NATIONAL RADIO ASTRONOMY OBSERVATORY
COMPUTER DIVISION
INTERNAL REPORT

DOPSET:

A Computer Program to Calculate Doppler-Corrected Reference Frequencies for Spectral Line and Pulsar Observations

by

R. N. Manchester and M. A. Gordon

Report No. 8

May 1970

TABLE OF CONTENTS

			Page
Section	I	Introduction	1
	II	Input	1
	III	Output	7
	IV	Accuracy	7
	V	Availability	8
	VI	Sample Input and Output	8
	VII	Index	17

I. INTRODUCTION

Observations of spectral lines and pulsars require corrections for the motion of the telescope with respect to the source. Generally, we reference these velocities to the Local Standard of Rest for line observations and to the Solar System Barycentre for pulsar observations. This program, written in Fortran IV for an IBM 360 computer, computes the relevant velocities and frequencies using an input and output format convenient for most radio astronomical applications. It employs subroutines written by J. A. Ball (Lincoln Laboratory, Tech. Note 1969-42) to precess coordinates to the date of observation and to compute the velocity of the telescope with respect to the relevant rest frame.

For spectral line observations, up to four local oscillator settings for different rest frequencies and/or velocity offsets may be calculated at one time. For pulsars, the apparent pulsar period and a related timing frequency--used when synchronizing equipment to the pulsar--are calculated, along with as many as two LO settings for associated spectral line observations such as observations of hydrogen line absorption against pulsars. The program permits uniform variation of the pulsar rest period with time.

The following sections describe the input and output formats of the program and discuss the accuracy of the calculated velocities. An abridged set of instructions is printed on the first page of output each time the program is run (see page 10).

II. INPUT

Data input is organized as <u>data sets</u>, one data set being required for each source. In general, data which does not change from one source

to the next, such as telescope coordinates, need not be re-entered with each data set. However, if part of the data on a given card is to be changed, all of the data on that card must be re-entered. Many parameters are preset within the program. For instance, site coordinates are preset for the NRAO 140-foot telescope, and local time calculated is the U.S. Eastern Standard Time. These preset quantities may be readily changed to suit other observatories.

Each data set must start with a Source card containing the source name, coordinates and epoch of the coordinates. Subsequent input cards are identified by a letter in the first column:

S : Site card
L : Spectral line card
P : Pulsar card
D : Day card
Y : Year card
E : End card

The first data set must contain at least a D card and either an L card or a P card. Up to four L cards may be entered in a data set, unless a P card is entered when up to two L cards may be entered. Every data set must end with an E card. Cards between the source card and the E card may be in any order.

Input format for the first card is 5A4, 3F20.0, and for all subsequent cards A1, 1X, F18.0, 3F20.0. Note that all input numbers are assumed to be floating point, and decimal points must be entered unless the numbers are right justified. Input format for coordinates is HHMMSS.SS... or -DDDMMSS.SS... for hours, minutes and seconds and degrees, minutes and seconds, respectively, with no spaces. Leading zeros may be omitted.

Detailed descriptions of the input data for each card are now given.

Source Card

Input data: Source name

Right ascension (hours, minutes, seconds)

Declination (degrees, minutes, seconds)

Epoch for coordinates (years)

The source name may have up to twenty characters. If the epoch is an integer number (e.g., 1960.0) the coordinates are assumed to refer to the mean place at the epoch given. If the epoch is not an integer (e.g., 1969.8, 1960.000001) the coordinates are assumed to refer to the apparent place at the epoch given. If the epoch is omitted (i.e., left blank) 1950.0 is assumed.

Site Card

Input data: Geodetic longitude (degrees, minutes, seconds)

Geodetic latitude (degrees, minutes, seconds)

Geodetic elevation above M.S.L. (m)

If a site card is not entered the coordinates of the NRAO 140-foot telescope are taken. To preset the program for a different telescope, the coordinates on card 502 and the elevation on card 194 should be altered.

Spectral Line Card

Input data: Rest frequency

Velocity offset from LSR, V_{off} (km/s)

Intermediate frequency

LO multiplier

The local oscillator reference frequency (LORF) is calculated assuming the Doppler-shifted line frequency f seen at the telescope is

$$f \equiv f_o \left(1 - \frac{v}{c}\right) = M \cdot \text{LORF} + f_{IF}$$

or

$$\text{LORF} = \left[f_o \left(1 - \frac{v}{c}\right) - f_{IF}\right]/M$$

where

f_o = rest frequency

v = velocity of source with respect to the telescope

f_{IF} = intermediate frequency

M = LO multiplier

The rest frequency and intermediate frequency must be entered in the same units and be such that the output frequency has sufficient significant digits. For example, for rest frequencies of 1-2 GHz, the rest frequency and intermediate frequency are generally entered in kHz. The intermediate frequency is positive when the signal frequency is above the LO.

