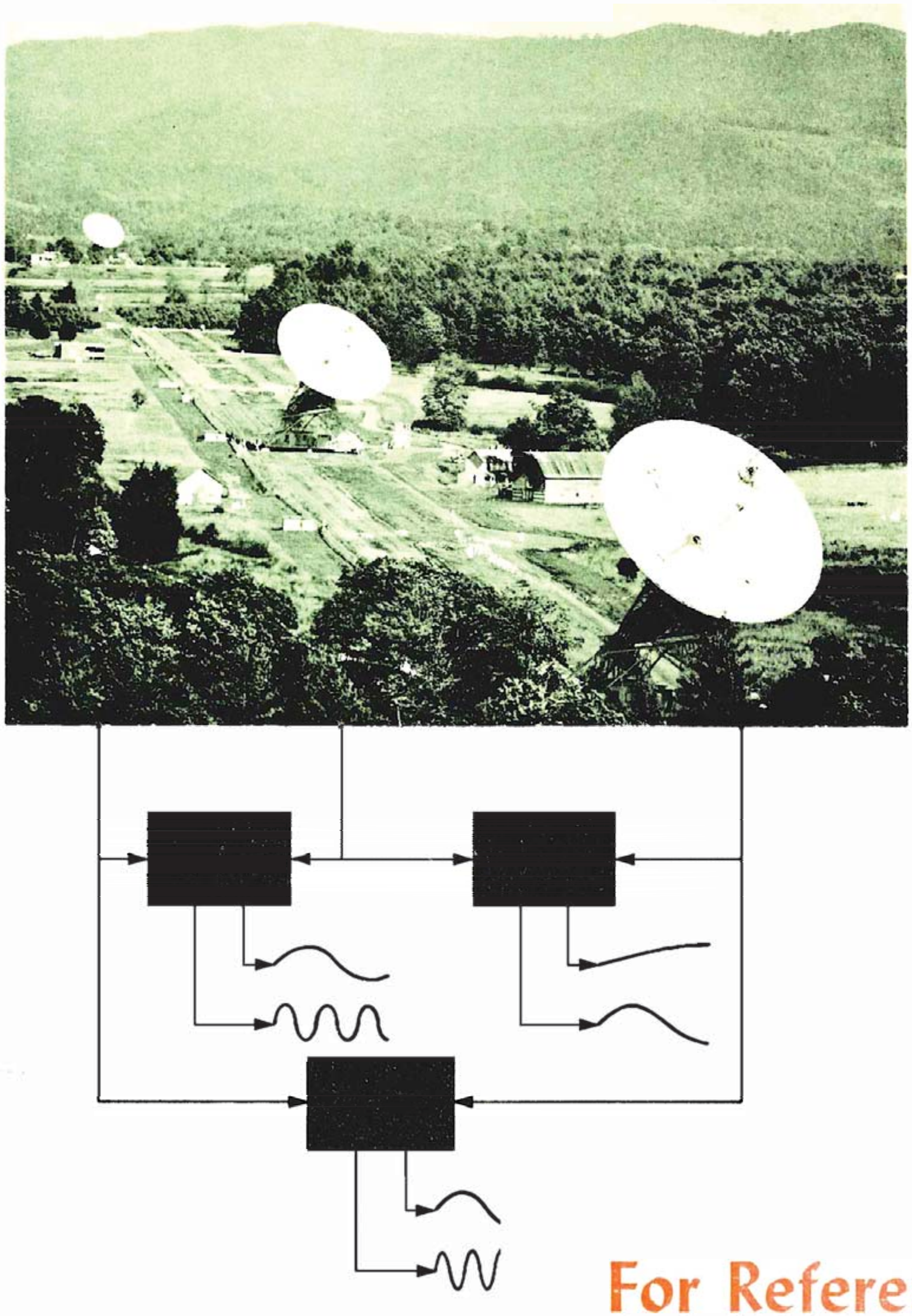
AN INTRODUCTION TO THE NRAO INTERFEROMETER



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AN INTRODUCTION TO THE NRAO INTERFEROMETER

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February 1973 Edition**

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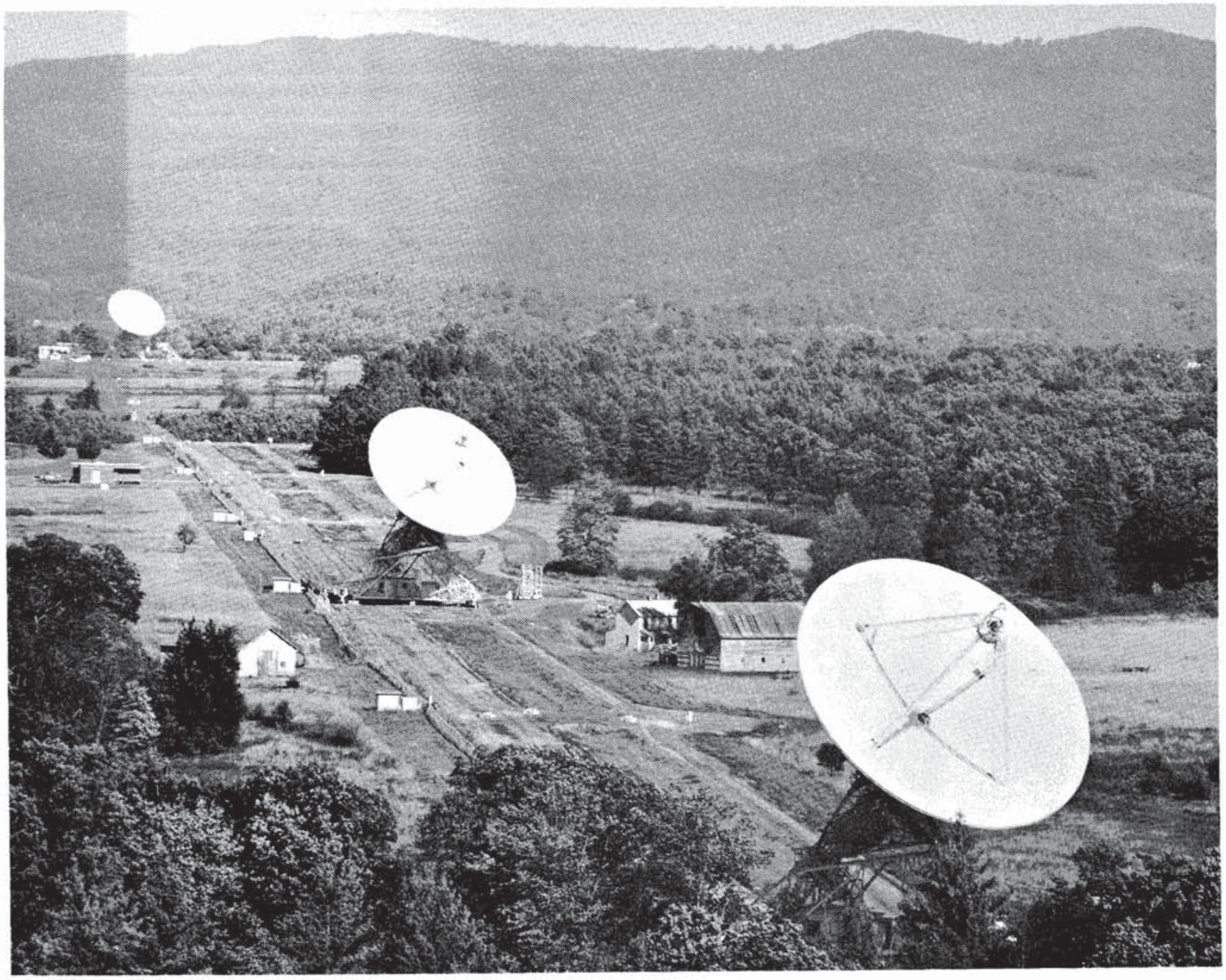
** Chapters in the Introduction will be updated at different times with a reissue title page to identify the latest updates included.



The NRAO Interferometer

SPECIAL NOTE TO READERS OF FEBRUARY 1973 EDITION

The user should be warned that the February 1973 edition of this Introduction to the NRAO Interferometer must be used with four limitations in mind.

1. Numerous errors may still infest its pages even though they have been put to considerable scrutiny.

2. The "standard" package of interferometer data reduction programs is still in a state of flux as we attempt to shift from a mode where the package consists of a miscellany written by many individuals to a set of programs written, consistently maintained, and documented by a combination of one programmer and one scientific project director.

3. Nothing in this documentation sheds light on the 4-element interferometer system (using the portable 45 foot) that is currently being put into operation and will be an integral part of the system by the summer of 1973.

4. Although the next edition will contain an extensive chapter on the programs to be used to extract scientific results from fully calibrated interferometric data, e.g., the mapping programs--this is not covered in the February 1973 edition. This is done so that the introduction to the more fundamental things can be distributed without further delay.

Another edition is planned for completion by September 1973. In this edition the errors in the present work can be removed if the readers will take the trouble to inform the author. Also, the system as described in the next edition will be a 4-element system. Furthermore, the chapter dealing with the analysis and interpretation of interferometric data will be included.

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PREFACE

The purpose of this introduction is to blend together a discussion of the basic principles of interferometry, a discussion of the particular characteristics of the NRAO interferometer, and an explicit discussion of most of the practical details that must be dealt with to do science with the NRAO interferometer. The level of this introduction is aimed at the astronomer who has never done radio interferometry and who is interested only in the technical details that must be grasped in order to do science with the instrument. For this reason we will spend less time on certain technical areas than some people would like. Further, we will deal mainly with the simplest and most straightforward methods of doing science with an interferometer. We assume that if the reader already has the expertise to want to do things differently, or if experience with the interferometer brings him to that stage of expertise, then he need not pay much attention to the procedures discussed here.

The virtually automatic operation of the interferometer in Green Bank makes life deceptively easy during the initial stages of an observing program. This paves the way for a number of possible mistakes to be made. After the observing is completed and the data reduction is under way, one can find out insufficient calibration was made or that the planning of observing time for program sources was insufficient to accomplish desired scientific objectives. Even more importantly, failure to monitor the behavior of at least the calibrators, while observing is under way, can cause failure to detect subtle malfunctions in the system. Because it is simple to pay attention to a few important things, it is almost entirely the observer's fault when, a few days or months later, he discovers that "something was wrong with the equipment" and large amounts of data are partially or completely useless. Early detection of anomalies will allow many problems to be fixed long before an observing session is ended.

It is also common for the observer to fail to plan to spend enough time reducing data in Charlottesville. The complexities of interferometry make it necessary for almost everyone to rely upon standard reduction and analysis programs. The observer must plan to spend enough time reducing his data with these programs. Despite considerable effort to make such reductions as automatic and faultless as possible, unusual problems frequently occur that take more time to solve than expected.

This introduction will deal only with the NRAO interferometer as a dual-channel, continuum instrument operating at 2695 and 8085 MHz. The interferometer also has the capability, when used with the 412-channel autocorrelator, of doing 21-cm line interferometry. This system is considerably more complicated to use than the dual-frequency continuum system. Those interested in line interferometry should read the documentation written by M. C. H. Wright and C. Moore.

Finally, the goal of this introduction and the reduction and analysis programs described therein is to cover only about 90% of the problems that might arise or the procedures and programs an observer might want to use. For those who wish to employ procedures beyond the scope of this introduction, we assume that a combination of the observer's own expertise and discussions with the appropriate NRAO staff will be needed.

Many members of the NRAO staff and a number of others familiar with the NRAO interferometer have contributed ideas, criticisms, and suggestions for this introduction. Particular thanks are due to B. Balick, R. Brown, E. Fomalont, P. Kronberg, J. Spencer, and C. Wade.

There is no upper limit to the amount of thanks due to Phyllis Jackson for typing this book.

CHAPTER I

THEORETICAL BASIS OF INTERFEROMETRY

1. Introduction

A thorough knowledge of the theory of interferometry is essential before one can do science with an interferometer. The main problem is not that an observer need understand the inner workings of the complex electronics, but rather one must master a large number of new concepts and a complicated terminology. In this chapter we discuss the theoretical basis of interferometry.

Since all interferometers are made up of different numbers of pairs of antennas, we will develop most of the theory in terms of a simple two-telescope interferometer which we can think of as one of the pairs in the NRAO interferometer.

In observing with an interferometer we are making measurements enormously more complicated than simply measuring the amount of radio power received by the antennas. The cross-correlation of signals from two antennas produces partial information not only about the intensity of all sources in the beams of the antennas but also information about their position in the sky relative to the position at which the interferometer is being pointed. Because of the position information being obtained, we will be very concerned with the geometry and coordinate systems involved in observing. Because an interferometer only obtains partial information about radiation sources in the antenna beams, for reasons we will discuss later, the observer must be very careful about interpreting his partial data. As will hopefully be clear later, one has almost completely summarized the essential characteristics of an interferometer when one says it measures the Fourier components of the apparent intensity distribution of sources in the antenna beams.

Before describing the behavior of an interferometer, a few fundamental concepts must be defined. In observing with an interferometer, we point the antennas at a particular point* in the sky with a specified right ascension and declination (α,δ). We will call this position the <u>reference position</u>. It is best thought of as the position at which we are attempting to point the antennas, since it always turns out that due to errors in instrumental parameters, the actual position of observation will differ by a small amount from the actual reference position. We define the position of an arbitrary point in the field of view of the antennas in terms of a vector displacement $(\Delta\alpha, \Delta\delta)$ from the reference position. Note that we have used the phrase "field of view" to describe the primary region of the sky to which the antennas are sensitive; this is important because we are not just collecting information about the total radiation in an antenna beam, rather we are collecting information about the properties and positions of all radiation sources in the field of view. When we discuss a <u>source position</u>, we are referring to the location of a radio source at some position in the field of view, and this will frequently differ from the reference position being observed.

Finally, the NRAO interferometer is a tracking interferometer, so all observing consists of following a particular right ascension and declination as a function of sidereal time (or hour angle). This will be assumed when we speak of observing a particular source or mapping a particular field of view.

2. Response to a Strong Point Source

(a) Definitions.

We begin with a discussion of the special case where we observe

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* As any radio astronomer will realize, we assume that pointing errors for each antenna have been determined and corrected for.

and track a region of the sky containing a strong point source which completely dominates the radiation received by the antennas.

Let us define:

$\underset{\sim}{s}_o$ = unit vector pointing from each telescope to the reference position (α,δ).

$\underset{\sim}{s}$ = unit vector pointing to the source position

$\Delta\underset{\sim}{s}$ = $\underset{\sim}{s}-\underset{\sim}{s}_o = \begin{pmatrix}\Delta\alpha \\ \Delta\delta\end{pmatrix}$ = vector displacement from reference position to source position

ν,λ,ω = frequency, wavelength, and angular frequency of wave front under consideration

ν_o,ω_o = frequency and angular frequency of local oscillator

$\underset{\sim}{B}$ = baseline vector extending from telescope 2 to telescope 1

$B = |\underset{\sim}{B}|$ = number of wavelengths that make up the baseline length

λB = physical length of baseline in same units as λ

In Figure I-1 we show a schematic representation of two elements of an interferometer. The fundamental basis of interferometry is the fact that wave fronts representing radiation which left a point source at the same time* arrive at slightly different times at telescopes 1 and 2. In particular, a wave front reaches antenna 1 (cf. Figure I-1) at a time

$$\Delta t = \lambda \frac{\underset{\sim}{B} \cdot \underset{\sim}{s}}{c}$$

later than at antenna 2. This corresponds to a phase difference of

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* Since all radio sources are sufficiently distant, we can assume that all wave fronts from the point source are parallel when reaching the antennas.

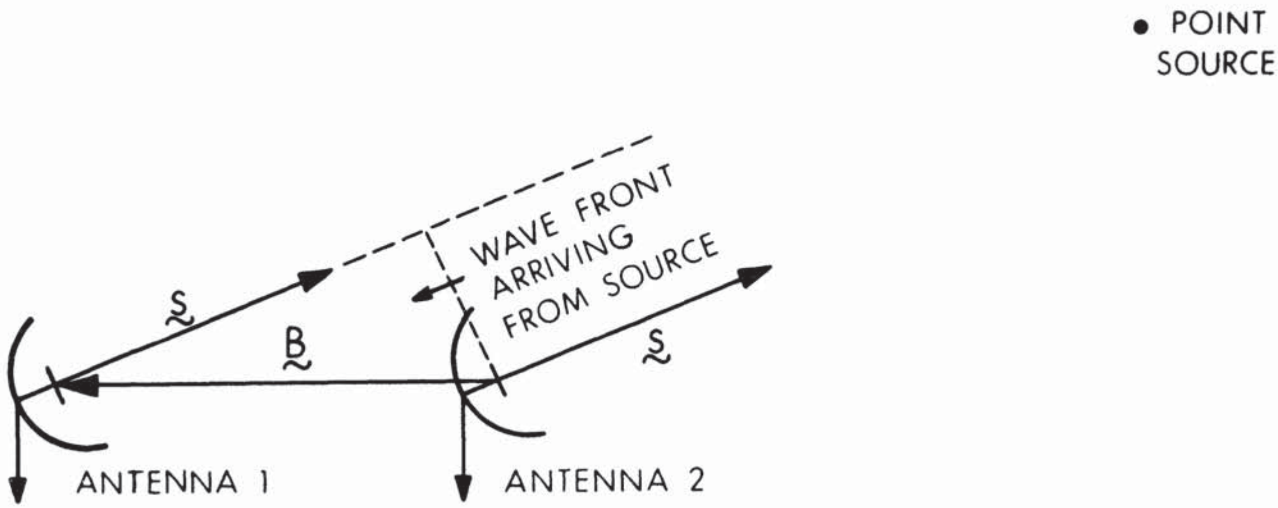


Fig. I-1. Geometry in which two antennas separated by a baseline vector $\underset{\sim}{B}$ receive a wave front arriving from a source, where the direction to the source is defined by the unit vector $\underset{\sim}{s}$.

$$\omega\Delta t = \frac{2\pi\nu\lambda \underset{\sim}{B} \cdot \underset{\sim}{s}}{c}$$

and using $c = \lambda\nu$, we get

$$\omega\Delta t = 2\pi \underset{\sim}{B} \cdot \underset{\sim}{s} \qquad \text{I-(1)}$$

<u>(b) How Incoming Signals Are Converted to Fringe Amplitude and Fringe Phase</u>.

We now wish to discuss what happens to the information about the incoming wave front in the interferometer. From now until we arrive at Equation I-(2), we must suffer through a discussion of what happens in the innards of the electronics of the interferometer. The reader is warned that the discussion will be too sketchy and simplified to satisfy those with a technical turn of mind and too extensive for those who feel that they don't want to get bogged down in technical details. Those who are willing to accept Equation I-(2) on faith can skip the following discussion which precedes that equation.

Let E be the electric field strength of the incoming wave front and $G_1(\nu)$ and $G_2(\nu)$ be the amplifier gains for frequencies between ν and $\nu + d\nu$ for telescopes 1 and 2. In the end, these gains will represent the effects of all the amplification stages in the system. The output voltages for telescopes 1 and 2, due to radiation in the frequency range ν to $\nu + d\nu$, <u>when the same wave front arrives</u>, are:

$$V_2(t) = \left[\frac{1}{2} G_2(\nu)\ E\ d\nu\right]^{1/2} \cos \omega t$$

and

$$V_1(t + \Delta t) = \left[\frac{1}{2} G_1(\nu)\ E\ d\nu\right]^{1/2} \cos \omega(t+\Delta t)$$

where the factors of one-half represent the fraction of the assumed unpolarized signal received by a single circular feed.

