MODIFICATIONS TO INTERFEROMETER FRINGE REDUCTION PROGRAM

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1. The source table has been expanded to accommodate up to 100 entries.

2. When the program cannot identify a source from the beginning SID, it skips directly to the end SID, and if it can identify this it backspaces, rather than recording the intervening data on scratch tape. This is done to make the program run faster in reducing only a few records from the tape.

3. After encountering 6 short records on tape the program skips a record. This is done to break a loop which sometimes occurs, when the tape unit finds a record it cannot pass. Previously, this skipping was done by the operator from the computer console.

4. Various changes have been made in read and write statements to make the version 9 IOCS, now on the computer, produce the same output that the previous version 7 did. The only change that affects the user is that source numbers are truncated on both left and right to yield a number of three digits and one decimal.

An up-to-date listing is available from me, if anybody needs one.

The Interferometer Fringe Reduction Program -- Version II

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I. PRINCIPLES OF OPERATION

The mathmatical principles upon which the reduction lies are developed in References 1 and 2 and will not be discussed further here. The particular variant used is the least squares fitting of a sine wave plus a constant, developed in the latter half of Reference 2.

1. Explanation of the Print-Out

a) The heading information for the baseline. This lists the baseline constants h, B_1, B_2, B_3 used for the reduction and the baseline number as well as tape number and date. It also lists the Bessel day numbers used for precessing the source table and the source table data card.

b) The heading for each source. This lists the apparent position of the source, precessed to the hour of observation, the Julian day number of the day upon which the source crosses the meridian, the local oscillator frequency, which is extended in the standard identification data (SID) block by means of manually set switches, and the scan number. The differences between the antenna pointing and the true source position are calculated and printed out under the title "pointing corrections." The coordinate encoders for antenna 1 are not connected, as of this writing, so the pointing corrections for antenna 1 are not correct.

c) The data print-out. There are 13 columns of data printed out for each minute's observation, as follows:

(i) Source number is automatically prefaced with a 3C as most, but not all, of our sources appear in the 3C catalogue. They appear to 1 decimal place.

(ii) N is a running integer number for convenience in plotting. It is the number of minutes after the source appeared at 6^h east hour angle.

(iii) Hour angle = apparent sidereal time - apparent right ascension

(iv) Apparent sidereal time

(v) The amplitude of the least squares sine wave fitted to the data, in units of the number of pulses per tenth second received from the voltage to frequency converter.

(vi) The phase of this least squares sine wave, in degrees, taken to lie between -180 and 180°. The phase is so defined that of two sources, the one with the most positive phase is nearer the northeast pole of the interferometer.

(vii) The fringe frequency in cycles/second

(viii and ix) The parameters describing the location in the spacial frequency plane. The units are wavelengths, u is the effective baseline length in the right ascension direction and v is the effective baseline length in the declination direction.

(x) The RMS deviation of the 600 points from the fitted sine wave, in counts per tenth second.

(xi) The constant component determined in the fitting of a sine wave plus constant.

(xii and xiii) The ALC feed-back voltages averaged over the minute. Mainly of engineering interest.

d) Error messages

(i) "B1 = ..., B2 = ..., is not consistent with IB = ..." An error was made in punching the baseline constants or baseline number in the card input. Exit is called.

(ii) "Date later than 30 June 1967" probably means that the date was punched in the wrong columns in the input card. Exit is called.

(iii) "Tape and card dates disagree." This is followed by the Julian day of the card and tape dates. The program will ignore a one day difference. Three such messages result in a call to Exit, unless Sense Switch 2 is depressed.

(iv) "Source not in table." The machine was unable to match the recorded antenna positions with the source table positions. It then proceeds forward until it encounters the ending SID block, and tries again. If it can identify the source from this block, it proceeds to reduce the data; if not, it is lost.

(v) "Tilt, antenna 1 moved ... and antenna 2 moved ... minutes of arc" occurs if the ending SID positions disagree with the beginning SID positions by more than 1!5.

(vi) "Reduction repeated." The ending SID time differed from that predicted by the beginning SID. The beginning time was changed to fit the second SID and the reduction was repeated, resulting in two sets of cards for this block of data.

(vii) "Ending SID missing." A beginning SID record was encountered directly after a data record, with no ending SID between.

(viii) "Beginning SID does not appear where expected." The record after a second SID was not a beginning SID. The machine scans ahead to the next SID. If it is an ending SID, its identification data are used to reduce the intervening data. If it is a beginning SID, the data are lost.

(ix) "Second SID disagrees with first. Cannot re-reduce." The record number in the ending SID is unbelievably large, so the data are not re-reduced, although the time in the ending SID is not that predicted by the beginning SID.

(x) "I-O check. Return to execution." An I-O check is probably a machine error, though it is possible that the tape may contribute to the condition.