The source velocity offset, V_{off}, is with respect to the local standard of rest (velocity of sun with respect to LSR is 20 km/s toward 18^h, +30° (1900.0)).

If none of the L cards entered for a given source are changed for the next source, they need not be re-entered. However, if any changes are required then all L cards must be re-entered.

Pulsar Card

Input data: Period (sec)

First derivative of period (sec/sec 10^{-15})

Julian day to which period is referenced

Timing factor

The period should be referred to the solar system barycentre; however for most applications the heliocentric period is adequate. The program computes the velocity of the telescope with respect to the heliocentre--planetary effects are not included. This is discussed further in the section on accuracy.

If no rate of change of period has been measured, enter zero for the first derivative and a reasonable value (say 2,440,000.0) for the Julian date.

The output timing frequency is calculated using

$$f_{timing} = \frac{F}{P_{apparent}}$$

where

F = timing factor

$P_{apparent}$ = pulsar apparent period at the telescope.

To calculate $P_{apparent}$, the rest period of the pulsar at the time of observation is first calculated and then modified by the Doppler factor.

If a pulsar source precedes a spectral line source in the input deck, then at least one L card must be entered with the line source, otherwise it will be assumed to be a pulsar.

Day Card

Input data: Start day (EST)
End day (EST)
Minute step (min)
Hour angle range (hr)

A day card must be entered with the first source. The start and end days delimit the range for which calculations are made and are given

as day numbers (e.g., 193.5, 368.0) in Eastern Standard time. The time zone (5 hr W) is set on card 184 and may be changed if necessary. Day numbers entered may be negative or greater than 365 (366) to allow for calculations extending through New Year.

The minute step is the interval between times at which frequencies are calculated. If it is not entered (i.e., the field left blank) the preset value of 30.0 minutes is assumed. This preset value may be altered on card 752.

The hour angle range gives the interval on either side of transit for which frequencies are calculated. If it is not entered, frequencies are calculated when the source is above the horizon and when the hour angle is less than seven hours (as for the NRAO 140-foot telescope). The hour angle limit can be changed on card 182. If a zenith angle limit other than 90° is required it can be changed on card 178. If the hour angle range is entered on the D card the hour angle and zenith angle limits are over-ridden and negative elevation angles can be obtained.

Year Card

Data Input: Year, e.g., 1971.0

The year is preset on card 192 to 1970. If the preset year is required, no year card need be entered.

End Card

Data Input: No data

Each data set (i.e., source) must end with an E card.

III. OUTPUT

The output is grouped according to source and has one page of output per transit. Asterisks are printed on the page fold to mark each new source. A header page for each source lists all input or preset data, the LSR offset in frequency units and the precessed coordinates. For each transit the source name, precessed coordinates, rest frequencies, LSR and heliocentric velocity offsets, Eastern Standard day, date and UT day number for the first line of calculations are printed at the head of the page. For pulsars, the heliocentric period at transit and the corresponding Julian day are also listed.

Each line of printout gives the local sidereal time, Eastern Standard time, Universal time, hour angle (east and west), local oscillator reference frequencies for rest frequencies 1-4, telescope azimuth and elevation and velocity of the LSR with respect to the telescope. For pulsars, local oscillator columns 3 and 4 are replaced by the timing frequency and apparent pulsar period respectively. Unused columns are filled with asterisks.

Calculations are performed at rounded Universal times. When the Eastern Standard day changes, a new day and date line is printed, and if more than one page of printout is obtained per transit a space is left at the page fold.

IV. ACCURACY

The basic subroutine used in this program--DOP, written by J. A. Ball--computes the velocity of the telescope with respect to the heliocentre and the sun's motion with respect to the LSR, both projected on the source direction. This subroutine requires no change from year to year.

Its accuracy has been checked by comparing results with those calculated from a solar system ephemeris tape generated by Lincoln Laboratory of the Massachusetts Institute of Technology (kindly provided by Dr. I. I. Shapiro) Velocities given on the ephemeris tape are normally used for planetary radar observations and are much more accurate than those calculated by the subroutine. Comparison of velocities calculated for a source near the ecliptic for a wide range of days in 1970, 1971 and 1974 showed that the heliocentric velocity calculated by DOP has a maximum error of about 0.005 km/s.

Strictly, both spectral line and pulsar Doppler shift calculations should be referred to the solar system barycentre rather than the heliocentre. (Most spectral line velocities are additionally corrected to the LSR.) Data from the ephemeris tape for the same years as above showed that the maximum difference between velocities referred to the heliocentre and those referred to the barycentre was about 0.010 km/s. This therefore is the major error in the program. It is however only varying on a time scale of the order of years.