As shown in the schematic in Figure I-2, the signals are then "mixed" with the local oscillator (LO) with angular frequency ω_o. The equations in Figure I-2 deal only with the changes in the time-dependent factors of the signal voltages. The mathematical equivalent of the mixing process is multiplication of $V_1(t + \Delta t)$ and $V_2(t)$ by $\cos \omega_o t$. After this process the signal consists of high and low-frequency terms. The IF (intermediate frequency) bandpass filter rejects the high-frequency terms. Next a compensating time delay $\Delta\tau$ is inserted in the lines from telescope 2 so that, despite the geometrical delay Δt, the time difference in arrival at the multiplier is only $(\Delta\tau - \Delta t)$, a quantity that we must make as small as possible for reasons that will be obvious in a moment. Multiplication of the signals from the two telescopes, which is the basic process by which one "correlates" the information about the wave front as seen by the two telescopes, once again results in a high-frequency and a low-frequency term, the latter being the only one to survive a low-pass filter. We then get the final result that radiation in the frequency range ν to $\nu + d\nu$, from the point source in the field being tracked, produces a response in the interferometer proportional to

$$\cos\left[(\omega - \omega_o)(\Delta\tau - \Delta t) - \omega_o \Delta t\right]$$

and this factor represents the time-dependent part of the correlated signal produced by the wave front. If we could assume that all sources were monochromatic, with frequency ν_o, or, if it were technically possible to make $(\Delta\tau - \Delta t)$ small enough, then the response of the interferometer would be

$$R(\Delta t) \propto \cos \omega_o \Delta t.$$

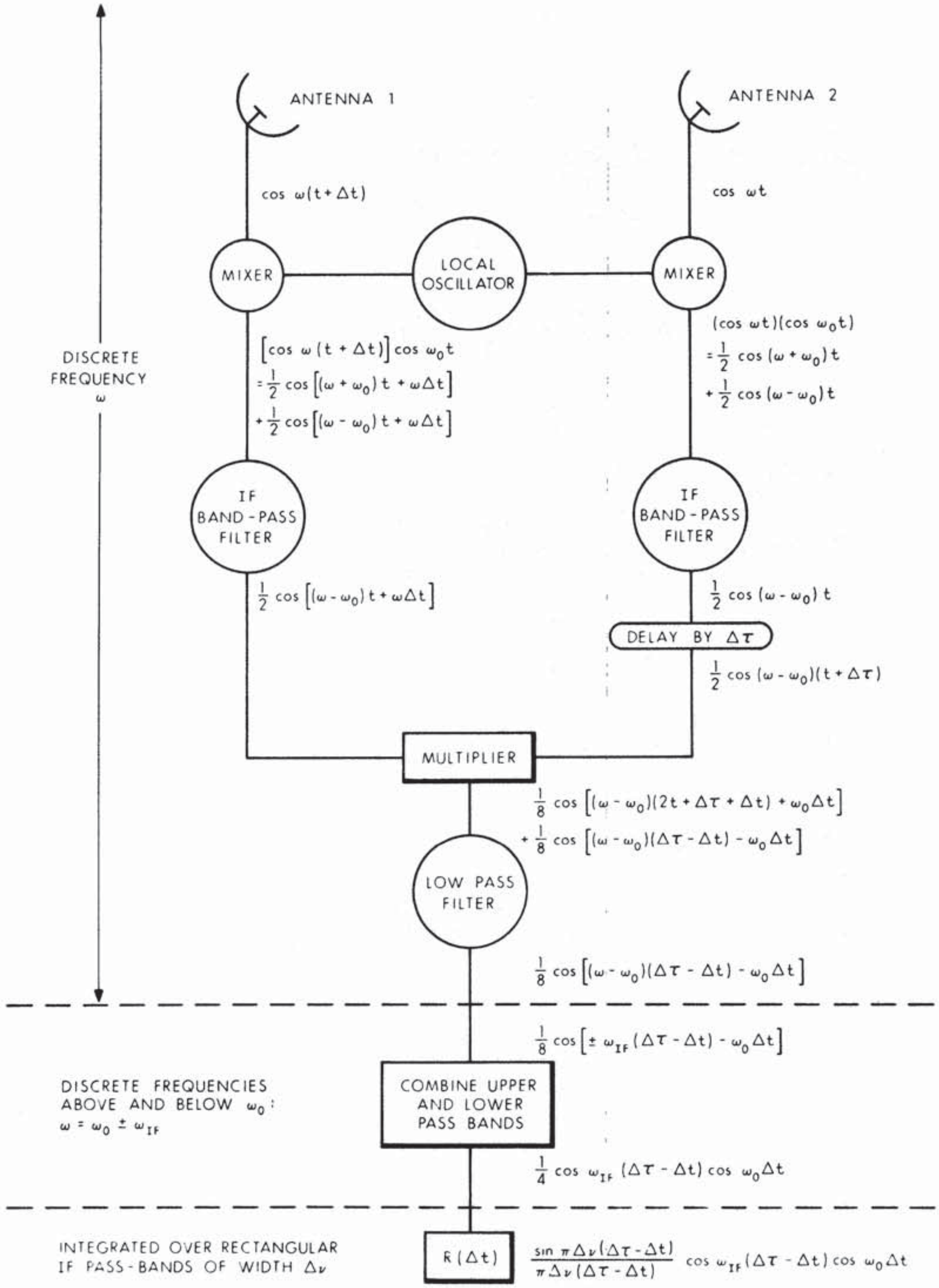


Fig. I-2. Schematic illustration of the changes in the time dependent part of the information about a single wave front, as received by two antennas, as this information is processed by interferometer electronics.

However, no source is monochromatic, and it is not possible to keep $(\Delta\tau-\Delta t)$ small enough; therefore the best we can do is to deal with sharply defined IF passbands. The NRAO interferometer is a so-called double sideband system. Frequencies in the upper and lower sidebands are denoted by $\omega = \omega_o \pm \omega_{IF}$. The range of IF frequencies is 5 to 35 MHz and the bandwidth is therefore 30 MHz. Useful properties are obtained by always combining upper and lower sidebands. Thus the signal out of the low pass filter is the sum of two terms, the combination of the upper and lower passbands:

$$\frac{1}{8} \cos \left[\pm\ \omega_{IF}(\Delta\tau-\Delta t)-\omega_o \Delta t\right]$$
$$\equiv \frac{1}{8} \{\cos\ [\omega_{IF}(\Delta\tau-\Delta t)-\omega_o\Delta t] + \cos\ [-\omega_{IF}(\Delta\tau-\Delta t)-\omega_o\Delta t]\}$$
$$= \frac{1}{4} \cos\ \omega_{IF}(\Delta\tau-\Delta t)\ \cos\ \omega_o\Delta t.$$

This, however, represents only the effects of wave fronts with frequencies $\omega_o + \omega_{IF}$ and $\omega_o - \omega_{IF}$, whereas one must include all of the upper and lower sidebands. If we assume $G_1(\nu)$ and $G_2(\nu)$ are perfect rectangular passbands with widths $\Delta\nu$ and with centers $\pm\ \omega_{IF}$ from ω_o, then integration over the bandpasses gives the following integral:

$$\int G_1(\nu_{IF})\ G_2(\nu_{IF})E^2\ \cos\ 2\pi\nu_{IF}(\Delta\tau-\Delta t)d\nu_{IF}$$
$$\propto \overline{G_1G_2E^2}\quad \frac{\sin\ \pi\Delta\nu(\Delta\tau-\Delta t)}{\pi\Delta\nu(\Delta\tau-\Delta t)}\ \cos\ \omega_{IF}(\Delta\tau-\Delta t).$$

The total response of the interferometer can then be written as

$$R(\Delta\tau,\Delta t) = \frac{1}{2}\ \overline{G_1G_2E^2}\ \frac{\sin\ \pi\Delta\nu(\Delta\tau-\Delta t)}{\pi\Delta\nu(\Delta\tau-\Delta t)}\ \cos\ \omega_{IF}\ (\Delta\tau-\Delta t)\ \cos\ \omega_o\Delta t \qquad \text{I-(2)}$$

where $\overline{G_1G_2E^2}$ represent the mean of a complicated function. We always assume that we can neglect the effects of frequency dependence of E^2 over the range $\pm$ 15 MHz about 2695 and 8085 MHz. The average $\overline{G_1G_2}$ then generally reflect the effects of non-rectangular bandpasses. It is never in practice possible to find $\overline{G_1G_2}$ from a knowledge of $G_1(\nu)$ and $G_2(\nu)$; therefore all amplitude (or flux) calibration of the interferometer is based upon empirically determining the response of the interferometer to a point source of known flux density.

Equation I-(2) shows that unless $(\Delta\tau-\Delta t)$ is very small; that is, the inserted delays compensate very well to the continuous changes in Δt, there will be considerable loss of signal strength. The function

$$F(\Delta\tau-\Delta t) = \frac{\sin \pi\Delta\nu(\Delta\tau-\Delta t)}{\pi\Delta\nu(\Delta\tau-\Delta t)} \cos \omega_{IF}(\Delta\tau-\Delta t)$$

is sometimes called the envelope function. In the NRAO interferometer the goal is to maintain $F(\Delta\tau-\Delta t)$ at about 0.98 to 1.0; this is done by allowing the computer to control changes in a digital delay system in steps as small as 2 nanosceconds. When all delays are working, we operate on the assumption that

$$R(\Delta t) = (\text{constant}) \times \cos \omega_o \Delta t$$

for a point source and lump all of the following under the heading of "noise" in the calibration of the constant in the above equation: (1) variations due to changing finite values of $(\Delta\tau-\Delta t)$*; (2) changes in $\overline{G_1G_2}$ due to fluctuations in amplification gains and due to imperfections in the upper and lower sidebands; (3) variations due to real effects of E^2 varying over the bandpasses; and (4) variations due to failure of the factor of one-half to represent the real polarization effects. Only

* Sometimes systematic errors occur which can be corrected for by special calibration of amplitude as a function of delay setting.

part of the latter effects can be eliminated by the proper polarization calibration.

The response function for an interferometer, $R(\Delta t)$, always produces sinusoidal variations which are described as fringes. In the special case discussed so far the proportionality constant would describe the fringe amplitude and the product $\omega_0 \Delta t$ would be the fringe phase.

(c) Relation Between Fringe Amplitude and Flux Density

Because the interferometer response is proportional to $\overline{E^2}$, we can identify the constant of proportionality (fringe amplitude) in the interferometer response with the flux density, S, of a point source. Therefore, we can write

$$R(\Delta t) = S \cos \omega_o \Delta t = S \cos 2\pi \underset{\sim}{B} \cdot \underset{\sim}{s} \qquad \text{I-(3)}$$

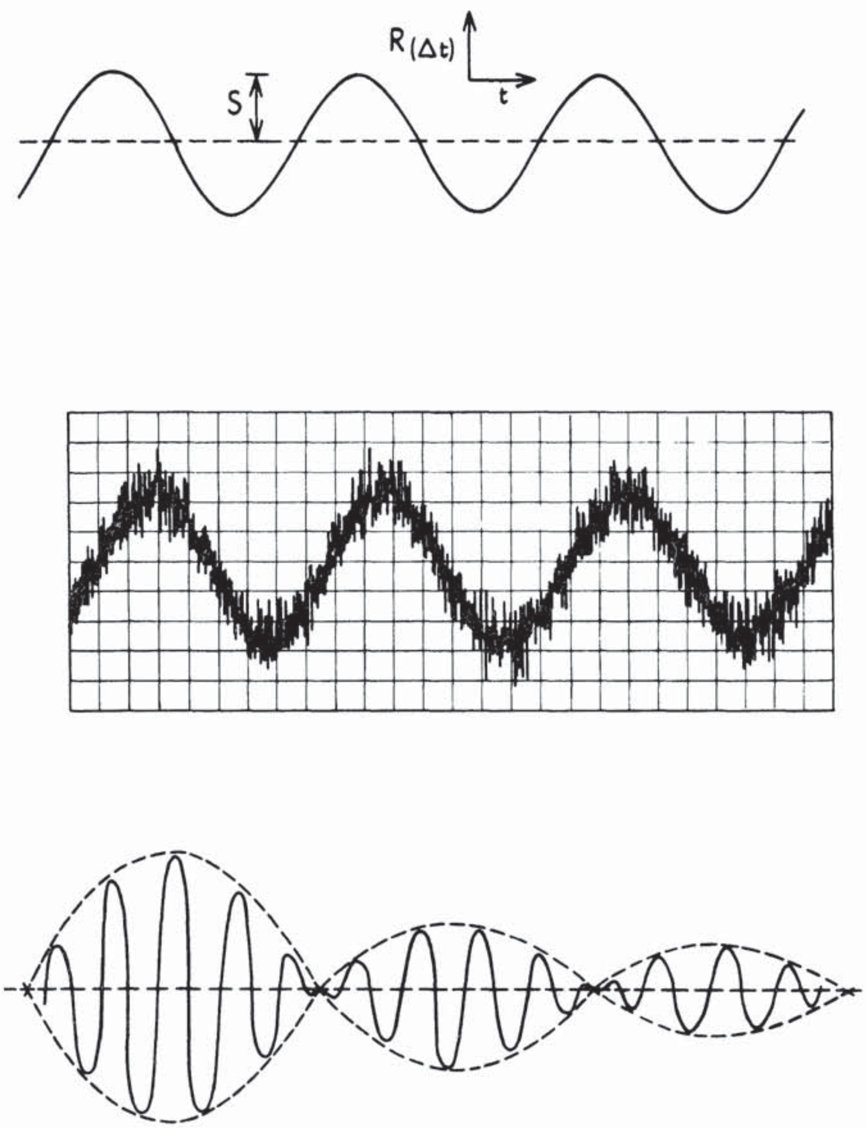
for a properly calibrated interferometer. If the source were too far from the center of the beam, the coefficient in Equation I-(3) would be modified by the antenna sensitivity pattern, but we will neglect this detail for the present time.

Figure I-3a shows the theoretical response to a point source. Figure I-3b shows an example of the actual response to a point source. The effects of noise clearly show up as fluctuations about the mean response.

If the delays are not inserted, we get results as shown in Figure I-3c for a point source. The normal response, $\cos \omega_o \Delta\tau$, is modulated by the more slowly varying envelope function.

The responses described by Equation I-(3) and Figure I-3 are frequently called fringes. As the telescopes track a source across the sky $\omega_o \Delta t = 2\pi \underset{\sim}{B} \cdot \underset{\sim}{s}$ changes continuously, producing continual sinusoidal variation of $R(\Delta t)$ which depends only on $\underset{\sim}{B}$ and $\underset{\sim}{s}$. This sinusoidal variation is called the "fringe pattern" of the interferometer.

At this point let us emphasize a fundamental point of interferometry: the only flux calibration possible is the comparison of the



a. Theoretical Response To Point Source

b. Actual Response To Point Source

c. Theoretical Response To Point Source Without Delay Insertion

Fig. I-3. Three different aspects of the interferometer response to a point source.

fringe amplitude of one point source with that of another source. There is no comparison "cal" in the system. One simply observes a point source that you know (or assume) has a particular flux density; then the flux density for all point sources can be determined relative to this standard. In practice, only gain instabilities, telescope pointing errors, and very minor effects of attentuation by the atmosphere can affect these conclusions. The interferometer is amplitude calibrated by doing two things: (1) observing a number of point sources with known flux densities to determine the coefficient in Equation I-(3); and (2) monitoring point sources once an hour or so throughout the observing program to make it possible to detect changes in gain which result in changes in the calibration constants.

Now that we have established Equation I-(3) as the first basic equation of interferometry, let us consider the geometry of $\underset{\sim}{s}$ and $\underset{\sim}{B}$ as related to astronomical coordinate systems.

3. Geometry of Interferometry

(a) Geometry and Coordinates

In Figure I-4 both right-handed (xyz) and left-handed (x'y'z') coordinate systems are shown. The z (or z') axis points to the equatorial north pole and the other two axes are in the equatorial plane, with the y-axis pointing east and the y'-axis pointing west.

With (θ,ϕ) = angular coordinates in a spherical right-handed system, and (θ',ϕ') = angular coordinates in a spherical left-handed system, we see that they relate to the hour angle (H) and the declination (δ) by:

$$\theta' = \theta = 90^\circ - \delta$$

$$\phi' = H = 180^\circ - \phi \ ,$$

hence the use of hour angle forces us to use a left-handed coordinate system. This creates one of the conceptual problems in interferometry, the mixture of right- and left-handed coordinate systems. Depending

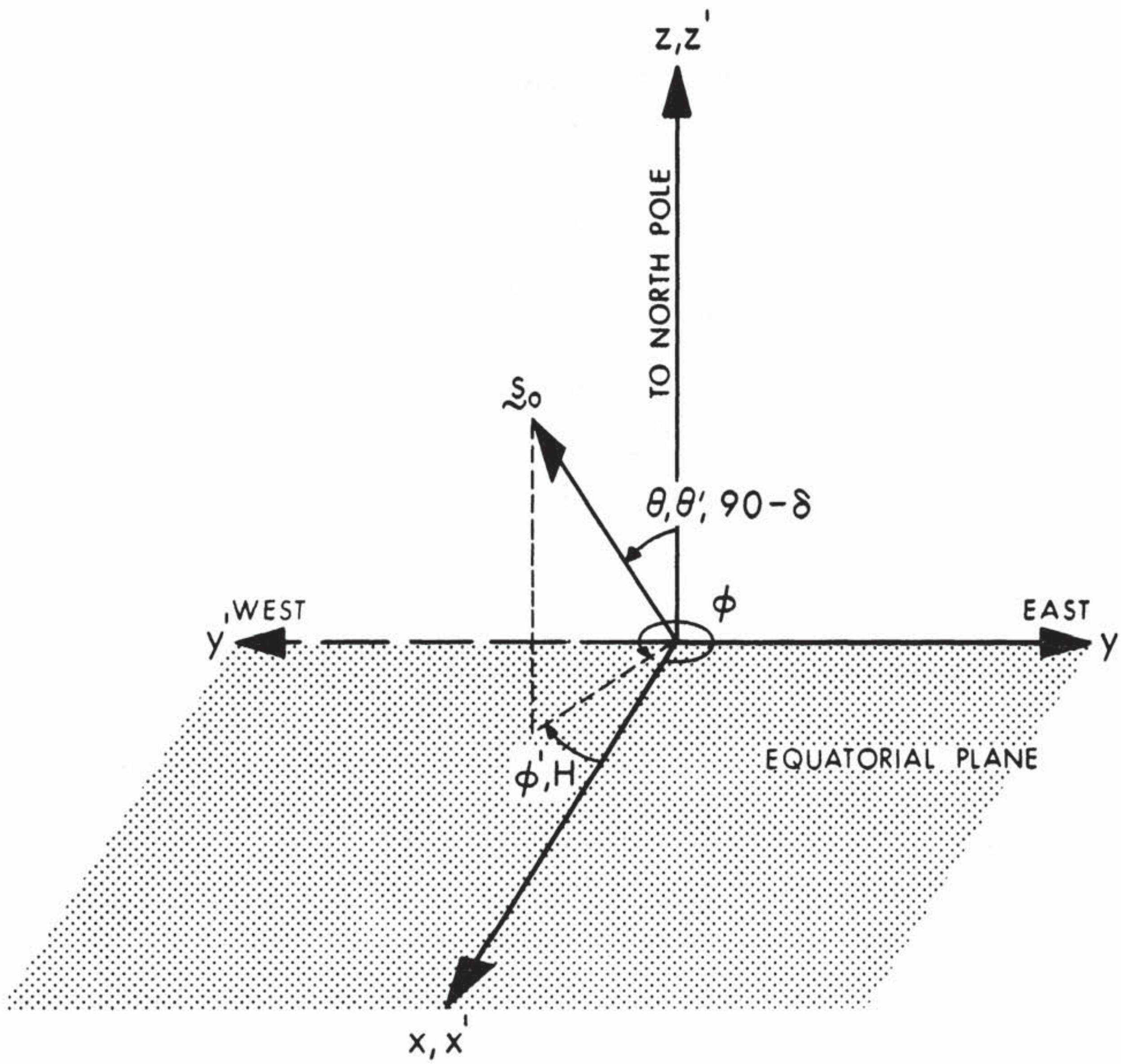


Fig. I-4. Geometry relating a rectangular coordinate system, in which the z-axis towards the North Pole and the y-axis is east, to spherical polar coordinates and hour angle-declination coordinates. The unprimed quantities refer to right-handed coordinates and the primed quantities refer to left-handed coordinates.

upon which coordinate system is used to describe the components of a vector like $\underset{\sim}{s}_o$, we indicate handedness by LH (left-handed) or RH (right-handed), i.e.,

$$\underset{\sim}{s}_o = \begin{pmatrix} \sin\theta\cos\phi \\ \sin\theta\sin\phi \\ \cos\theta \end{pmatrix}_{RH} = \begin{pmatrix} \sin\theta'\cos\phi' \\ \sin\theta'\sin\phi' \\ \cos\theta' \end{pmatrix}_{LH} = \begin{pmatrix} \cos\delta\cos H \\ -\cos\delta\sin H \\ \sin\delta \end{pmatrix}_{LH} \qquad \text{I-(4)}$$

We define h and d to be the hour angle and declination of the baseline vector, hence

$$\frac{\underset{\sim}{B}}{B} = \begin{pmatrix} \cos d\cos h \\ -\cos d\sin h \\ \sin d \end{pmatrix}_{LH} \cong \begin{pmatrix} -0.280 \\ -0.883 \\ 0.376 \end{pmatrix}_{LH}$$

Virtually all practical uses of radio interferometry are based upon the fact that, to an observer sitting on a radio source in the sky, the interferometer baseline appears to rotate and change length as the earth rotates. In fact, <u>virtually every practical equation of importance in interferometry makes use of the natural coordinate system of an observer sitting on the reference position in the sky</u>.

