotting with the following job:

```
//  JOB  card
//      EXEC  PGM = IEF BR14
//XXX    DD  DSNAME = PLOTTER.XXX,DISP=(OLD,DELETE)
```

Programs involving the Calcomp plotter are largely the work of Ted Williams.

Fig. 1. The synthesis program system.