V. AVAILABILITY

The program is written in Fortran VI language for an IBM 360/50 computer. Copies of the listing, source deck or compiled deck may be obtained from either author. The compiled program is stored on disk at NRAO. See the NRAO standard write-up for details.

VI. SAMPLE INPUT AND OUTPUT

The following pages list two typical input data sets (1 line source and 1 pulsar), and some of the program output for those sets.

INPUT

```
G43.2+0.0 (W49 OH)  190751.8          090053.0
D 127.              137.              10.
L 1665401.           18.              150000.           6.
L 1667358.           18.              150000.           6.
L 1667358.          10.               150000.           6.
E
0329+54             032911.08          542438.3
P 0.71451855076     2.061             2440105.2292       818600.
S   795054.53       382545.48          798.5
L 1665401.          20.               150000.           6.
D 127.              137.                 20.              2.
E
```

OUTPUT

```
  INPUT CARD FORMATS FOR DOPSET ARE AS FOLLOWS:
  SOURCE,RA,DEC,EPOCR                (5A4,3F20.0)
  S,LONG,LAT,ELEV                    (A1,1X,F18.0,3F20.0)
  L,RESTFQ,VELOFF,FREQIF,FREQMF      (A1,1X,F18.0,3F20.0)
  P,PERIOD,PDRV,ORIGIN,PULMF         (A1,1X,F18.0,3F20.0)
  D,STRTDY,ENDDY,MINSTP,DELHA        (A1,1X,F18.0,3F20.0)
  Y,NYR                              (A1,1X,F18.0,3F20.0)
  E                                  (A1,1X,F18.0,3F20.0)

    THE ABOVE DATA CARD SET MUST BEGIN WITH A SOURCE CARD AND END
WITH AN E-CARD. EACH DATA SET MAY HAVE AS MANY AS 4 L-CARDS AND NO P-CARDS,
OR 1 P-CARD AND AS MANY AS 2 L-CARDS. OUTPUT COLUMNS NOT REQUIRED WILL BE FILLED WITH ASTERISKS.

    INPUT PARAMETERS ARE DEFINED AS FOLLOWS:
  SOURCE                          SOURCE NAME
  RA                              RIGHT ASCENSION(HHMMSS.S...)
  DEC                             DECLINATION(DDMMSS.S...)
  EPOCH                           EPOCH OF ABOVE(XXXX.X...
  S                               CODE FOR SITE CARD
  LONG                            SITE WEST LONGITUDE(DDDMMSS.S.)
  LAT                             SITE LATITUDE(DDMMSS.S...)
  ELEV                            SITE ELEVATION IN METERS
  L                               CODE FOR LINE CARD
  RESTFQ                          LINE REST FREQUENCY
  VELOFF                          DOPPLER SHIFT FROM LSR(KM/S)
  FREQIF                          IF FREQUENCY AFTER MIXING ( + WHEN LO IS LESS THAN SIGNAL FREQUENCY)
  FREQMF                          LO FREQ=FREQMF*LORF
                                LORF= LOCAL OSCILLATOR REFERENCE FREQUENCY
  P                               CODE FOR PULSAR CARD
  PERIOD                          PULSAR PERIOD IN SECONDS
  PDRV                            FIRST DERIVATIVE OF PERIOD ( IN UNITS OF 10**-15 SEC/SEC)
  ORIGIN                          PERIOD EPOCH (JULIAN DAYS)
  PULMF                           MULT. FACTOR FOR TIMING PULSE
  D                               CODE FOR DATE CARD
  STRTDY                          FIRST OBSERVING DAY, EST
  ENDDY                           LAST OBSERVING DAY, EST
  MINSTP                          INTERVAL(MINUTES) BETWEEN CALC.
  DELHA                           HOUR ANGLE RANGE IN HOURS
  Y                               CODE FOR YEAR CARD
  NYR                             CURRENT YEAR FOR CALCULATIONS
  E                               CODE FOR END OF DATA SET

    THE PROGRAM COMPUTES LORF ACCORDING TO THE FORMULA:

    LORF=(RESTFQ*(1.-VELOFF/C)-FREQIF)/FREQMF

    THE PULSAR CALCULATIONS RELATE THE TIMING FREQUENCY TO THE  PULSAR
MULTIPLYING FACTOR AND DOPPLER SHIFTED PERIOD BY:

    PULFQ=PULMF/DOPPRD

**************************************************************
*       WRITTEN BY R. N. MANCHESTER AND M. A. GORDON         *
*                    JANUARY 1970                            *
*   SUBROUTINES DOP, COORD, MOVE, JULDA  BY J. A. BALL       *
**************************************************************
```