<u>(b) Transformation to Coordinate System at Reference Position.</u>

We must therefore derive the equations of transformation from the equatorial system used to describe and track sources to the coordinate system of an observer at the reference position. We will adopt a new coordinate system in which the z" axis is along the direction of $\underset{\sim}{s}_o$, the y" axis is oriented from south to north, and the x" axis then increases to the east. This coordinate system is right-handed and, by definition, its origin is at the reference position. Figure I-5 shows this coordinate system, all the other coordinate systems, and the important vectors defining the source-interferometer geometry.

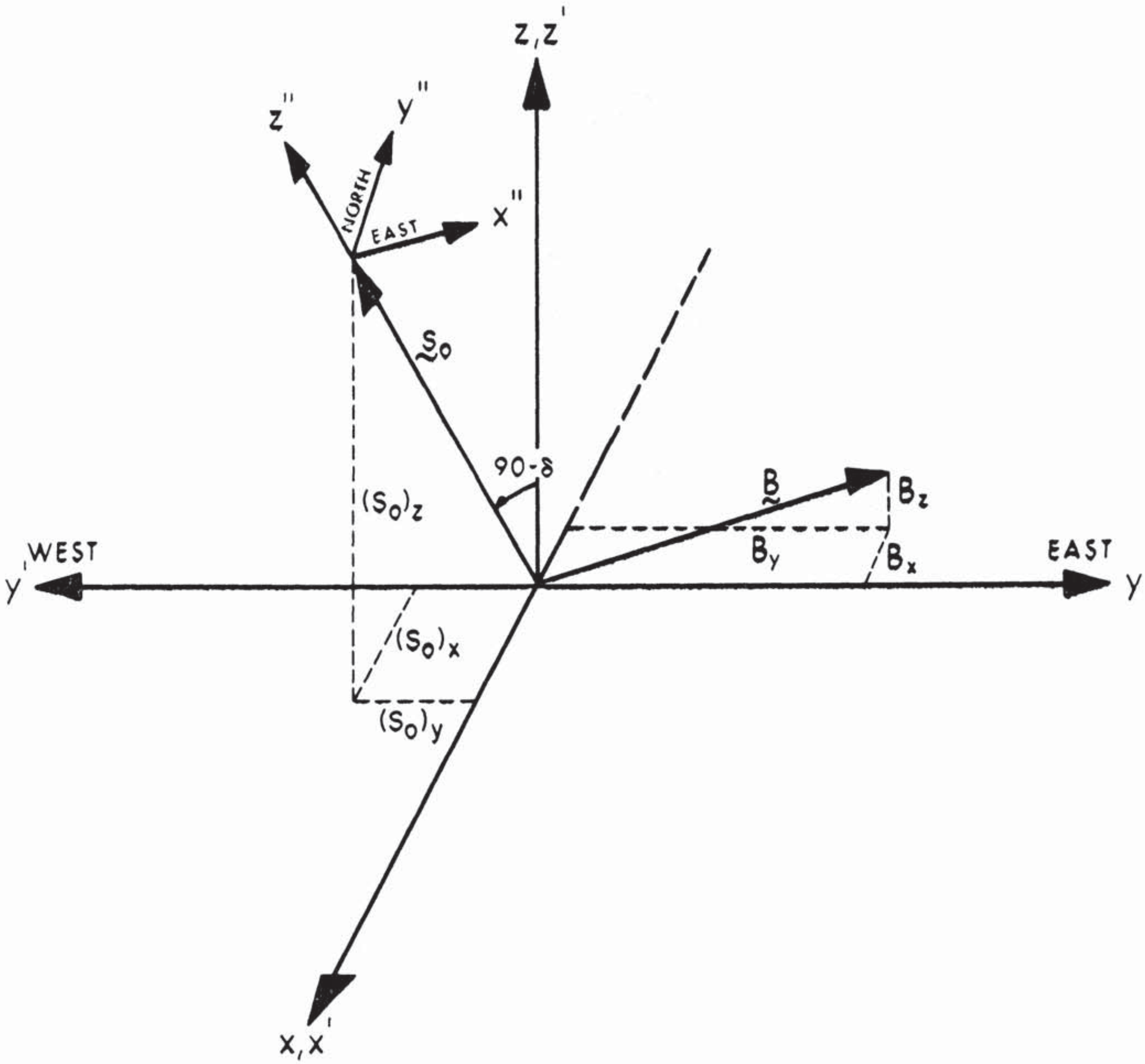


Fig. I-5. Basic geometry of earth-related coordinates systems related to coordinate system (x''y''z'') of an observer situated on the sky, for a direction defined by $\underset{\sim}{s}_o$.

Let us derive the transformation matrices for going from the $x'y'z'$ system to the $x''y''z''$ system, i.e., from the equatorial (left-handed) coordinate system to the right-handed system of an observer at the reference position. The transformation can be divided into four parts*:

(1) a clockwise rotation about the z axis by H

$$\begin{pmatrix} \cos H & \sin H & 0 \\ -\sin H & \cos H & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

(2) a clockwise rotation about the y-axis by 90−δ

$$\begin{pmatrix} \cos 90-\delta & 0 & -\sin 90-\delta \\ 0 & 1 & 0 \\ \sin 90-\delta & 0 & \cos 90-\delta \end{pmatrix}$$

$$= \begin{pmatrix} \sin\delta & 0 & -\cos\delta \\ 0 & 1 & 0 \\ \cos\delta & 0 & \sin\delta \end{pmatrix}$$

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* Note the following general results:

clockwise rotation of θ about x-axis
$$\begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & \sin\theta \\ 0 & -\sin\theta & \cos\theta \end{pmatrix}$$

clockwise rotation of θ about y-axis
$$\begin{pmatrix} \cos\theta & 0 & -\sin\theta \\ 0 & 1 & 0 \\ \sin\theta & 0 & \cos\theta \end{pmatrix}$$

clockwise rotation of θ about z-axis
$$\begin{pmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

(3) A clockwise rotation of 90 about the z-axis to put the y-axis in direction of north pole
$$\begin{pmatrix} 0 & 1 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

(4) Reversal of the x-axis, changing the handedness of the system
$$\begin{pmatrix} -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Combining all four transformations into one matrix, any vector specified in the x'y'z' coordinate system is transformed into a vector in the x"y"z" coordinate system by the following matrix:

$$\begin{pmatrix} \sin H & -\cos H & 0 \\ -\sin\delta\cos H & -\sin\delta\sin H & \cos\delta \\ \cos\delta\cos H & \cos\delta\sin H & \sin\delta \end{pmatrix}$$

Applying this transformation matrix to the baseline vector, $\underset{\sim}{B}$, we obtain special quantities of great importance:

$$\underset{\sim}{B} = \begin{pmatrix} u \\ v \\ D \end{pmatrix}_{RH} = \begin{pmatrix} \sin H & -\cos H & 0 \\ -\sin\delta\cos H & -\sin\delta\sin H & \cos\delta \\ \cos\delta\cos H & \cos\delta\sin H & \sin\delta \end{pmatrix} \begin{pmatrix} B_x \\ B_y \\ B_z \end{pmatrix}_{LH}, \qquad \text{I-(5)}$$

where the three components of B in the x"y"z" system are denoted u,v, and D. The components u and v represent the projection of the interferometer baseline on the sky. They completely describe the orientation and separation of the two elements of the interferometer as it observes the source--from the point of view of an observer at the reference position. From Equation I-(5), we have:

$$u(H,\delta) = B_x \sin H - B_y \cos H \qquad \text{I-(6)}$$

and

$$v(H,\delta) = -\sin\delta(B_x \cos H + B_y \sin H) + B_z \cos\delta. \qquad \text{I-(7)}$$

4. Relation Between Geometry of Interferometer and Response Function

(a) Meaning of Delay Parameter

The parameter D, which is the component of $\underset{\sim}{B}$ along the line of sight to the source, is called the "delay" and it simply describes the extra distance a wave front originating from the reference position must travel beyond telescope 2 to get to telescope 1, i.e.,

$$D(H,\delta) = B_x \cos\delta \cos H + B_y \cos\delta \sin H + B_z \sin\delta, \qquad \text{I-(8)}$$

and the corresponding phase difference, which plays an important role in describing the response of an interferometer to a source at the reference position (cf. Equations I-(3)),is

$$\omega\Delta t = 2\pi \underset{\sim}{B} \cdot \underset{\sim}{s}_o = 2\pi D. \qquad \text{I-(9)}$$

Another way of describing the delay D is that it is the phase difference in turns (1 turn = 2π radians) between the two telescopes. Using equation I-(8), the computer calculates for each (H,δ) the delay insertions $(\Delta\tau = D/\nu_o)$ necessary to minimize $(\Delta\tau-\Delta t)$.

(b) Re-description in Reference Frame on the Sky

Before turning to the most general case where radiation is distributed throughout the antenna beam, let us re-describe in a very useful form the response of a point source displaced by a vector $\Delta\underset{\sim}{s}$ from $\underset{\sim}{s}_o$. The projection of $\Delta\underset{\sim}{s}$ on the x"-y" plane (plane of the sky) is shown in Figure I-6. We will use the following equivalent expression for $\Delta\underset{\sim}{s}$* where the components are projections on the tangent plane:

$$\Delta\underset{\sim}{s} = \begin{pmatrix} \Delta\alpha \cos\delta \\ \Delta\delta \end{pmatrix}_{RH} \qquad \text{I-(10)}$$

* Note to reader: We are glossing over some minor approximations involving spherical trigonometry to get at the equations of practical interest.

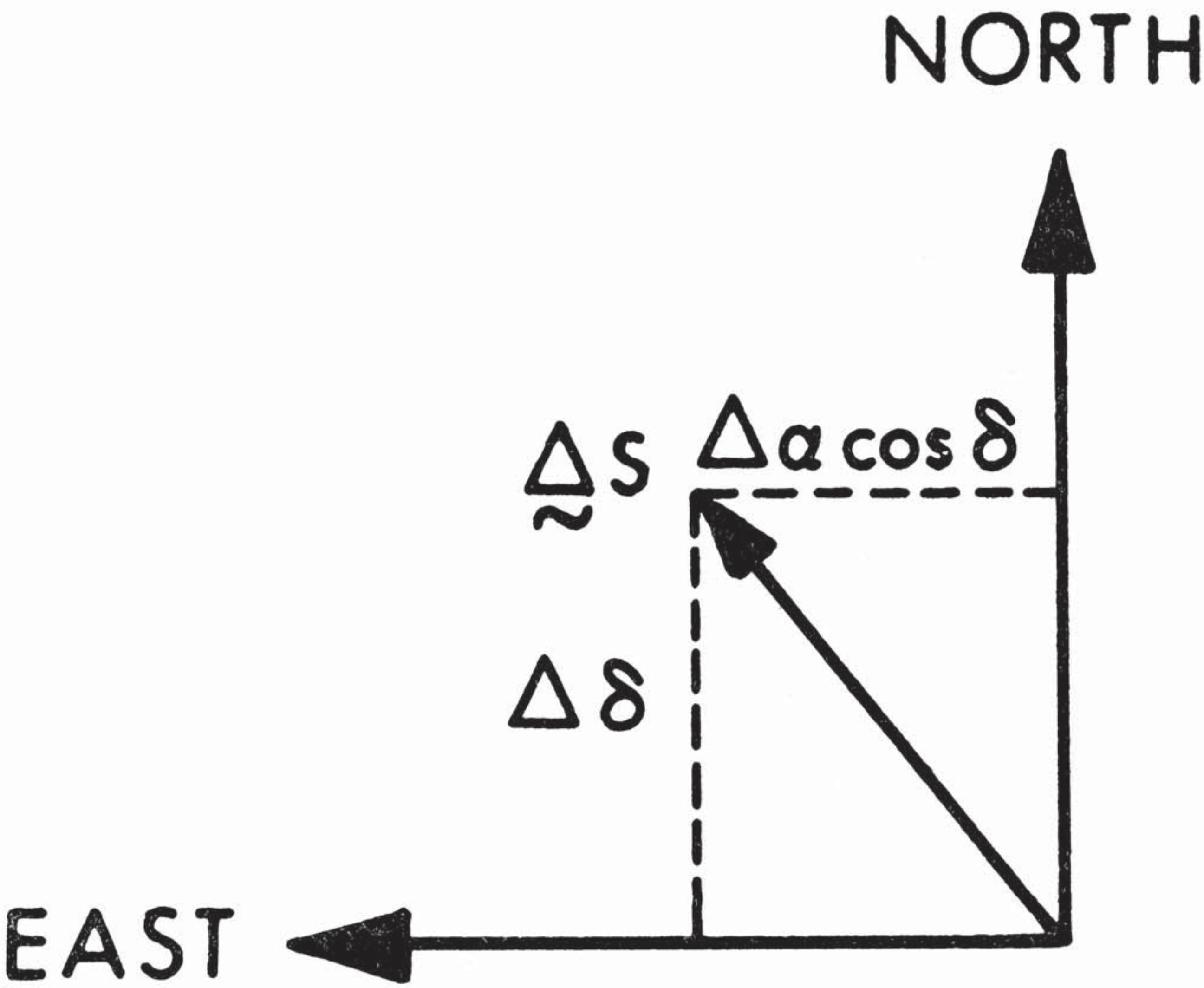

Fig. I-6. The relationship between the geometry of the displacement vector, $\Delta \underset{\sim}{s}$, and displacements in right ascension and declination appropriate to a point in the sky with a declination δ.

where $(\Delta\alpha, \Delta\delta)$ denotes the vector displacement from the reference position in right ascension and declination.

We now use Equation I-(3) to describe the response of the interferometer to this point source, but $\underset{\sim}{s}$ is replaced by $\underset{\sim}{s}_o + \Delta\underset{\sim}{s}$, i.e.,

$$R = S \cos [2\pi \underset{\sim}{B} \cdot (\underset{\sim}{s}_o + \Delta\underset{\sim}{s})]. \qquad \text{I-(11)}$$

Now we can use Equations I(5) and I-(10), which describe $\underset{\sim}{B}$ and $\Delta\underset{\sim}{s}$ in the reference frame at the reference position, to obtain

$$\Phi = 2\pi \underset{\sim}{B} \cdot \Delta\underset{\sim}{s} = 2\ (u,v)_{RH} \begin{pmatrix} \Delta\alpha \cos \delta \\ \Delta\delta \end{pmatrix}_{RH} \qquad \text{I-(12)}$$

$$= 2\pi(u \cdot \Delta\alpha \cos \delta + v \cdot \Delta\delta)$$

or, writing out the full dependence on $\Delta\alpha, \Delta\delta$, H, and δ:

$$\Phi(\Delta\alpha,\Delta\delta;H,\delta) = 2\pi\ \Delta\alpha(B_x \cos \delta \sin H - B_y \cos \delta \cos H) \qquad \text{I-(13)}$$

$$+ 2\pi\ \Delta\delta(-B_x \sin \delta \cos H - B_y \sin \delta \sin H + B_z \cos \delta).$$

Let us now use the fact that $\underset{\sim}{B} \cdot \underset{\sim}{s} = D$ to write the interferometer response to a point source as

$$R = S \cos [2\pi(D + u \cdot \Delta\alpha \cos \delta + v \cdot \Delta\delta)]. \qquad \text{I-(14)}$$

Equation I-(14) describes the instantaneous response of the interferometer to a point source displaced $(\Delta\alpha, \Delta\delta)$ from the reference position (α, δ).

(c) Fringe-Fitting.

For the special case of a dominant point source displaced from the reference position, the interferometer response is

$$R = S \cos (2\pi D + \Phi), \qquad \text{I-(15)}$$

where Φ is given by Equation I-(12) and S is the flux density of the source. As we shall see later, the more general case of a distribution of radiation sources in the beam produces a response that can be described in an analogous manner with amplitudes and phases that have a more complicated interpretation.

The response of an interferometer, R, which is the final product of the cross-correlation of signals from two antennas, is basically just the amplitude of this cross-correlation as a function of time. However, most of the variation of R has nothing to do with the properties of radiation sources in the sky but is simply due to the variation of D, which produces the intrinsic fringe pattern of the interferometer. For this reason, the output of the interferometer which is actually recorded for later use is not R as a function of time but rather the amplitude and phase of R as a function of time. The meaning of the amplitude and phase of R is best understood by understanding the process of "fringe-fitting".

Fringe-fitting is basically a solution for the fringe amplitude A and the fringe phase ϕ for which one obtains the best fit of the response function data to an equation of the form

$$R(t) = A \cos [2\pi D(t) + \phi]. \qquad \text{I-(16)}$$

The fitting process is carried out as follows. The value of $D = D(t)$ is calculated at all times, by the DDP 116 computer which controls the interferometer, using an assumed set of baseline parameters (B_x, B_y, B_z) and Equation I-(8). Every 20 milliseconds the computer takes a 20 millisecond average of the correlated signal (R) being received and this constitutes an amplitude R_i for a particular t_i. After 30 seconds during which such samples are gathered, the measured R_i vs t_i are fit in a least squares sense to Equation I-(16) to determine the measured fringe amplitude A and fringe phase ϕ for that 30-second period.

For reasons that will be clear in a moment, we separate ϕ into a variable component Φ and a constant component ϕ_s, called the system phase center, so that

$$\phi = \phi_s + \Phi. \qquad \text{I-(17)}$$

If we denote by R' a sort of modified response function from which the effects of the delay D have been removed,

$$R' = A \cos \phi = A \cos (\phi_s + \Phi). \qquad \text{I-(18)}$$

By comparison of Equations I-(16) and I-(18), we see that after fringe-fitting the phase delay $2\pi D$ has been replaced by an instrumental constant, ϕ_s, which we call the phase center.