(xi) "...Word record encountered and ignored." Standard data records are 601 words long. Shorter records are discarded with this message. If the record is more than 12 words long, the machine checks to see if it is an SID record before discarding it.

(xii) "Record of length exceeding 601 words. Excess words ignored."

e) The card output. The card deck punched by the program is headed by four cards, the first of which contains the tape number and baseline parameters, the second contains the clock error, and the third contains the last six digits of the Julian day. The fourth card carries two precession constants and four Bessel day numbers (M,N,A,B,C,D) in radians. Then comes the source table, which consists of cards containing source number,

and the apparent RA and declination in radians. The source table is terminated with a blank card and is followed with data cards punched with the source number, H.A., Amplitude, u, v, RMS, offset, and N, as explained under the description of the print-out. The last digit of the Julian day of meridian passage is also punched.

2. Small Corrections to the Phase

The amplitudes are corrected for the influence of integration, by division by $\frac{\sin (\Delta/2)}{\Delta/2}$, where Δ is the phase change during the 0.1 second integration interval, and several small corrections are made to the phase, immediately before output. All phase effects greather than 0".2 have been included.

a) The change of the Bessel day numbers with time. The aberrational Bessel day numbers sometimes change 0".35/day. Therefore, the Bessel day numbers are to be read in for 0^h UT and extrapolated by the following formulae:

$$\frac{dA}{dt} \approx .0000002674 \text{ radians/day}$$

(This is general precession only.)

$$\frac{dB}{dt} \approx 0$$

$$\frac{dC}{dt} \approx .000001566 \sin \phi \text{ radians/day},$$

where ϕ is the angle the earth has traveled in its orbit since the vernal equinox and

$$\frac{dD}{dt} \approx -.0000017075 \cos \phi \text{ radians/day}.$$

(These assume that the earth's orbit is circular.)

These corrections are applied after every beginning SID instead of every minute as the others are.

b) Refraction is covered in Reference 3. The coefficient was assumed to be 1.00028 (i.e., dew point $\approx 0°C$).

c) The spherical term of refraction is also covered in Reference 3, and the correction is applied to the data.

d) A term in the phase arises from the approximation of the interferometer function by a sine wave. It is derived as follows: The true interferometer function, f(t) is (Reference 4)

$$f(t) = A \cos 2\pi(B_1 \cos \delta + B_2 \cos \delta \cos \tau + B_3)$$

or approximately, in the vicinity of time t_o

$$f(t) \approx A \cos 2\pi(C + R(t-t_o) + R^1(t-t_o)^2)$$

where

$$R = -B_2 \cos \delta \sin \tau$$

and

$$R^1 = -B_2 \cos \delta \cos \tau$$

$$f(t) \approx A[\cos 2\pi(C + R(t-t_o)) - 2\pi R^1(t-t_o)^2 \sin 2\pi(C + R(t-t_o))]$$

when fitted with the sine wave

$$A_C \cos 2\pi R(t-t_o) + A_S \sin 2\pi R(t-t_o)$$

(neglecting end effects), the result is

$$A_C = A\left[\frac{1}{2} \cos 2\pi C - 2\pi \frac{T^2}{24} R^1 \sin 2\pi C\right]$$

$$A_S = A\left[\frac{1}{2}\sin 2\pi C - 2\pi\frac{T^2}{24}R^1\cos 2\pi C\right]$$

where T is the interval of observation which results in a phase $2\pi\left(C + \frac{R^1T^2}{12}\right)$, i.e., $\frac{2\pi R^1T^2}{12}$ greater than the true phase. For T = 1 min, 0°.00042837 $B_2 \cos\delta\cos\tau$ must be added to the observed phase.

e) Diurnal aberration. This is discussed in Reference 5. The displacements in α and δ derived there are

$$\Delta\alpha = {}^{s}.0213\ \rho\cos\phi^1\cos H\sec\delta$$

$$\Delta\delta = ''.320\ \rho\cos\phi^1\sin H\sin\delta$$

where $\rho\cos\phi^1$ is the distance to the axis of the earth compared to the equatorial radius. If these quantities are inserted in the equations of Reference 4, the phase changes by

$$\Delta\phi = 2\pi(B_1\cos\delta\sin H\sin\delta + B_2\cos\delta\sin\tau\cos H\sec\delta - B_2\cos\tau\sin^2\delta\sin H)\ \text{const.}$$

$$\Delta\phi = 2\pi(B_1\sin H\sin\delta\cos\delta + B_2\sin h + B_2\cos^2\delta\cos\tau\sin H).\ \text{const}$$

The second term is constant for all H and δ and so may be lumped with B_3. The remainder is

$$\Delta\phi = 2\pi\sin H\cos\delta\,(B_1\sin\delta + B_2\cos\delta\cos\tau).\ \text{const}$$

$$2\pi\cdot\text{const} = 0°.0003289$$

This quantity is added to the observed phase.