DOPSET
FCR

LINE SOURCE G43.2+0.0 (W49 OH)

COORDINATES	RIGHT ASCENSION H	M	S	DECLINATION D	M	S	EPOCH
GIVEN	19	7	51.800	9	0	53.000	1950.00
PRECESSED	19	8	51.336	9	2	36.746	1970.36

LINE	RESTFREQUENCY	LSR VELOCITY OFFSET KM/S	LSR FREQUENCY OFFSET	MULTIPLIER	IF
1	1665401.0000	18.000	-99.9931	6.00	150000.00
2	1667358.0000	18.000	-100.1106	6.00	150000.00
3	1667358.0000	10.000	-55.6170	6.00	150000.00

UT STARTDAY = 127.21

ENDDAY = 137.21

MINUTE INTERVAL = 10

HOUR ANGLE RANGE = 6.48 HOURS

TELESCOPE LONGITUDE = 79 50 9.470

LATITUDE = 38 26 15.540

ELEVATION = 816.80 METERS

LINE SOURCE G43.2+0.0 (W49 OH)

RA 19 8 51.191 DEC 9 2 36.025 EPOCH 1970.35

	REST FREQUENCY	LSR VELOCITY OFFSET KM/S	HELIOCENTRIC VELOCITY OFFSET KM/S
LINE 1	1665401.CCCCC	18.000	C.C29
LINE 2	1667358.CCCCC	18.000	0.C29
LINE 3	1667358.CCCCC	10.CCC	-7.971

EASTERN STANDARD DAY WEDNESDAY 6 MAY 1970 UT DAY NUMBER 127

LST H M S	EST H M S	UT H M S	HA H M S	LO FREQUENCY 1	LO FREQUENCY 2	LO FREQUENCY 3	LO FREQUENCY 4	AZIMUTH DEG	ELEVATION DEG	VELOCITY KM/S
12 38 49	22 0 0	3 0 0	E 6 30 1	252588.2434	252914.4353	252921.85C9	**********	78.27	-0.19	-41.1245
12 48 51	22 10 0	3 10 0	E 6 19 59	252588.2438	252914.4356	252921.8512	**********	79.82	1.74	-41.1249
12 58 53	22 20 0	3 20 0	E 6 9 57	252588.2435	252914.4353	252921.8509	**********	81.37	3.67	-41.1246
13 8 54	22 30 0	3 30 0	E 5 59 56	252588.2426	252914.4344	252921.8500	**********	82.90	5.62	-41.1236
13 18 56	22 40 0	3 40 0	E 5 49 54	252588.241C	252914.4329	252921.8485	**********	84.44	7.57	-41.1219
13 28 58	22 50 0	3 50 0	E 5 39 53	252588.2389	252914.4307	252921.8463	**********	85.97	9.53	-41.1196
13 38 59	23 0 0	4 0 0	E 5 29 51	252588.2360	252914.4279	252921.8435	**********	87.51	11.49	-41.1165
13 49 1	23 10 0	4 10 0	E 5 19 49	252588.2326	252914.4244	252921.8400	**********	89.05	13.45	-41.1128
13 59 3	23 20 0	4 20 0	E 5 9 48	252588.2285	252914.4203	252921.8359	**********	90.61	15.41	-41.1084
14 9 4	23 30 0	4 30 0	E 4 59 46	252588.2238	252914.4156	252921.8312	**********	92.18	17.38	-41.1033
14 19 6	23 40 0	4 40 0	E 4 49 44	252588.2185	252914.4103	252921.8259	**********	93.78	19.34	-41.0976
14 29 8	23 50 0	4 50 0	E 4 39 43	252588.2126	252914.4044	252921.8200	**********	95.39	21.30	-41.0912