Comparison of Equation I-(18) with Equation I-(14), which described the response to a dominant point source displaced from the pointing position, shows that in this case*

$$R' = S \cos [\phi_s + 2\pi(u \cdot \Delta\alpha \cos \delta + v \cdot \Delta\delta)]. \qquad \text{I-(19)}$$

It follows from this that when the source position coincides with the reference position

$$\Phi = 2\pi(u \cdot \Delta\alpha \cos \delta + v \cdot \Delta\delta) = 0$$

and

$$\phi = \phi_s$$

---

* In real data there are a few other corrections to be applied before the following is strictly true; but since they are in the category of details and not related to the essence of interferometry, we postpone a discussion of them until Chapter III.

so that observations of calibrators at the reference position determine not only the calibration of the amplitudes but also the instrumental phase centers. The calibration problem can, in principle, be described as follows. Let S_i be the flux density of the i-th calibrator, where $i = 1, \ldots, N$ have been observed. Observations with the source positioned at the reference position give measurements of amplitudes A_i and ϕ_i. Combining a number of measurements, one determines

$$\phi_s = \sum_{i=1}^{N} \phi_i/N \qquad \text{I-(20)}$$

and

$$g_s = \sum_{i=1}^{N} S_i/(A_i N), \qquad \text{I-(21)}$$

where g_s is the system gain,
so that for any observations of any source we transform A, ϕ, and R' from the raw data form of

$$R' = A \cos \phi$$

to the calibrated form

$$R' = g_s A \cos (\phi - \phi_s). \qquad \text{I-(22)}$$

Obviously g_s is the gain, and for any point source $S = g_s A$.

(d) Visibility Function for a Point Source

In practice there are a number of reasons why the modified response function R' is inconvenient to work with. It is most convenient to use the fringe amplitude A and fringe phase ϕ to define a complex function, V, called the visibility function:

$$V = A\ e^{i\phi} = \mathcal{R} + i\mathcal{I} \qquad \text{I-(23)}$$

where $\mathcal{R}$ and $\mathcal{I}$ are the real and imaginary parts of V. However, we must be careful to distinguish between the uncalibrated visibility function as expressed in Equation I-(23) and the calibrated visibility function:

$$\mathrm{V} = g_s A\ e^{i(\phi-\phi_s)} = g_s A\ e^{i\Phi}. \qquad \text{I-(24)}$$

Obviously, when the field of view is dominated by a single point source, the uncalibrated visibility function will be

$$V = \frac{S}{g_s} \exp\ [i\phi_s + 2\pi i(u \cdot \Delta\alpha \cos\delta + v \cdot \Delta\delta)] \qquad \text{I-(25)}$$

where δ is the declination of the reference position and $(\Delta\alpha,\Delta\delta)$ is the displacement from the reference position to the point source. After calibration by multiplying Equation I-(25) by $g_s \exp(-i\phi_s)$, the calibrated visibility function is

$$V = S \exp\ [2\pi i(u \cdot \Delta\alpha \cos\delta + v \cdot \Delta\delta)] \qquad \text{I-(26)}$$

5. Visibility Function for General Distribution of Sources

(a) Relation Between Visibility Function and Brightness Distribution

We are now in a position to discuss the response of an interferometer to a general distribution of radiation. Our discussion is based upon the principle that any infinitesimal region of the sky behaves as a point source of radiation as far as the interferometer is concerned.

Let

$$x = \Delta\alpha \cdot \cos\delta$$
$$y = \Delta\delta$$

and consider an infinitesimal area dxdy at the position (x,y). Now we know that, by definition, for any source with a brightness (or intensity) distribution B(x,y) the flux density S is given by

$$S = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} B(x,y)dxdy;$$

therefore the infinitesimal area dxdy can be considered to make an infinitesimal contribution to the flux density of B(x,y)dxdy. If we further define f(x,y) to be the normalized antenna pattern, the contribution of the area dxdy to the uncalibrated visibility function is, by generalization of Equation I-(25),

$$dV(x,y;\ u,v) = \frac{f(x,y)B(x,y)}{g_s} \exp\ [i\phi_s + 2\pi i(ux+vy)]dxdy$$

where g_s is still the gain and ϕ_s the phase center. Integrating over the entire antenna beam, we get the visibility function produced by all the radiation sources in the beam:

$$V(u,v) = \frac{1}{g_s} e^{i\phi_s} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} f(x,y)B(x,y)\ e^{2\pi i(ux\ +\ vy)}\ dxdy$$

Since it is trivial to calibrate the visibility function by determining g_s and ϕ_s from calibrators, let us work from now on with the calibrated visibility function

$$V(u,v) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} f(x,y)B(x,y)\ e^{2\pi i(ux\ +\ vy)}\ dxdy. \qquad \text{I-(27)}$$

At this point the reader is advised to sit back and admire the beauty and generality of Equation I-(27). Recognizing that Equation I-(27) is the complex Fourier transform of the apparent brightness distribution f(x,y) B(x,y), we now see that <u>every measurement made by an interferometer is the measurement of a Fourier component of f(x,y) B(x,y)</u>.

Recognizing this important fact we can invoke all that is known about Fourier transforms to analyze the meaning of interferometric data. In particular, we know how in principle to determine f(x,y) B(x,y) from our data. In principle

$$f(x,y)\ B(x,y) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} V(u,v)\ e^{-2\pi i(ux + vy)}\ du dv, \qquad \text{I-(28)}$$

so we need only determine all we can about V(u,v) and use Equation I-(28) to interpret the data.

(b) Single Point Source

To check on whether the general formulation still meshes with our earlier, more simplified discussions, let us begin with Equation I-(27) and discuss the case of a single dominant point source displaced by $(\Delta\alpha \cos\delta,\ \Delta\delta) = (x_s,\ y_s)$ from the reference position. For this case Equation I-(27) reduces to

$$V(u,v) = e^{2\pi i(ux_s + vy_s)}\ f(x_s,\ y_s)\ S \qquad \text{I-(29)}$$

which is essentially the same as I-(26) except for a different notation for the displacement from the reference position, and we are now correcting for the antenna sensitivity pattern (which is unity unless the source is far from the beam center).

(c) Sampling of Fourier Components

Using the language of the Fourier transform, there is a very simple way to describe the essential operation of an interferometer. One considers u and v to define a particular angular separation and orientation in the sky, which we will call a "spatial frequency". The E-W and N-S components of a spatial frequency are defined by $u = 1/x$ and $v = 1/y$, respectively. We can then say that the interferometer at any particular instant samples the Fourier component of the brightness distribution corresponding to that spatial frequency. Because of the rotation of the Earth, when a source is tracked a range of Fourier components are sampled. Changing telescope separations and/or using many telescope pairs with different separations causes more spatial frequencies to be sampled. In principle Equation I-(28) tells us that all possible (u,v) must be sampled to allow determination of the brightness distribution. In practice an interferometer samples pitifully few spatial frequencies, hence the determination of f(x,y)B(x,y) is incomplete. The effects of this must be clearly understood.

(d) Coverage of Spatial Frequencies

Let us now discuss in some detail the spatial frequencies the NRAO interferometer can sample and the resulting limitations. From Equations I-(6) and I-(7):

$$u = B_x \sin H - B_y \cos H$$

and

$$v = -\sin \delta (B_x \cos H + B_y \sin H) + B_z \cos \delta .$$

From these equations one can show that u and v are related to each other by

$$\frac{u^2}{a^2} + \frac{(v - v_o)^2}{b^2} = 1, \qquad \text{I-(30)}$$

which is the equation for an ellipse, where

$$a = \sqrt{B_x + B_y} = \cos d, \qquad \text{I-(31)}$$

$$b = a \sin \delta = B \cos d \sin \delta, \qquad \text{I-(32)}$$

and

$$v_o = B_z \cos \delta = B \sin d \cos \delta . \qquad \text{I-(33)}$$

The u-v ellipse for a particular telescope pair has a center located at $u = 0$, $v = v_o = B_z \cos\delta$ and has a major axis a, a minor axis b, and an eccentricity $\cos\delta$. As we see from Equations I-(31)-(33), the size of the ellipse is proportional to B, the actual baseline separation of the two telescopes. The NRAO interferometer has three telescopes of which two are movable and can be placed on the stations indicated in Figure I-7. There is a set of possible ellipses for each declination; the possible ellipses for $\delta = -40, -20, 0, +20°, +40°$, and $+60°$ are shown in Figure I-8. As one sees in Figure I-8, only parts of the ellipses are obtainable because of the limitations on possible hour angles for the telescopes. The plots of Figure I-8, it should be remembered, show the possible spatial frequencies that can be sampled when observing a source at a particular declination. It is obvious that many spatial frequencies cannot be sampled, and, further, at low declinations there is very little sampling of N-S orientations.

From Equations I-(30)-(32) it is clear that the maximum values of u and v are:

$$u_{max} = (B_x{}^2 + B_y{}^2)^{1/2} \qquad \text{I-(34)}$$

and

$$v_{max} = B_z \cos\delta + (B_x{}^2 + B_y{}^2)^{1/2} \sin\delta. \qquad \text{I-(35)}$$

The smallest structures resolvable with the NRAO interferometer correspond to angular sizes $1/u_{max}$ and $1/v_{max}$ in the N-S and E-W directions, respectively. As a rough rule, all parts of sources with structure smaller than 1".5 at 11.1 cm and 0".5 at 3.7 cm will respond as if each such part were a point source. On the other hand, to detect all of a source confined within angular dimensions x_s and y_s (in radians), the spatial frequencies need to be sampled at intervals down to $\Delta u = 1/x_s$ and $\Delta v = 1/y_s$. Also, data must be available no more than

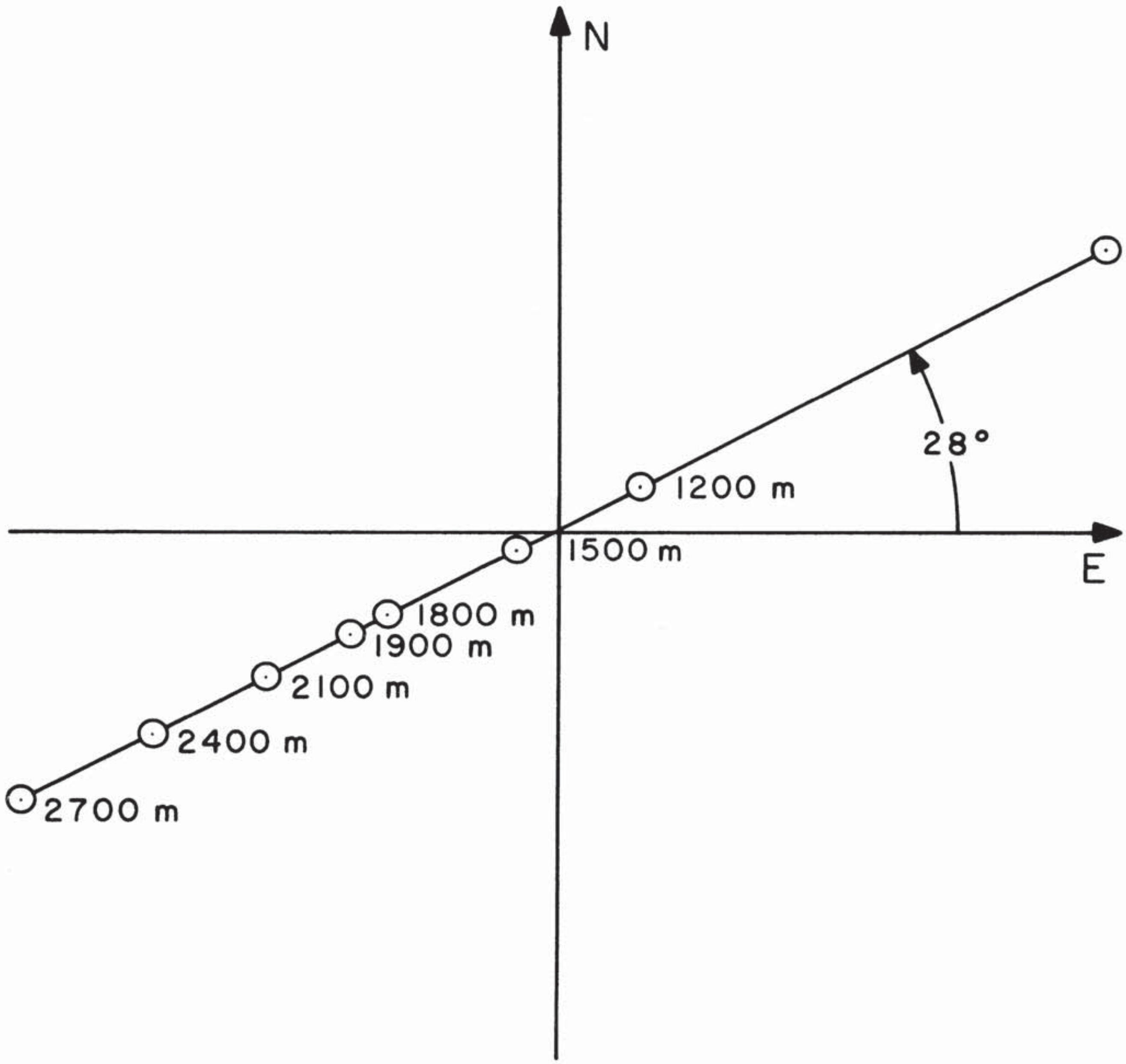

Fig. I-7. The orientation of the NRAO interferometer baselines with respect to the E-W line, with available stations indicated by their distance from 85-1.