II. OPERATING INSTRUCTIONS

1. Card Formats

a) Input cards

i) Baseline parameter card

A) In columns 1-10 the hour angle of the southwest pole of the interferometer, in hours, minutes, seconds and fractions, written with a decimal point after the seconds and no internal spaces.

B) B_1 in columns 11-19 with a decimal point. In wavelengths.

C) B_2 in columns 20-28 in wavelengths, with a decimal point.

D) B_3 in columns 29-37 in fractions of a revolution with a decimal point.

E) The baseline number in column 41

ii) Day card

A) Columns 3-8 YYMMDD where YY is the year, MM is the month, and DD the day. No internal spaces permitted.

B) Columns 11-13 tape number. While tape numbers are less than 100 they appear in columns 12-13.

C) Columns 14-23, 24-33, 34-43 and 44-53 contain the 4 Bessel day numbers for Oh V.T. on the date specified in columns 3-8. In seconds of arc, with sign and decimal point.

D) Column 54-59 clock error with sign (- = slow + = fast) and decimal point.

iii) Source table date in columns 2-7 allows source table to be identified without precessing the positions back to 1950.

This card should be updated every time the source table is modified.

iv) Source table. For each source prepare a card containing:

A) Columns 1-7; the source number with decimal point.

B) Columns 8-21; right ascension in hours, minutes, seconds and fractions, with a decimal point after the seconds, and no internal spaces.

C) Columns 22-35; declination in degrees, minutes, and seconds, with a decimal point after the seconds and a sign in front of degrees. No internal spaces.

The source table is terminated with a blank card. It may contain at most 50 cards. If it has exactly 50 sources, the blank card should be omitted.

b) Output cards

i) Parameter card

A) Tape number I4, columns 13-16

B) h. I3, I2, F5.2 hours, minutes and seconds in columns 19-21, 24-25, and 28-32

C) B_1 in columns 42-49 F8.2

D) B_2 in columns 58-65 F8.2

E) B_3 in columns 74-79 F6.2

Other columns than those listed may have alphabetic characters.

ii) Clock error card. Clock error in columns 1-6, F6.2

iii) Date card. The last 6 digits of the Julian day in columns 1-6.

iv) Precession constant card. Constants M and N in radians in columns 1-12 and 13-24 respectively. F12.10. The Bessel

day numbers, also in radians, appear in columns 25-36, 37-48, 49-60, and 60-72, respectively, in E format E12.5.

iv) The punched source table. The source number is punched in columns 3-7, with 1 decimal place, F5.1, the apparent R.A. of date in radians in columns 13-24, the apparent declination in radians in columns 25-36, both with format F12.8. The source table is terminated with a blank card.

v) The data cards.

A) Source number in columns 1-5 F5.1

B) H.A. sign in column 8, hours in column 9, minutes in 11-12, seconds in 14-17. Decimal point in 16

C) Amplitude in columns 18-27. Decimal point in column 25

D) Phase in columns 28-37. Phase in degrees, decimal point in column 34

E) u and v in columns 38-45 and 46 to 53. Decimal points in columns 45 and 53

F) RMS deviation in columns 54-61. Decimal point in columns 58

G) DC offset in columns 62-72. Decimal point in column 70

H) Last digit of Julian day of meridian transit is punched in column 74.

I) The running number N is punched in columns 75-80.

2. Normal Operating Procedure

a) The baseline parameters are first estimated from the survey list of Reference 6, or they are eventually taken from the position-calibration program operating on observations of several point sources.

b) The date, tape numbers, Bessel day numbers and clock error must be punched in the format described above. The Bessel day numbers must be for 0^h U.T. on the date punched.

c) As many stacks of data cards as desired may be stacked one behind the other, separated only by the blank card terminating each source table. The computer operator should be told to put on the tapes in the order corresponding to that of the day cards.

d) The card decks should be filed, marked with the date of reduction and the first card interpreted. The bad cards should then be edited out of this deck before it is placed on tape.

References

1. C. M. Wade, "A Method for Finding the Phase and Amplitude of Interferometer Fringe Patterns," NRAO Internal Report, November 1964

2. B. G. Clark, "On the Reduction of Digital Interferometer Records," NRAO Internal Report, December 1964

3. B. G. Clark, "Refraction," NRAO Internal Report, December 1964

4. C. M. Wade and G. W. Swenson, "Geometrical Aspects of Interferometry," NRAO Internal Report, December 1964

5. Explanatory Supplement American Ephemeris and Nautical Almanac, p. 49

6. C. M. Wade, "Interferometer Constants Predicted from the Survey Data," NRAO Internal Report, January 1965