EASTERN STANDARD DAY THURSDAY 7 MAY 1970 UT DAY NUMBER 127

14 39 9	0 0 0	5 0 0	E 4 29 41	252588.2061	252914.3979	252921.8135	**********	97.04	23.25	-41.0842
14 49 11	0 10 0	5 10 0	E 4 19 39	252588.1990	252914.3908	252921.8064	**********	98.72	25.19	-41.0765
14 59 12	0 20 0	5 20 0	E 4 9 38	252588.1913	252914.3831	252921.7987	**********	100.44	27.13	-41.0682
15 9 14	0 30 0	5 30 0	E 3 59 36	252588.1831	252914.3748	252921.7904	**********	102.20	29.05	-41.0593
15 19 16	0 40 0	5 40 0	E 3 49 34	252588.1743	252914.3660	252921.7816	**********	104.02	30.97	-41.0499
15 29 17	0 50 0	5 50 0	E 3 39 33	252588.165C	252914.3567	252921.7723	**********	105.89	32.86	-41.0398
15 39 19	1 0 0	6 0 0	E 3 29 31	252588.1551	252914.3469	252921.7625	**********	107.83	34.74	-41.0292
15 49 21	1 10 0	6 10 0	E 3 19 30	252588.1448	252914.3365	252921.7521	**********	109.85	36.60	-41.0180
15 59 22	1 20 0	6 20 0	E 3 9 28	252588.1340	252914.3257	252921.7413	**********	111.94	38.44	-41.0063
16 9 24	1 30 0	6 30 0	E 2 59 26	252588.1227	252914.3144	252921.7300	**********	114.13	40.24	-40.9941
16 19 26	1 40 0	6 40 0	E 2 49 25	252588.11C9	252914.3026	252921.7182	**********	116.42	42.02	-40.9814
16 29 27	1 50 0	6 50 0	E 2 39 23	252588.C988	252914.2904	252921.7060	**********	118.82	43.76	-40.9683
16 39 29	2 0 0	7 0 0	E 2 29 21	252588.C862	252914.2778	252921.6934	**********	121.35	45.46	-40.9547
16 49 31	2 10 0	7 10 0	E 2 19 20	252588.C732	252914.2648	252921.6804	**********	124.02	47.11	-40.9407
16 59 32	2 20 0	7 20 0	E 2 9 18	252588.0599	252914.2515	252921.6671	**********	126.84	48.71	-40.9263
17 9 34	2 30 0	7 30 0	E 1 59 16	252588.0462	252914.2378	252921.6534	**********	129.82	50.25	-40.9115
17 19 35	2 40 0	7 40 0	E 1 49 15	252588.C322	252914.2238	252921.6394	**********	132.99	51.72	-40.8964
17 29 37	2 50 0	7 50 0	E 1 39 13	252588.C180	252914.2095	252921.6251	**********	136.34	53.12	-40.8810
17 39 39	3 0 0	8 0 0	E 1 29 11	252588.C034	252914.1950	252921.6106	**********	139.89	54.43	-40.8653
17 49 40	3 10 0	8 10 0	E 1 19 10	252587.9886	252914.1802	252921.5958	**********	143.66	55.65	-40.8493