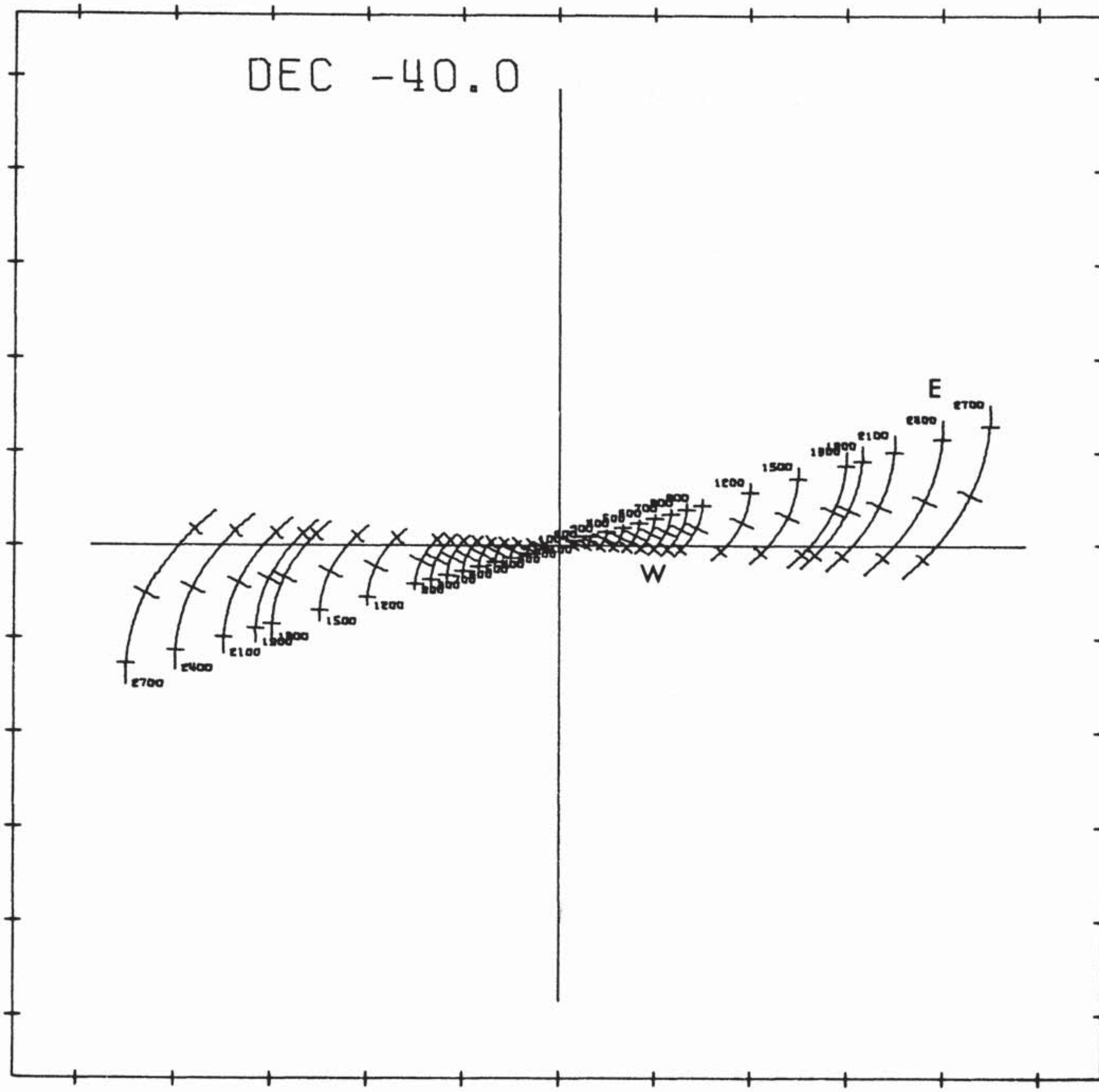

Fig. I-8a. Possible u-v plane coverage for $\delta = -40°$

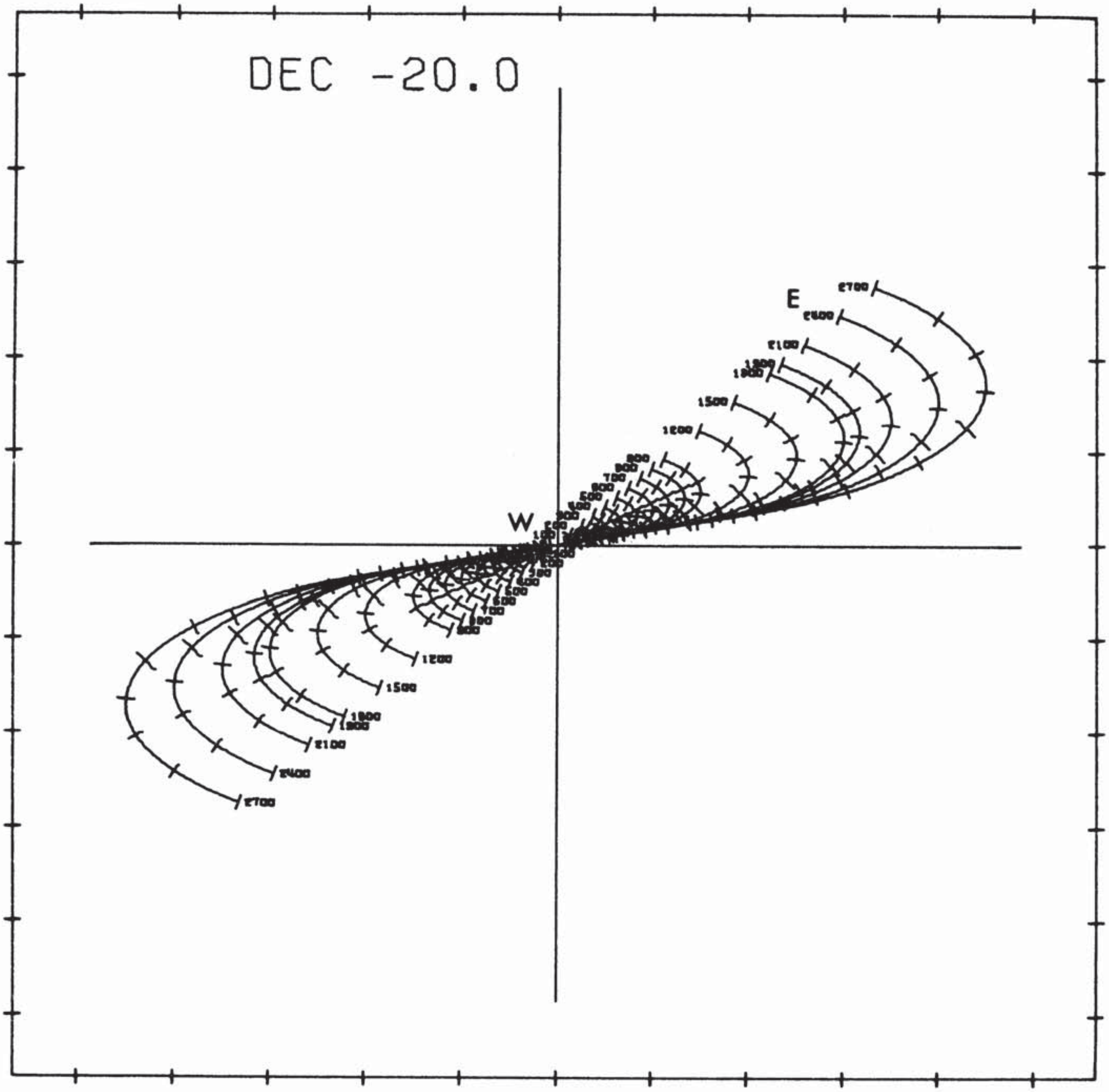

Fig. I-8b. Possible u-v plane coverage for $\delta = -20°$

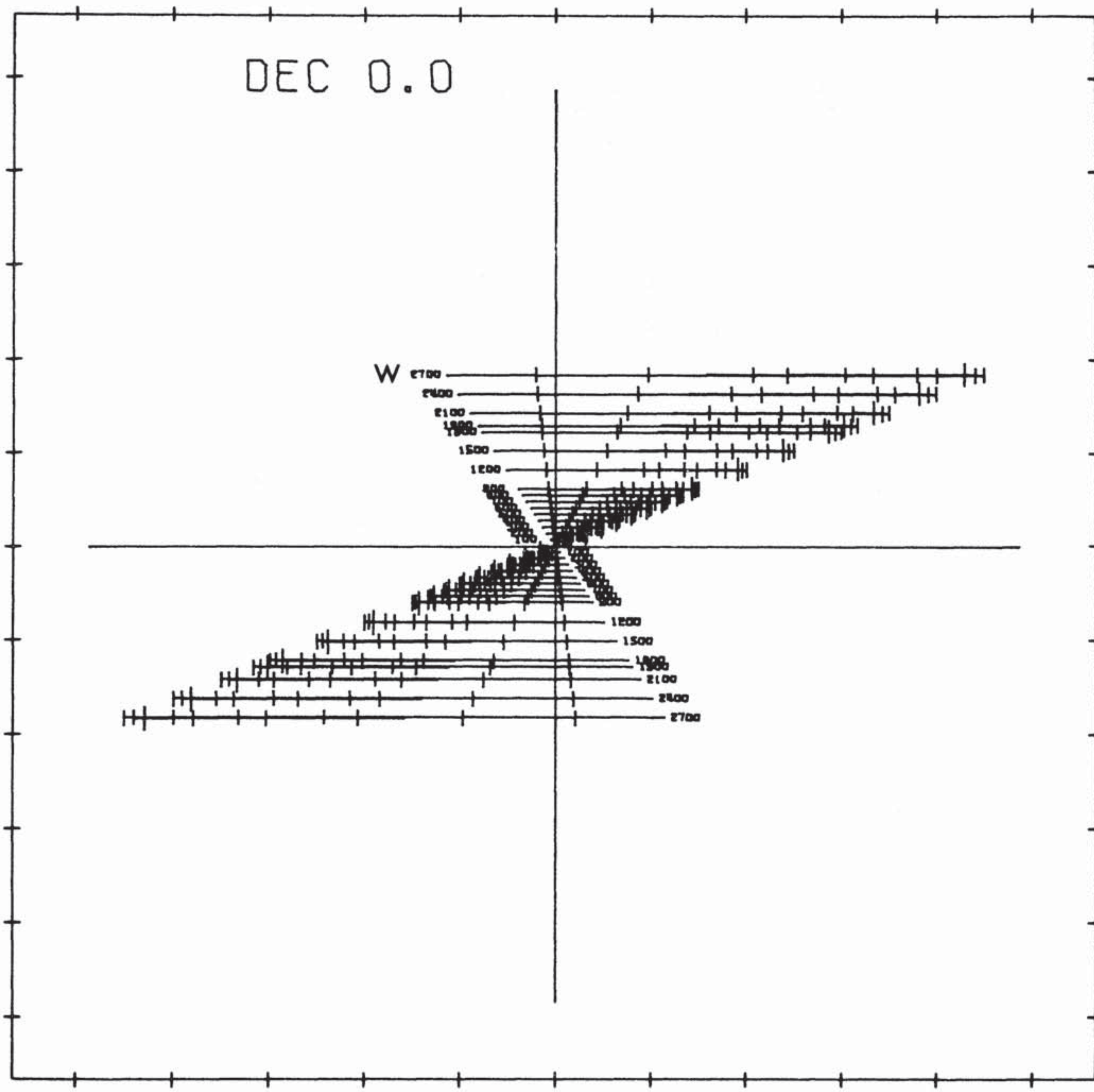

Fig. I-8c. Possible u-v plane coverage for $\delta = 0$.

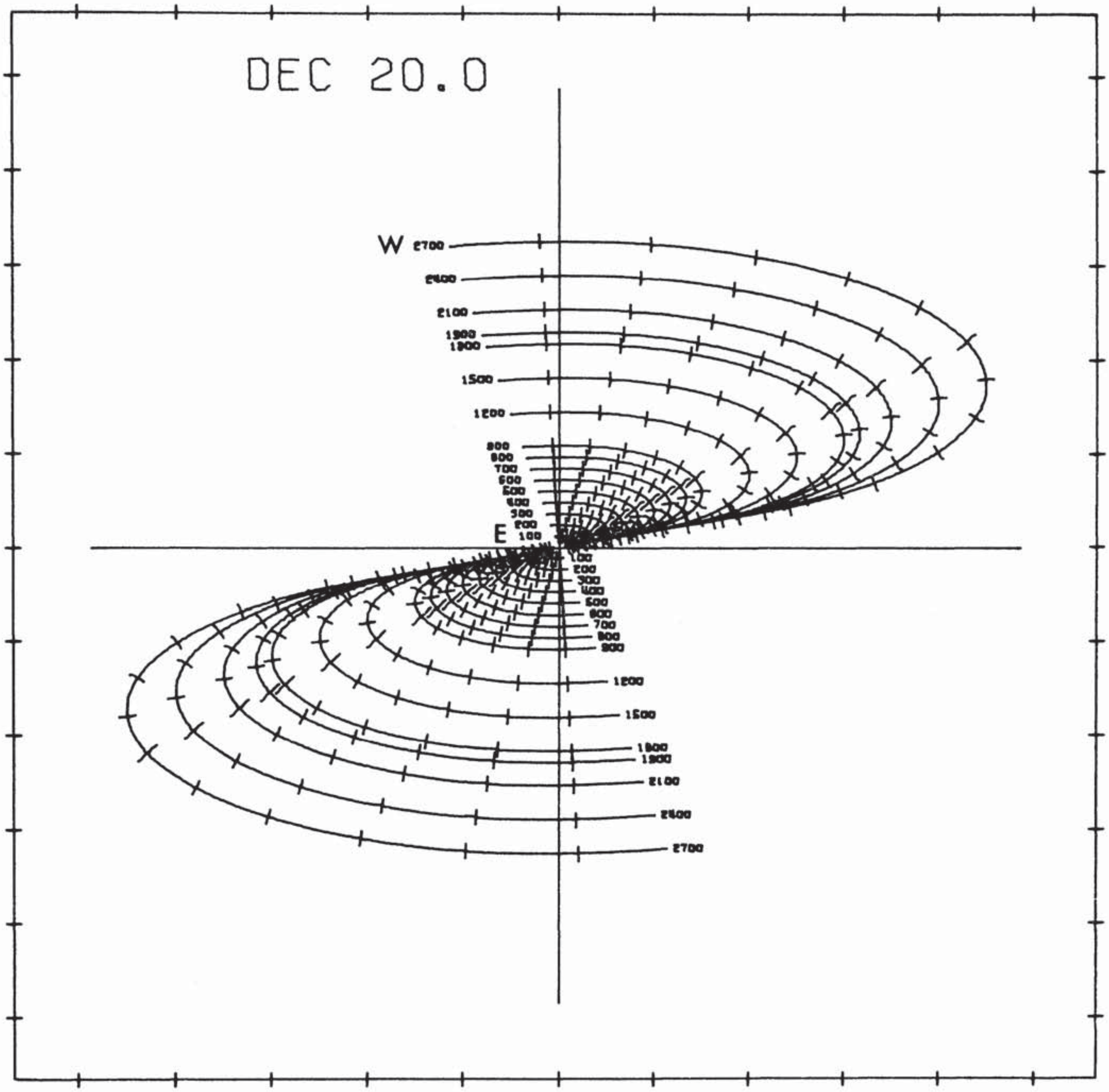

Fig. I-8d. Possible u-v plane coverage for $\delta = 20°$.

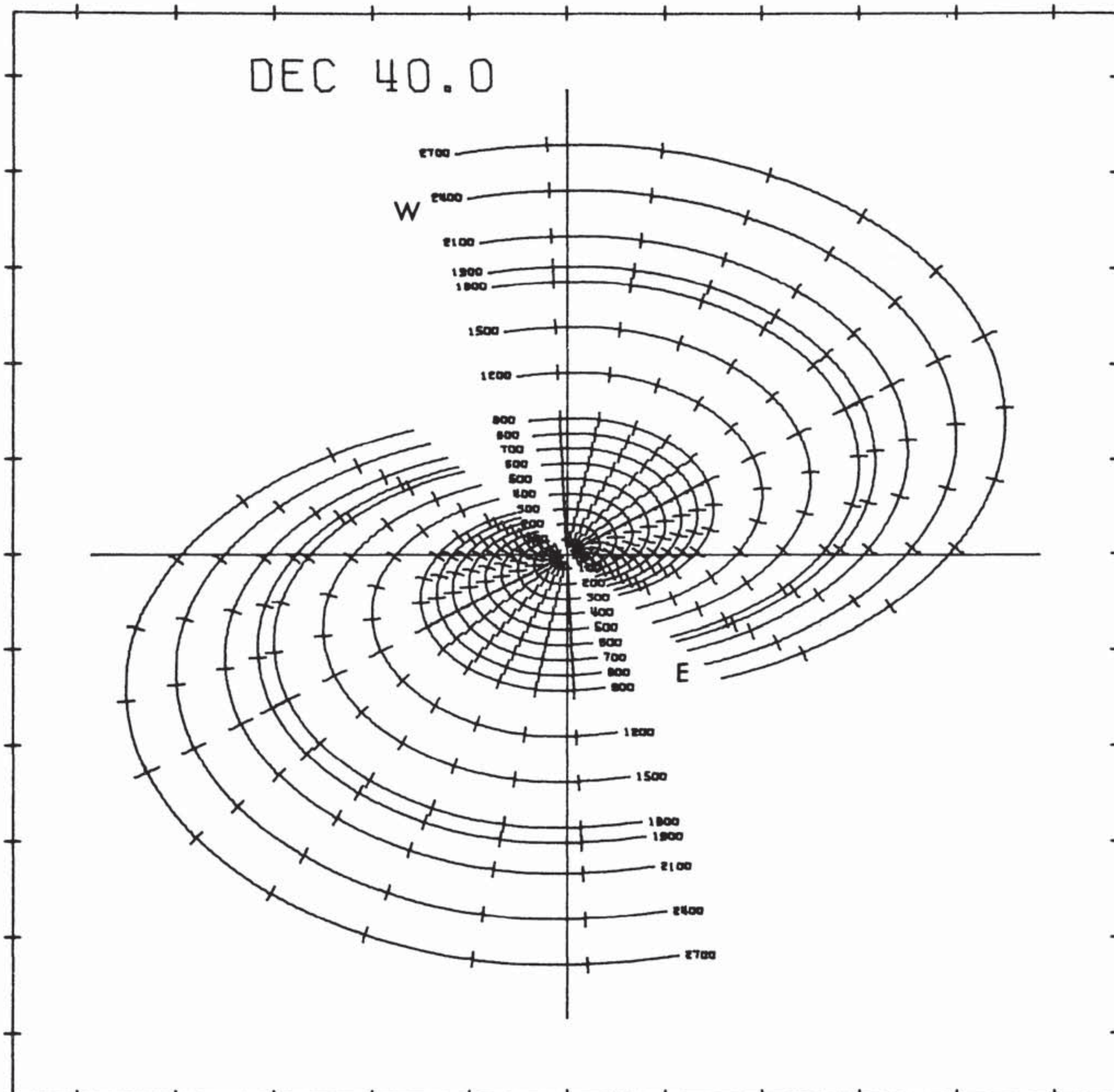

Fig. I-8e. Possible u-v plane coverage for $\delta = 40°$.

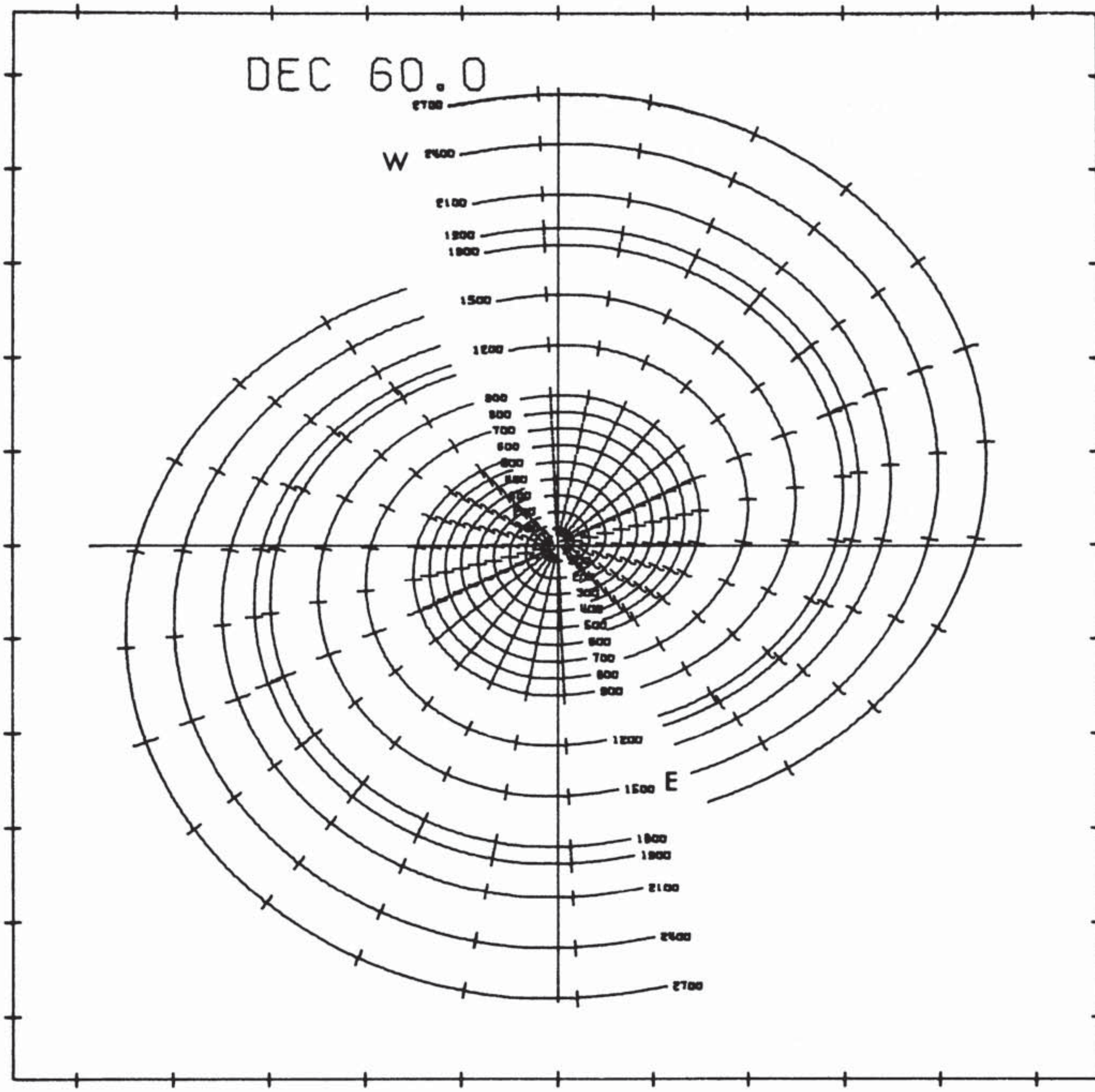

Fig. I-8f. Possible u-v plane coverage for δ = 60°.

Δu and Δv from the origin in the u-v plane. This means that when the source is too large, the limitations of u-v plane coverage cause the spatial frequencies of the largest structures to not be sampled. This means structures with angular sizes greater than $\sim 6'$ at 11.1 cm and $\sim 2'$ at 3.7 cm are undetectable with the NRAO interferometer. This causes a common difficulty when observing sources with structures on size scales ranging from very small to tens of arcminutes or more: Only a small part of the source is detectable--that part corresponding to the spatial frequencies (angular sizes) sampled with the interferometer. When this occurs the observer must be careful because the source he "sees" is not the same as observed with single antennas.

(e) Gridding

How does one, in practice, use Equation I-(28) to obtain synthesis maps (solutions for $f(x,y)B(x,y)$)? First the observer selects a "field of view" which we denote by x_s and y_s. Later we will discuss the reasons for adopting different fields of view. The data gathered for the visibility function $V(u,v)$ is sorted and averaged by (u,v) into a rectangular grid having spacings $\Delta u = 1(2x_s)$ and $\Delta v = 1/(2y_s)$. One can then make use of the fact that, since $f(x,y)B(x,y)$ is real, the function $V(u,v)$ must be Hermitian*, therefore

$$V(-u,-v) = V^*(u,v)$$

where the asterisk indicates complex conjugation. Samples taken in one-half of the u-v plane then provide data for cells in the other half of the u-v plane. Once the complex visibility function has been measured at all of the accessible grid points, the summation equivalent of the integral in Equation I-(28) gives

---

* This is valid for total intensity measurements but not for measurements of the other three Stokes parameters.

$$f(x,y)B(x,y) = \sum_{-u_{max}}^{u_{max}} \sum_{-v_{max}}^{v_{max}} V(u,v)\, e^{-2\pi i(ux + vy)} \Delta u \Delta v. \qquad \text{I-(34)}$$

Maps produced using Equation I-(34) are also gridded and are called "synthesis maps."

(f) Controversial Assumptions

There are two details in this process that are still subjects of controversy. First, do you assume the observed visibilities for a grid point are equal to the averages for all data sampled in the cell or do you interpolate with the available samples to give a value at the grid point? Secondly, when no data has been sampled in a cell, do you set V(u,v) = 0 for that cell or do you take data for available cells and interpolate by some fancy scheme to obtain values for all grid points? In the latter case, the problem of inserting false data (V(u,v) = 0 when it isn't) is offset by the problem that the way you would perform the interpolation could also give spurious results. As of 1973, the standard NRAO mapping programs follow the practice of setting V(u,v) = 0 for unsampled cells. Similarly, data within a cell is simply averaged to get a value for the grid point. Whether these are the best procedures can be argued. More sophisticated procedures are under development, but are beyond the scope of this introduction.

(g) Synthesized Beams

What is the practical effect of limited coverage of the u-v plane when observing a source? This is best illustrated by showing how a point source would look if observed with limited coverage; maps of point sources are referred to as "beam maps" and one can think of such maps as the synthesized beams of the interferometer. The inner portions of synthesized beams for full tracks with $\delta = -40°$, $-20°$, 0, $+20°$, $+40°$, and $+60°$ are shown in Figure I-9, where it is assumed that all available interferometer spacings are used. The effect of partial coverage is shown in Figure

I-10 where only 2700, 1800, and 900 meter spacings are included. Poor u-v plane coverage results in considerably larger sidelobes and more as-symetrical synthesized beams. To evaluate the effects of partial coverage on observations of sources with structure, one can consider each point in the source as having a contribution like the beam image; however, all points in the source contribute negative or positive images at every other point, and the combination, which is determined only by the true radiation structure, is what comes out in the synthesis map. As we will discuss later, this makes it virtually impossible to obtain flux densities from interferometer maps of extended sources and makes it difficult to interpret the reality of minor features in these maps.