17 59 42	3 20 0	8 20 0	E 1 9 8	252587.9736	252914.1651	252921.5807	**************	147.64	56.75	-40.8331
18 9 44	3 30 0	8 30 0	E 0 59 7	252587.9584	252914.1499	252921.5655	**************	151.83	57.74	-40.8167
18 19 45	3 40 0	8 40 0	E 0 49 5	252587.9431	252914.1346	252921.5502	**************	156.24	58.60	-40.8001
18 29 47	3 50 0	8 50 0	E 0 39 3	252587.9276	252914.1191	252921.5347	**************	160.83	59.32	-40.7834
18 39 49	4 0 0	9 0 0	E 0 29 2	252587.9120	252914.1034	252921.5190	**************	165.60	59.89	-40.7666
18 49 50	4 10 0	9 10 0	E 0 19 0	252587.8963	252914.0878	252921.5033	**************	170.50	60.30	-40.7496
18 59 52	4 20 0	9 20 0	E 0 8 58	252587.8806	252914.0720	252921.4876	**************	175.49	60.54	-40.7326
19 9 54	4 30 0	9 30 0	W 0 1 2	252587.8649	252914.0562	252921.4718	**************	180.53	60.60	-40.7156
19 19 55	4 40 0	9 40 0	W 0 11 4	252587.8491	252914.0405	252921.4561	**************	185.56	60.50	-40.6986
19 29 57	4 50 0	9 50 0	W 0 21 6	252587.8334	252914.0247	252921.4403	**************	190.54	60.23	-40.6816
19 39 58	5 0 0	10 0 0	W 0 31 7	252587.8177	252914.0090	252921.4246	**************	195.41	59.78	-40.6647
19 50 0	5 10 0	10 10 0	W 0 41 9	252587.8021	252913.9935	252921.4091	**************	200.14	59.18	-40.6479
20 0 2	5 20 0	10 20 0	W 0 51 11	252587.7867	252913.9780	252921.3936	**************	204.70	58.44	-40.6312
20 10 3	5 30 0	10 30 0	W 1 1 12	252587.7714	252913.9626	252921.3782	**************	209.06	57.55	-40.6146
20 20 5	5 40 0	10 40 0	W 1 11 14	252587.7562	252913.9475	252921.3631	**************	213.21	56.53	-40.5983
20 30 7	5 50 0	10 50 0	W 1 21 15	252587.7412	252913.9325	252921.3481	**************	217.15	55.40	-40.5821
20 40 8	6 0 0	11 0 0	W 1 31 17	252587.7265	252913.9177	252921.3333	**************	220.87	54.16	-40.5662
20 50 10	6 10 0	11 10 0	W 1 41 19	252587.7120	252913.9032	252921.3188	**************	224.38	52.83	-40.5505
21 0 12	6 20 0	11 20 0	W 1 51 20	252587.6978	252913.8890	252921.3046	**************	227.69	51.42	-40.5352
21 10 13	6 30 0	11 30 0	W 2 1 22	252587.6839	252913.8750	252921.2906	**************	230.81	49.93	-40.5201
21 20 15	6 40 0	11 40 0	W 2 11 24	252587.6703	252913.8614	252921.2770	**************	233.76	48.38	-40.5054
21 30 17	6 50 0	11 50 0	W 2 21 25	252587.6570	252913.8481	252921.2637	**************	236.55	46.77	-40.4911
21 40 18	7 0 0	12 0 0	W 2 31 27	252587.6441	252913.8352	252921.2508	**************	239.19	45.11	-40.4772
21 50 20	7 10 0	12 10 0	W 2 41 29	252587.6316	252913.8227	252921.2383	**************	241.69	43.40	-40.4637
22 0 21	7 20 0	12 20 0	W 2 51 30	252587.6195	252913.8106	252921.2262	**************	244.07	41.65	-40.4506
22 10 23	7 30 0	12 30 0	W 3 1 32	252587.6078	252913.7989	252921.2145	**************	246.34	39.87	-40.4380
22 20 25	7 40 0	12 40 0	W 3 11 34	252587.5966	252913.7877	252921.2033	**************	248.50	38.05	-40.4259
22 30 26	7 50 0	12 50 0	W 3 21 35	252587.5859	252913.7769	252921.1925	**************	250.58	36.21	-40.4143
22 40 28	8 0 0	13 0 0	W 3 31 37	252587.5756	252913.7667	252921.1823	**************	252.58	34.35	-40.4032
22 50 30	8 10 0	13 10 0	W 3 41 38	252587.5659	252913.7569	252921.1725	**************	254.51	32.47	-40.3927
23 0 31	8 20 0	13 20 0	W 3 51 40	252587.5567	252913.7477	252921.1633	**************	256.37	30.57	-40.3827
23 10 33	8 30 0	13 30 0	W 4 1 42	252587.5480	252913.7390	252921.1546	**************	258.17	28.65	-40.3734
23 20 35	8 40 0	13 40 0	W 4 11 43	252587.5398	252913.7308	252921.1464	**************	259.93	26.72	-40.3646
23 30 36	8 50 0	13 50 0	W 4 21 45	252587.5323	252913.7233	252921.1389	**************	261.64	24.79	-40.3564
23 40 38	9 0 0	14 0 0	W 4 31 47	252587.5253	252913.7163	252921.1319	**************	263.31	22.84	-40.3489
23 50 40	9 10 0	14 10 0	W 4 41 48	252587.5189	252913.7098	252921.1254	**************	264.95	20.89	-40.3419
0 0 41	9 20 0	14 20 0	W 4 51 50	252587.5131	252913.7040	252921.1196	**************	266.56	18.93	-40.3357
0 10 43	9 30 0	14 30 0	W 5 1 52	252587.5079	252913.6988	252921.1144	**************	268.15	16.97	-40.3301
0 20 44	9 40 0	14 40 0	W 5 11 53	252587.5033	252913.6942	252921.1098	**************	269.72	15.00	-40.3251
0 30 46	9 50 0	14 50 0	W 5 21 55	252587.4993	252913.6903	252921.1059	**************	271.27	13.04	-40.3208
0 40 48	10 0 0	15 0 0	W 5 31 57	252587.4960	252913.6869	252921.1025	**************	272.81	11.08	-40.3172
0 50 49	10 10 0	15 10 0	W 5 41 58	252587.4933	252913.6842	252921.0998	**************	274.35	9.12	-40.3143
1 0 51	10 20 0	15 20 0	W 5 52 0	252587.4912	252913.6821	252921.0977	**************	275.88	7.16	-40.3121
1 10 53	10 30 0	15 30 0	W 6 2 1	252587.4898	252913.6807	252921.0963	**************	277.42	5.21	-40.3105
1 20 54	10 40 0	15 40 0	W 6 12 3	252587.4890	252913.6799	252921.0955	**************	278.96	3.27	-40.3096
1 30 56	10 50 0	15 50 0	W 6 22 5	252587.4888	252913.6797	252921.0953	**************	280.50	1.33	-40.3094

CCPSET
FCR

PULSAR 0329+54

CCCRDINATES	RIGHT ASCENSICN H	M	S	DECLINATICN D	M	S	EPCCH
GIVEN	3	29	11.C80	54	24	38.3CC	1950.0C
PRECESSEC	3	30	41.564	54	28	53.416	1970.36

FERICC S	FIRST CERIVATIVE (S/S).E+15	CRIGIN(JULIAN CAYS)	PULSE RATE FACTOR
C.7145185576CCC	2.C61CC0	2440105.2292CC	8186C0.CC

LINE	RESTFREQLENCY	LSR VELCCITY CFFSET KM/S	LSR FREQUENCY CFFSET	MULTIPLIER	IF
1	166540.CCCC	2C.CCC	-111.1C34	6.CC	150CCC.00

UT STARTDAY = 127.21

ENDDAY = 137.21

MINUTE INTERVAL = 2C

HOUR ANGLE RANGE = 2.00 HOURS

TELESCOPE LONGITUDE = 79 5C 54.53C

LATITUDE = 38 25 45.48C

ELEVATION = 798.50 METERS

PULSAR 0329+54

RA 3 32 41.530 DEC 54 28 54.125 EPOCH 1970.35

	REST FREQUENCY	LSR VELOCITY OFFSET KM/S	HELIOCENTRIC VELOCITY OFFSET KM/S
LINE 1	1665C1.CCCCC	20.000	19.791

TRANSIT PERIOD IS 0.714516659207 SECONDS AT JULIAN DAY NUMBER 2440714.242691

EASTERN STANDARD DAY THURSDAY 7 MAY 1970 LT DAY NUMBER 127

LST H M S	EST H M S	LT H M S	HA H M S	LO FREQUENCY 1	LO FREQUENCY 2	TIMING FREQUENCY	PERIOD SEC	AZIMUTH DEG	ELEVATION DEG	VELOCITY KM/S
1 20 51	10 40 C	15 4C C	E 2 9 49	252541.2990	**********	1145636.6107	0.71453722C9C	43.12	62.86	7.5790
1 40 55	11 0 C	16 0 C	E 1 49 46	252541.2893	**********	1145636.5708	0.71453724583	40.17	65.48	7.5894
2 0 58	11 20 C	16 2C C	E 1 29 43	252541.279C	**********	1145636.528C	0.71453727253	36.11	67.91	7.6006
2 21 1	11 4C C	16 4C C	E 1 9 39	252541.2680	**********	1145636.4828	0.71453730C69	30.68	70.08	7.6124
2 41 4	12 0 C	17 0 C	E C 49 36	252541.2566	**********	1145636.4358	0.71453733CC1	23.65	71.88	7.6247
3 1 8	12 20 C	17 2C C	E C 29 33	252541.2449	**********	1145636.3875	0.71453736C14	14.96	73.18	7.6374
3 21 11	12 4C C	17 4C C	E C 9 29	252541.2330	**********	1145636.3384	C.71453739C78	4.97	73.87	7.6502
3 41 14	13 0 0	18 0 C	W C 10 33	252541.2211	**********	1145636.289C	0.71453742157	354.48	73.85	7.6632
4 1 18	13 20 C	18 2C C	W C 30 36	252541.2092	**********	1145636.2395	C.71453745218	344.54	73.13	7.6760
4 21 21	13 40 C	18 4C C	W C 50 39	252541.1975	**********	1145636.1917	0.71453748228	335.94	71.79	7.6886
4 41 24	14 0 C	19 0 C	W 1 10 42	252541.1861	**********	1145636.1448	C.71453751154	328.99	69.97	7.7009
5 1 27	14 20 0	19 20 C	W 1 30 46	252541.1752	**********	1145636.0997	0.71453753963	323.64	67.79	7.7127
5 21 31	14 4C C	19 4C C	W 1 50 49	252541.1649	**********	1145636.0571	0.71453756623	319.65	65.34	7.7238