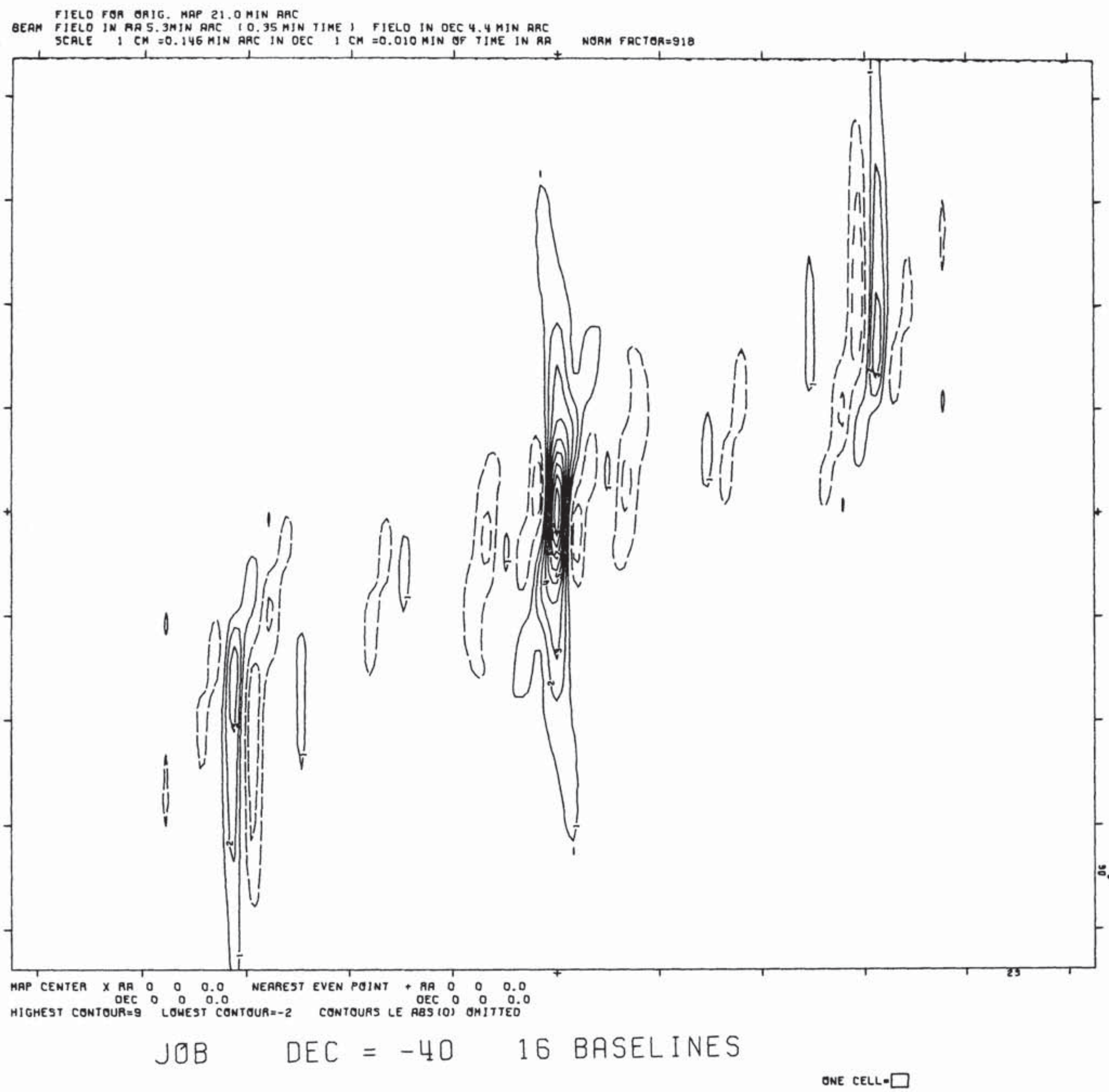

Fig. I-9a. Inner quarter of synthesized beam when $\delta = -40°$, assuming data on all 16 baselines and all possible hour angles are used.

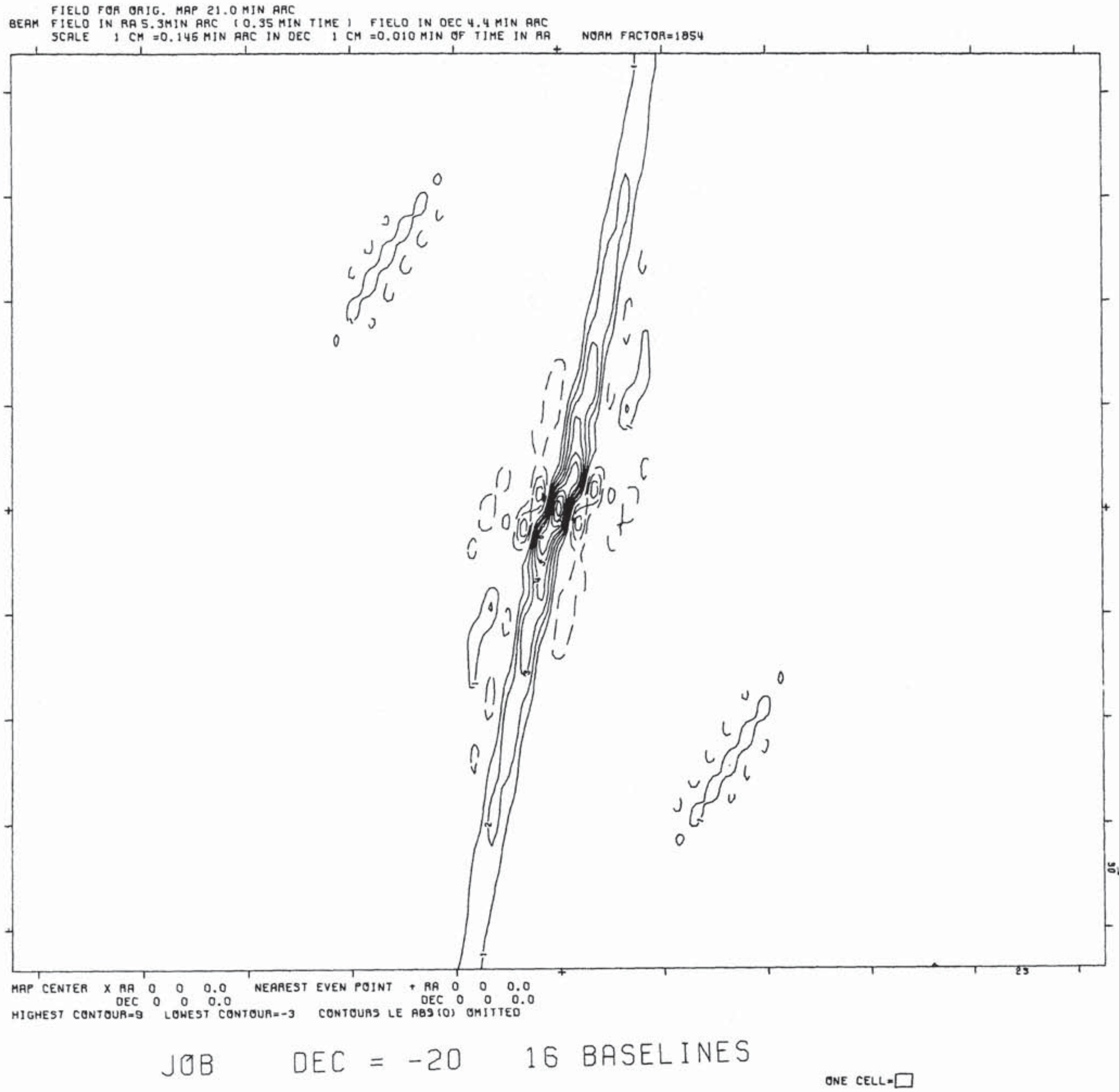

Fig. I-9b. Inner quarter of synthesized beam when $\delta = -20°$, assuming data on all 16 baselines and all possible hour angles are used.

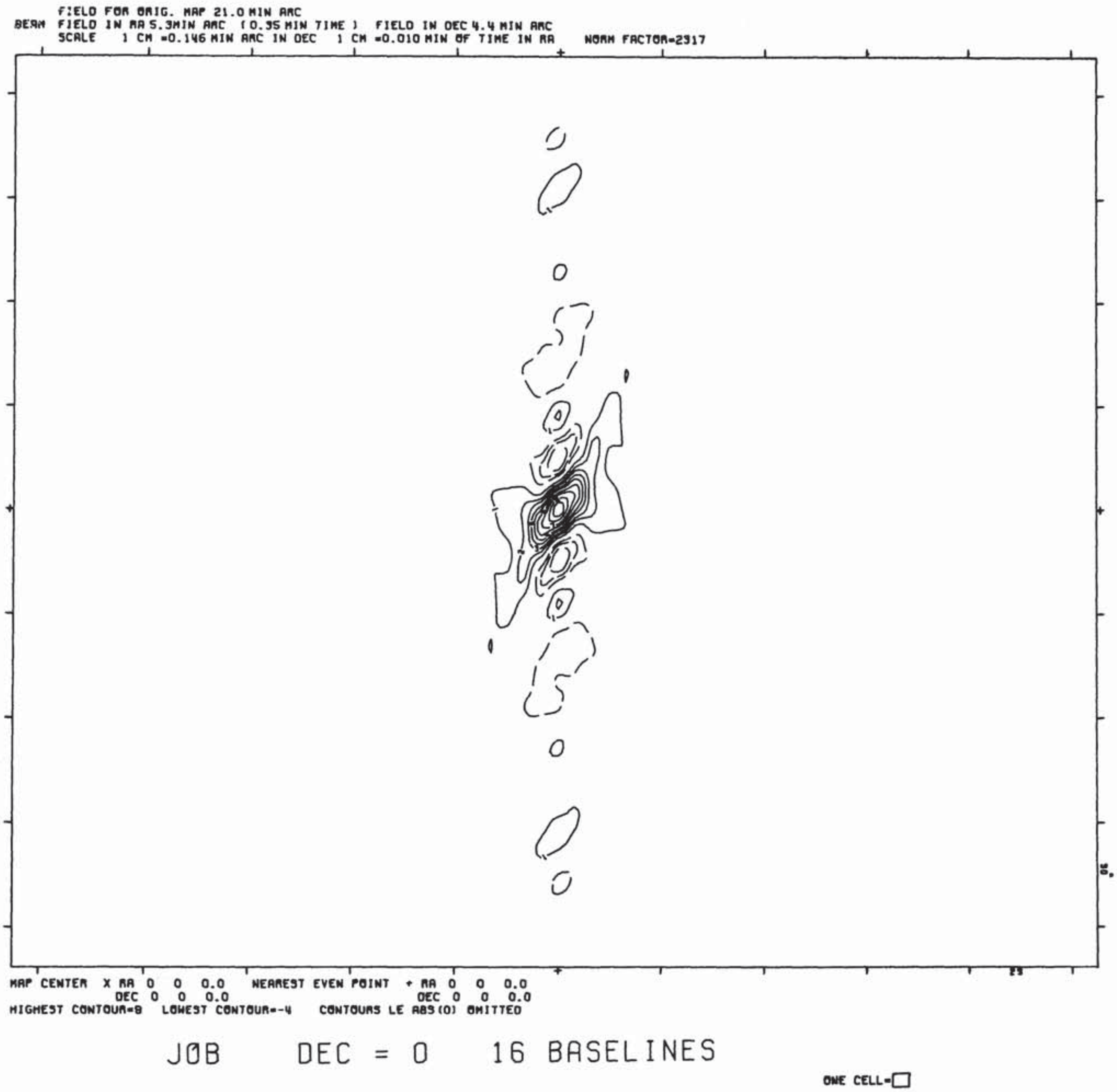

Fig. I-9c. Inner quarter of synthesized beam when $\delta = 0°$, assuming data on all 16 baselines and all possible hour angles are used.

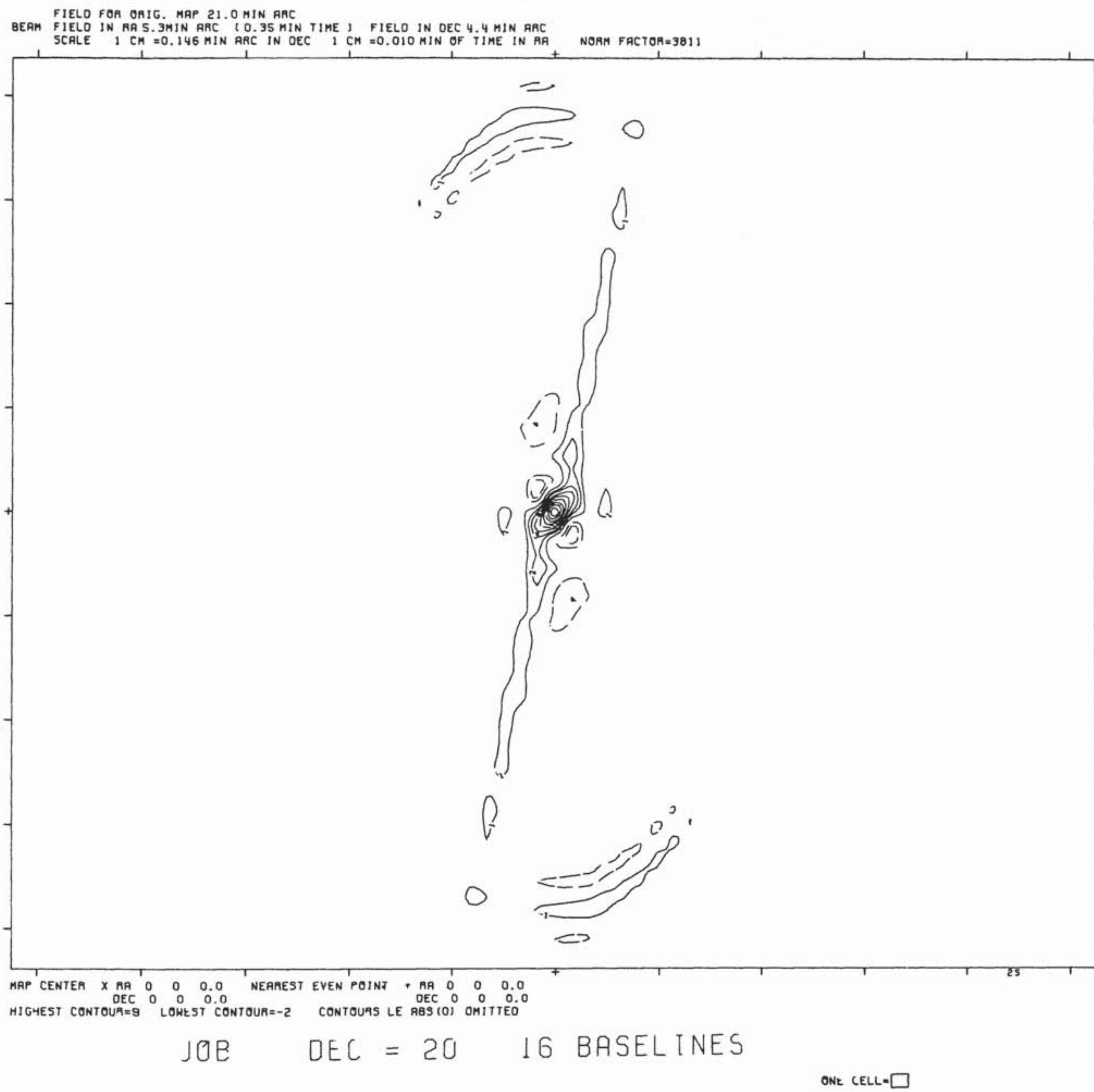

Fig. I-9d. Inner quarter of synthesized beam when $\delta = 20°$, assuming data on all 16 baselines and all possible hour angles are used.

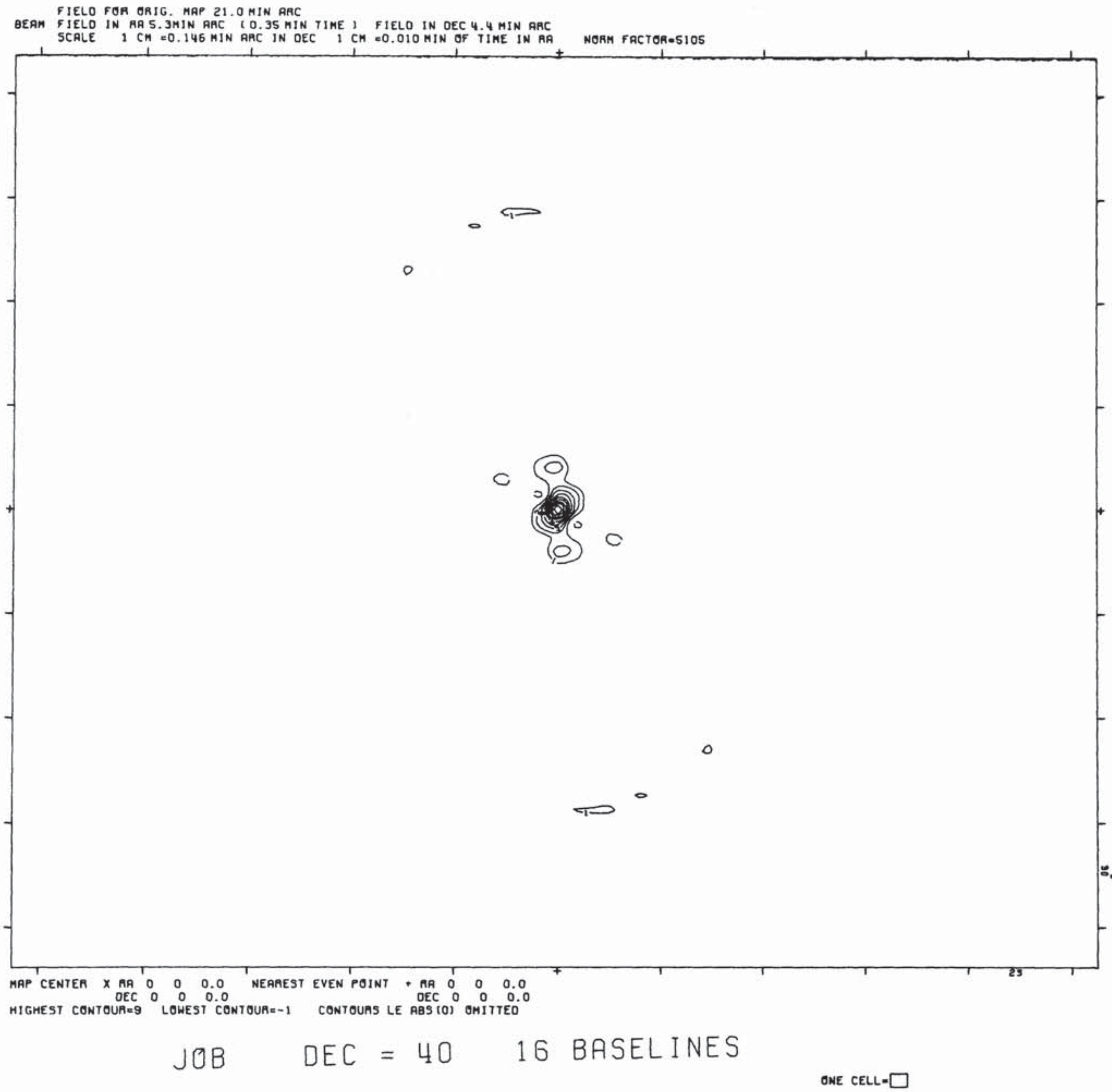

Fig. I-9e. Inner quarter of synthesized beam when $\delta = 40°$, assuming data on all 16 baselines and all possible hour angles are used.

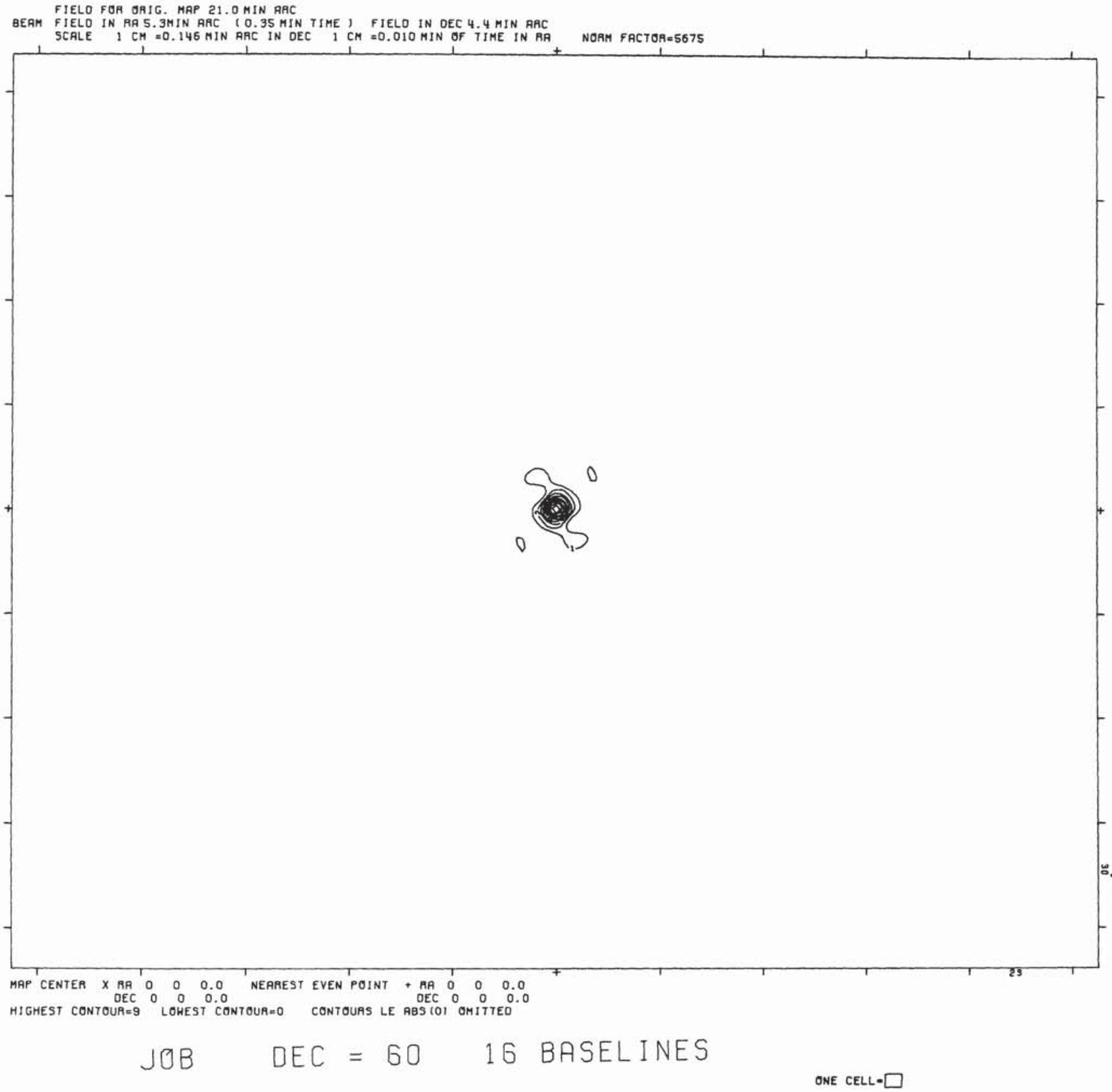

Fig. I-9f. Inner quarter of synthesized beam when $\delta = 60°$, assuming data on all 16 baselines and all possible hour angles are used.

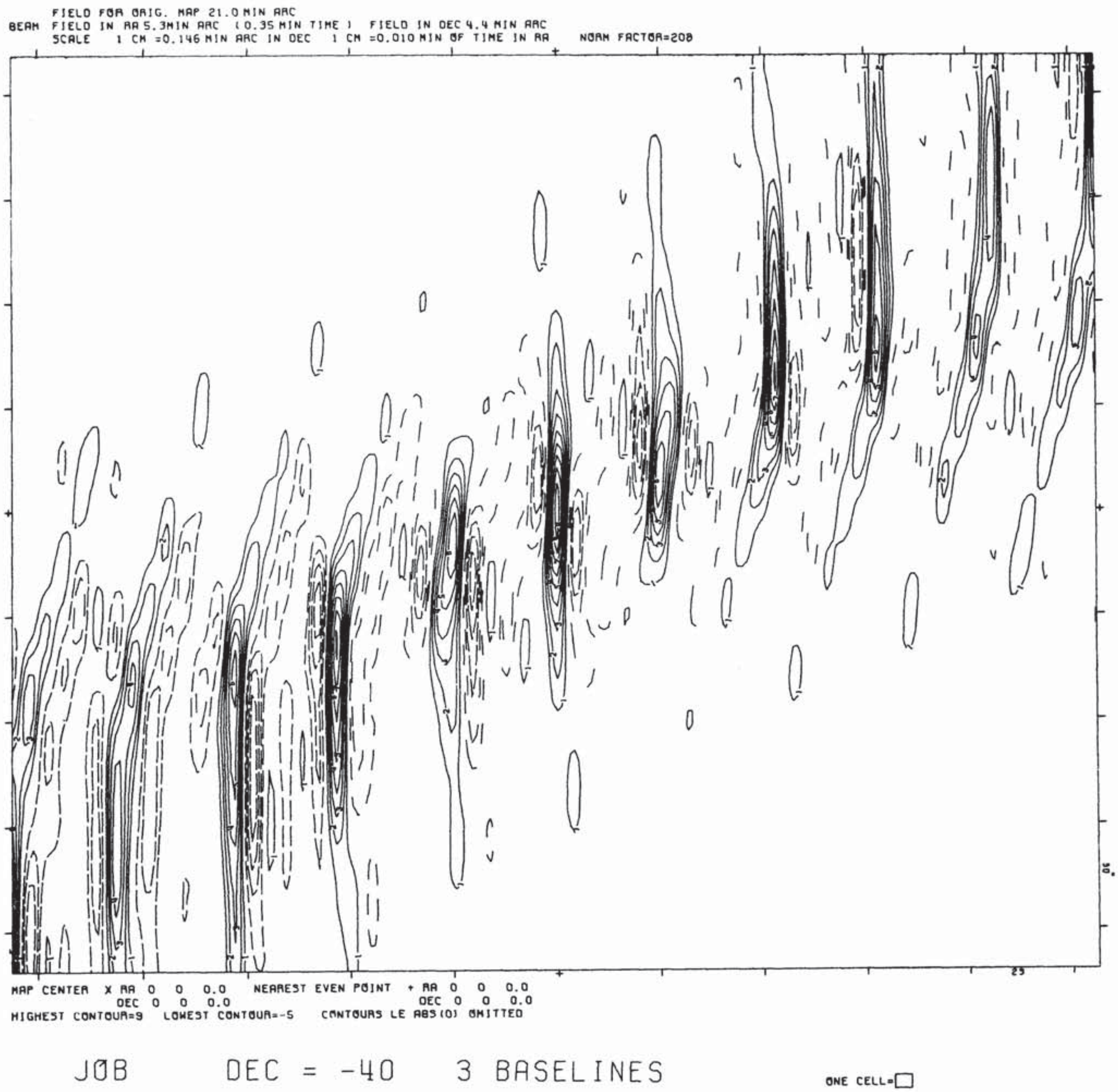

Fig. I-10a. Inner quarter of synthesized beam when δ = -40°, assuming data on only 2700, 1800, 900 m baselines, when all possible hour angles are used.

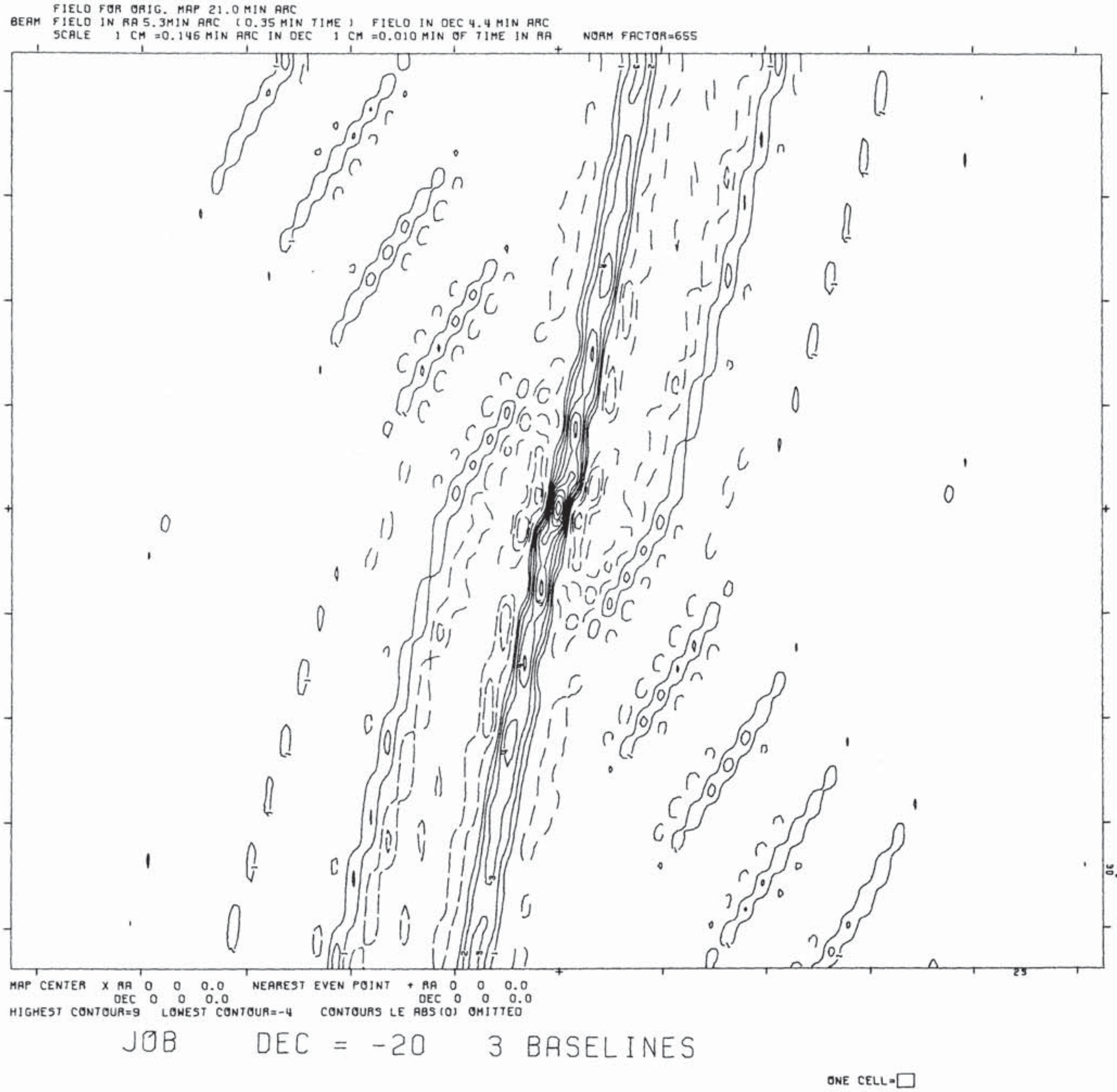

Fig. I-10b. Inner quarter of synthesized beam when $\delta = -20°$, assuming data on only 2700, 1800, 900 m baselines, when all possible hour angles are used.

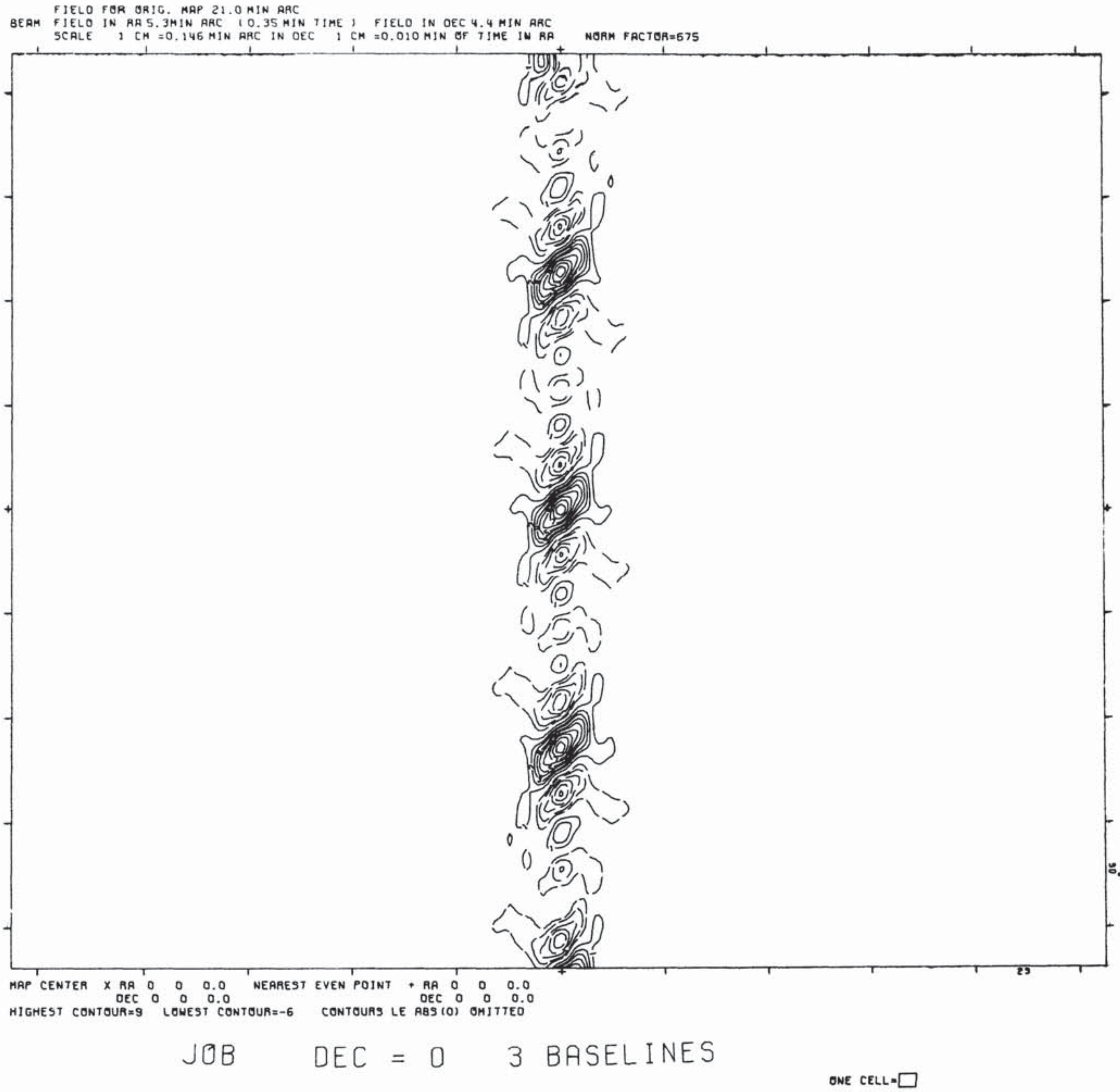

Fig. I-10c. Inner quarter of synthesized beam when $\delta = 0°$, assuming data on only 2700, 1800, 900 m baselines, when all possible hour angles are used.

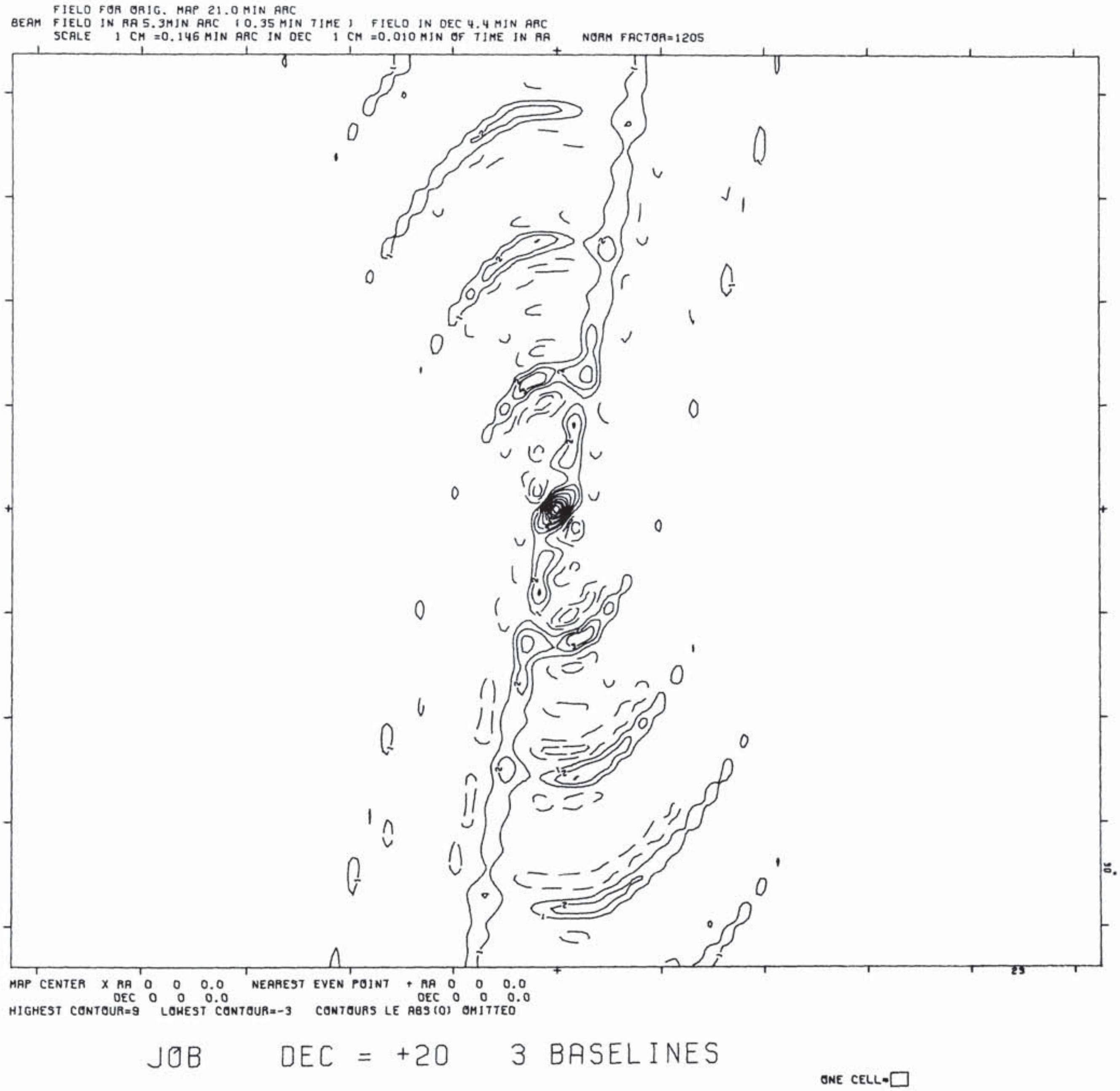

Fig. I-10d. Inner quarter of synthesized beam when $\delta = 20°$, assuming data on only 2700, 1800, 900 m baselines, when all possible hour angles are used.