PULSAR 0329+54

RA 3 30 41.537 DEC 54 28 53.947 EPOCH 1970.35

	REST FREQUENCY	LSR VELOCITY OFFSET KM/S	HELIOCENTRIC VELOCITY OFFSET KM/S
LINE 1	1665401.00000	20.000	19.791

TRANSIT PERIOD IS 0.714518659385 SECONDS AT JULIAN DAY NUMBER 2440715.239960

EASTERN STANDARD DAY FRIDAY 8 MAY 1970 LT DAY NUMBER 128

LST H M S	EST H M S	LT H M S	HA H M S	LO FREQUENCY 1	LO FREQUENCY 2	TIMING FREQUENCY	PERIOD SEC	AZIMUTH DEG	ELEVATION DEG	VELOCITY KM/S
1 24 48	10 40 C	15 40 C	E 2 5 53	252541.6651	**********	1145638.1215	0.71453627861	42.62	63.39	7.1835
1 44 51	11 0 C	16 0 C	E 1 45 49	252541.6553	**********	1145638.0811	0.71453630385	39.47	65.97	7.1941
2 4 54	11 20 C	16 20 C	E 1 25 46	252541.6449	**********	1145638.0379	0.71453633080	35.16	68.36	7.2054
2 24 58	11 40 C	16 40 C	E 1 5 43	252541.6338	**********	1145637.9924	0.71453635916	29.43	70.46	7.2173
2 45 1	12 0 C	17 0 C	E 0 45 40	252541.6224	**********	1145637.9452	0.71453638860	22.07	72.18	7.2297
3 5 4	12 20 C	17 20 C	E 0 25 36	252541.6107	**********	1145637.8968	0.71453641881	13.08	73.37	7.2424
3 25 8	12 40 C	17 40 C	E 0 5 33	252541.5988	**********	1145637.8476	0.71453644944	2.92	73.92	7.2552
3 45 11	13 0 C	18 0 C	W 0 14 29	252541.5868	**********	1145637.7984	0.71453648017	352.45	73.76	7.2681
4 5 14	13 20 C	18 20 C	W 0 34 33	252541.5750	**********	1145637.7495	0.71453651065	342.73	72.91	7.2809
4 25 17	13 40 C	18 40 C	W 0 54 36	252541.5634	**********	1145637.7016	0.71453654055	334.44	71.47	7.2934
4 45 21	14 0 C	19 0 C	W 1 14 39	252541.5521	**********	1145637.6551	0.71453656955	327.82	69.57	7.3056
5 5 24	14 20 C	19 20 C	W 1 34 42	252541.5413	**********	1145637.6106	0.71453659731	322.76	67.32	7.3172
5 25 27	14 40 C	19 40 C	W 1 54 46	252541.5312	**********	1145637.5685	0.71453662353	319.00	64.84	7.3282

INDEX

	Page
Accuracy	7
Angle, hour	6,7
Availability	8
Ball	1,7
Barycentre, solar system	1,5,8
Cards, data (see data cards)	2
Coordinates, astronomical	2,3
site	2,3
Data cards, Source	2,3
Site	2,3
Spectral	2,3
Pulsar	2,4
Day	2,5
Year	2,6
End	2,6
Data sets	1
Declination, source	3
Doppler correction	4
Elevation, site	3
Ephemeris	8
Epoch	3
Factor, timing	4,5
Format, input	2
Frequency, LORF	4
IF	4
Local oscillator	1
Rest	4
Timing	5
Geodetic coordinates	3
Hour angle	6,7

Page

Intermediate frequency..... 4
Input..... 1
Input, sample..... 9
Julian day..... 4
Latitude, site..... 3
Local oscillator frequency..... 2
Local Standard of Rest..... 1,4
Longitude..... 3
LORF..... 4
Minute interval..... 5
Multiplier, LO 4
Output, printer..... 7
sample..... 10
Pulsar period..... 4
Range, hour angle..... 5
Shapiro..... 8
Sample, Input..... 9
Sample, Output..... 10-16
Time, local..... 6
Eastern Standard..... 6,7
Sidereal..... 7
Universal..... 7
Timing factor..... 4,5
Transit..... 7

NATIONAL RADIO ASTRONOMY OBSERVATORY

Charlottesville, Virginia

October 26, 1972

MEMORANDUM

TO: Users of DOPSET

FROM: M. A. Gordon

SUBJECT: Correction of Errors

Don Backer (NRAO) has found two errors in DOPSET which should be corrected. Both errors have been corrected in the NRAO library program.

DOPSET has been relocated in the NRAO program library. (Simply remove the //JOBLIB card from the JCL cards of your old deck.)

Error 1:

In subroutine DOP, the radius from the earth's center to the observer has been calculated using geocentric latitude rather than the correct geodetic latitude.[1] To correct this error, move the block of cards DPST 1628, 1630, 1632, 1634, and 1636 to the position immediately following card DPST 1650. Be certain to renumber these cards sequentially after repositioning.

Error 2:

In REAL FUNCTION EUT, card DPST 1364 contains an incorrect formula to compute mean sidereal time. The correct formula should read

```
DST=0.2783295623D0+(8640184.665D0*DT+0.0929D0*DT**2)/864.D2
```

The magnitude of this error has been approximately -25 ms.

[1] See American Ephemeris and Nautical Almanac (1972) p. 517, 518.