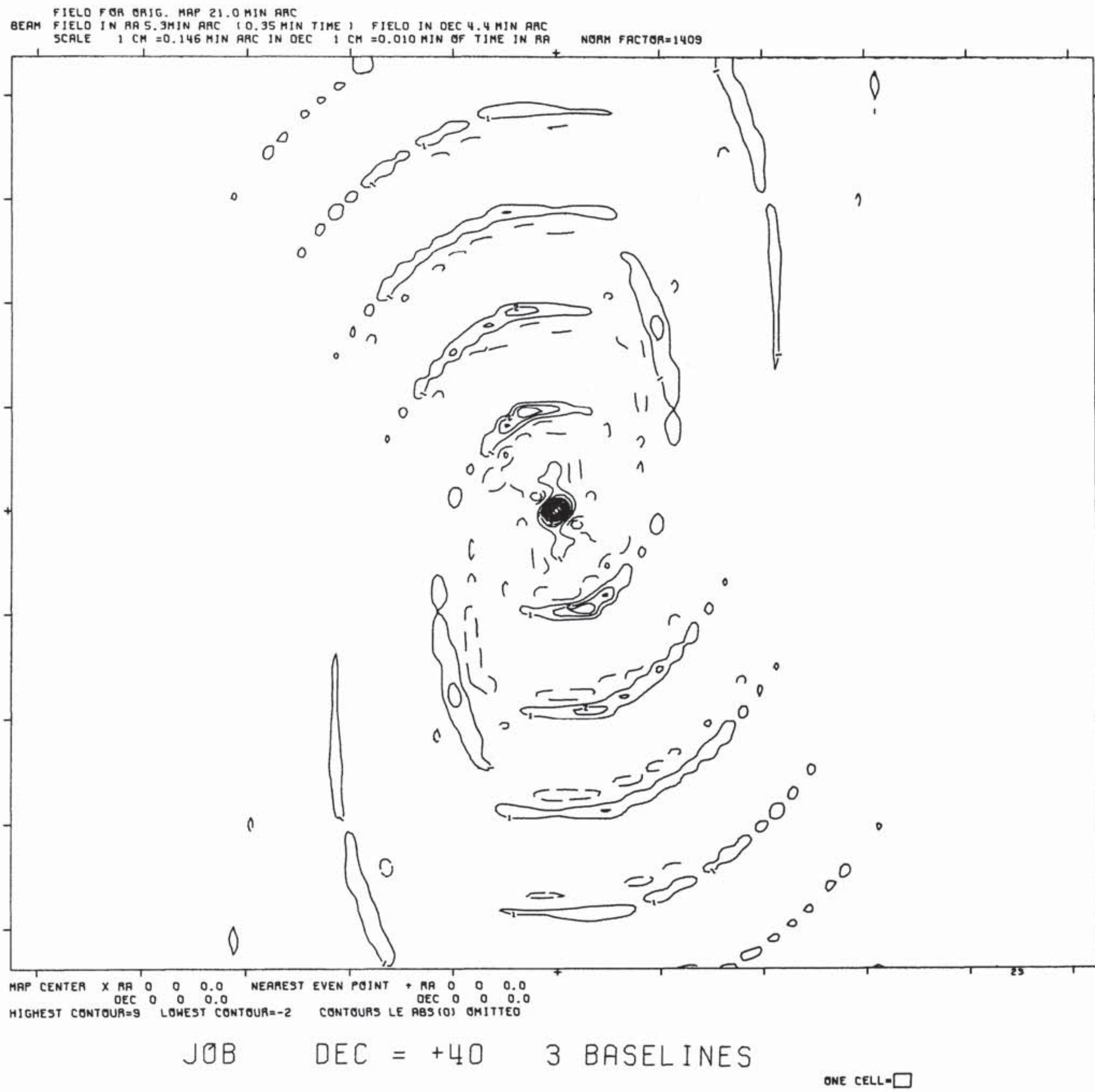

Fig. I-10e. Inner quarter of synthesized beam when $\delta = 40°$, assuming data on only 2700, 1800, 900 m baselines, when all possible hour angles are used.

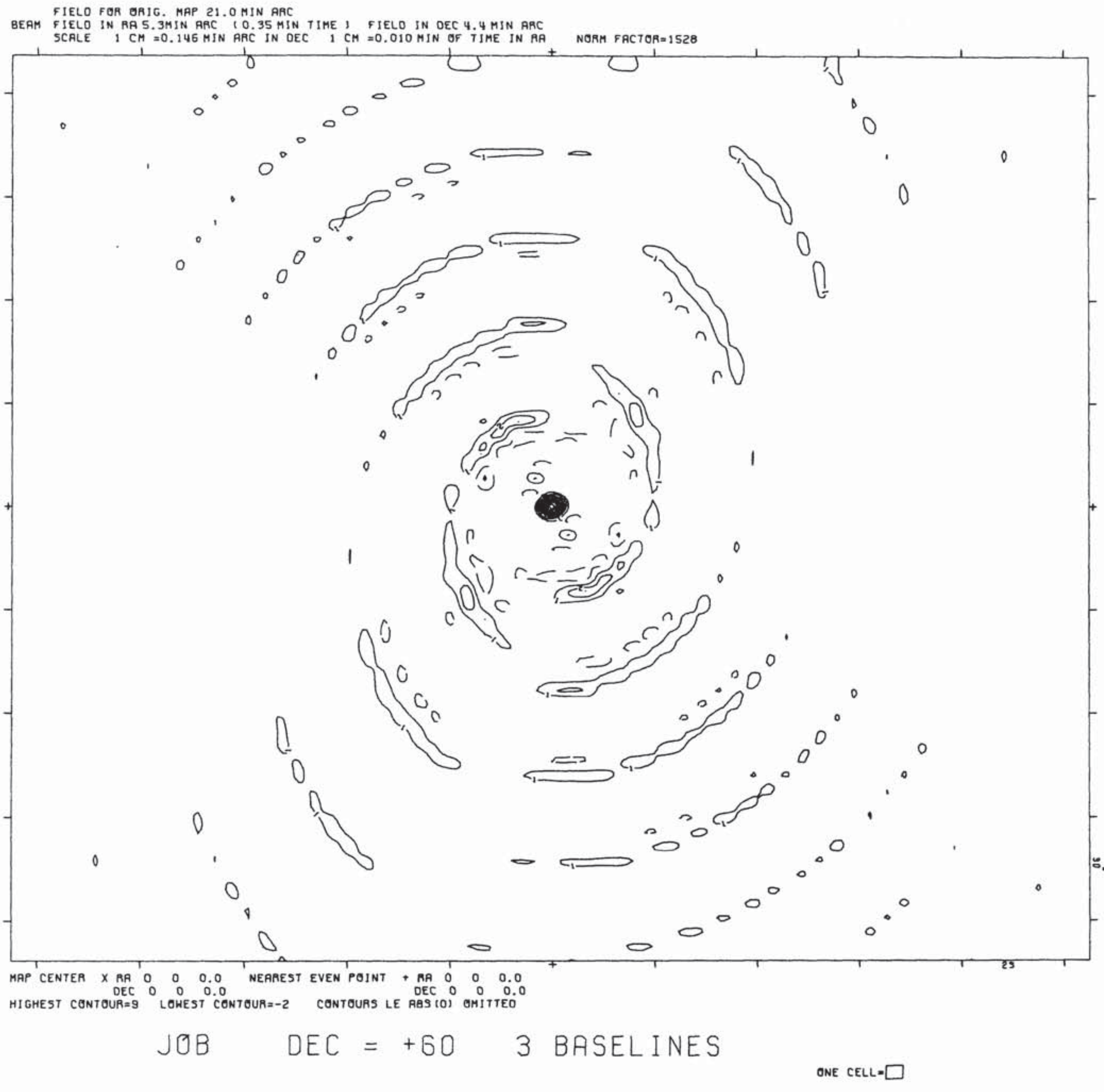

Fig. I-10f. Inner quarter of synthesized beam when $\delta = 60°$, assuming data on only 2700, 1800, 900 m baselines, when all possible hour angles are used.

CHAPTER II

OBSERVING WITH INTERFEROMETER AT GREEN BANK

1. Terminology

As with any instrument, there is a special terminology used to describe the parts and functions of the NRAO interferometer.

The three 85-foot telescopes are identified as 85-1, 85-2, and 85-3. The frontispiece shows a photograph of the three elements of the interferometer and the control building. The fixed telescope, 85-1, is at the northeast end of the baseline, as shown in Figure I-7, and is the furthest telescope in the frontispiece. The second telescope to be constructed, designated 85-2, the nearest telescope in the frontispiece, is movable but always occupies the extreme southwest position. The last telescope constructed, 85-3, is movable and at some intermediate position between 85-1 and 85-2. The telescope pairs are referred to as the 1-2, 1-3, and 2-3 pairs. For example, when 85-2 is on station 27 and 85-3 is on station 18, the 1-2, 1-3, and 2-3 pairs correspond to baseline lengths of 2700, 1800 and 900 meters. The available stations are identified by the first two digits of their distance in meters from 85-1.

The frequency 2695 MHz (wavelength 11.1 cm) is called SBAND and the frequency 8085 MHz (wavelength 3.7 cm) is called XBAND. A particular telescope pair (e.g., 13) observing at a particular frequency (e.g., 8085 MHz) is frequently designated by X or S followed by the pair numbers (e.g., X13).

Each telescope has feeds sensitive to both right (designated R) and left (designated L) circular polarization at both SBAND and XBAND. Thus designation of a particular output pair from the interferometer involves specifying: frequency, pair, and polarization. For example, the 1-3 pair operating at 8085 MHz observing right circular polarization in both telescopes is designated X1R3R or X13R. If the correlation involved R for 85-1 and L for 85-3, it would be designated X1R3L. All output is identified in terms of identifying a particular correlator.

The interferometer operates in four possible modes, called mixed-mode (M), S-mode (S), X-mode (X), and dual-mode (D). The following table shows the correlators involved in each mode, together with the designations that are meaningful when running in these modes, together with the numbers assigned to each correlator:

Mode	Correlator Number	Correlator Designation
M	0	X1R2R (or X12R or X12)
	1	S1L2L (or S12L or S12)
	2	X1R2R (or X13R or X13)
	3	S1L3L (or S13L or S13)
	4	X2R3R (or X23R or X23)
	5	S2L3L (or S23L or S23)
S	0	S1R2R
	1	S1L2L
	2	S1R3R
	3	S1L3L
	4	S2R3R
	5	S2L3L
	6	S1R2L
	7	S1L2R
	8	S1R3L
	9	S1L3R
	10	S2R3L
	11	S2L3R
X	0	X1R2R
	1	X1L2L
	2	X1R3R
	3	X1L3L
	4	X2R3R
	5	X2L3L
	6	X1R2L
	7	X1L2R
	8	X1R3L
	9	X1L3R
	10	X2R3L
	11	X2L3R

Mode	Correlator Number	Correlator Designation
D	0	S1R2R
	1	S1L2L
	2	S1R3R
	3	S1L3L
	4	S2R3R
	5	S2L3L
	6	S1R2L
	7	S1L2R
	8	S1R3L
	9	S1L3R
	10	S2R3L
	11	S2L3R
	14	X1R2R
	15	X1L2L
	16	X1R3R
	17	X1L3L
	18	X2R3R
	19	X2L3L
	20	X1R2L
	21	X1L2R
	22	X1R3L
	23	X1R3L
	24	X2R3L
	25	X2L3R

In mixed mode there is no cross-correlation between different polarizations. In both S- and X-mode the crossed-hand correlators are involved and sufficient information is obtained to determine all four Stokes parameters. In dual-mode the interferometer alternates observation in S-mode and X-mode every 30 seconds. When simultaneous operation at both frequencies is desired, it is usually done in mixed mode unless complete polarization information is desired, then dual mode is used.

The interferometer output from each correlator can be recorded in crude form on six available channels of chart recorders. Each correlator being recorded then has the response function ($R(\Delta t)$) plotted as a function of time at various possible chart speeds. Figure II-1 shows a photograph of four of the possible recording channels in operation. The four channels give the interferometer response for the 1R2R, 1L2L, 1R3R,

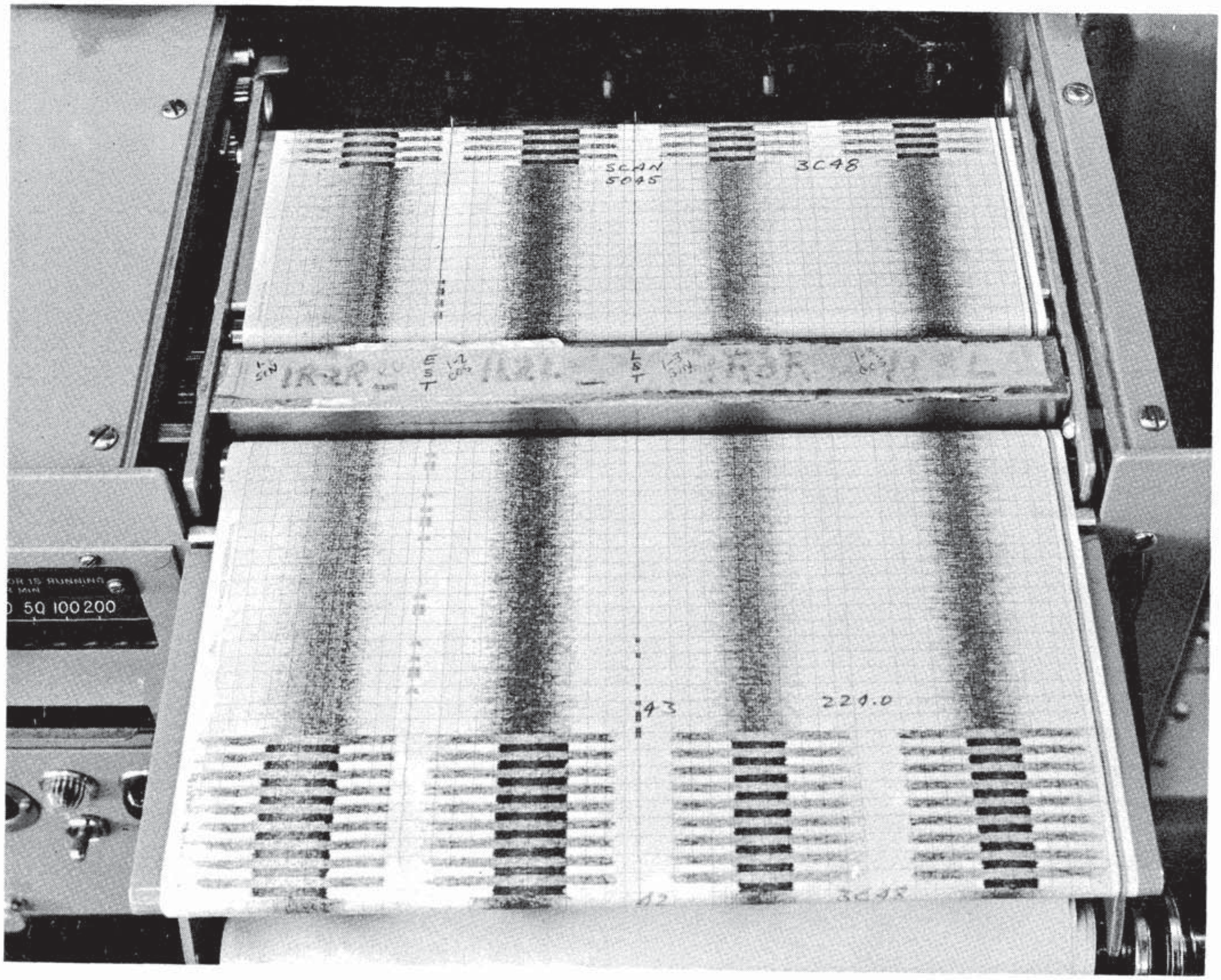

Fig. II-1. Photograph of four-channel chart recorder displaying plots of response functions for four correlators as functions of time.

and 1L3L correlators before the fringe-fitting algorithm has been applied. Scans 5042 and 5043 show the fringes for a strong calibrator, 3C 48, being observed in dual mode with a gain code of 444 (see p. II-13) The pattern for the source "224.0" is characteristic of a pattern indistinguishable from noise, which is also obtained for very weak sources observed with a gain code of 000 (see p. II-13).

The DDP computer, using the "fringe-fitting" algorithm, solves for A(u,v) and ϕ(u,v) (cf. Equations I-(16)-(18) for each 30-second record. To obtain the solution it takes 1500 successive 20 millisecond samples which are used in a least-squares solution for fringe amplitude and fringe phase. All of these data, for all correlators, are recorded on magnetic tape, together with a great deal of information concerning the observed source, time, and the state of important interferometer functions. We will discuss the format and uses of this output in Chapter III. The data measured for each 30 seconds is referred to as a data record.

There are two more ways of examining the on-line output of the interferometer. The teletype output records source name, source position, scan number, and other information concerning the status of the system. Then, once the scan (the period of time the source is tracked continuously) is completed, the vector average of amplitudes and phases for each scan for each correlator are printed out, together with the rms variation of the amplitudes and more information about the state of the system. A photograph of the teletype and its output is shown in Figure II-2. There is also a CRT display which can exhibit, for each 30-second data record, any six of the following: A(u,v), ϕ(u,v), $\mathcal{R}$ (u,v) and $\mathcal{I}$ (u,v) for different correlators. None of this data has been phase-centered or calibrated in any way. All values of A(u,v), $\mathcal{R}$ (u,v) and $\mathcal{I}$ (u,v) are measured in counts. Under normal operation there are roughly 1000 counts per flux unit (frequently abbreviated CPFU); hence one count is roughly one milliflux unit. In practice the appropriate counts per flux unit varies with each correlator, with 1200 being typical for SBAND correlators and 800 being typical for XBAND correlators.

Fig. II-2. Photograph of teletype and teletype output whereby one communicates with DDP116 and in return receives information about system, observation status, scan averages, etc.

2. Pointing Calibration

The first calibration procedure necessary to observe with the NRAO interferometer is pointing calibration of the individual antennas. When one of the telescopes has been moved and placed at a new observing station it cannot be assumed that the pointing properties are the same as before. Therefore, pointing calibration must be carried out after each move. In addition, even though 85-1 does not move, over a long period of time things can change so occasional pointing checks must be made for this antenna also.

Pointing calibration is quite straightforward. The computer is told to run the interferometer in pointing mode and observations are made of a large number of strong sources covering as many hour angles and declinations as possible. The observations on each source consist of the measurement of the total power received at each of four off-set positions plus the "actual" position where the source should be. A simple computer analysis of the results for each set of five observations is interpreted in terms of (true minus apparent) position shift in hour angle and declination. This data, for a complete range of hour angles and declinations, is used to determine the constants in an empirical formula predicting the needed corrections in hour angle and declination for every point in the sky. Once all the data has been obtained, this fit is made (with the DDP and/or the Charlottesville computer). Then the goodness of fit is evaluated in terms of both the fit to each actual observation and the mean rms fit. Good solutions are obtained when (1) the predicted and actual errors agree to less than about 1 arcminute for all points; (2) the total rms is of the order of 0!4 or less; and (3) the fit is uniformly good over the whole sky. Once the pointing constants are determined they are read into the DDP and remain in force until the next move.

In general, NRAO staff will do pointing calibration after each run. However, occasionally circumstance may make it necessary for the observer to do this. In this case the observer should read the special manual discussing the method of obtaining the pointing solution through use of the DDP and the CRT display. The observer is cautioned to resist all temptations to cut the pointing observations short to get on with the science. Extra observing time is always allotted to do such calibrations and succeeding observers must depend upon the initial calibration. Very poor pointing calibration can result in large, non-random variations of amplitudes.

3. Setting Delays

After the pointing calibration has been made and the pointing constants are read into the DDP, the next calibration necessary is the setting of the delays. As shown in Chapter I, when tracking a particular point in the sky, called the reference position, there is a geometrical time delay Δt reflecting the time difference in arrival of the same wave front at two different telescopes. In the electronics a computer controlled digital delay system inserts a compensating delay $\Delta\tau$ for each pair of telescopes. When $\Delta\tau-\Delta t$ is kept close to zero, the envelope function, which is, under ideal conditions approximated by

$$F(\Delta t-\Delta\tau) = \frac{\sin \pi\Delta\nu(\Delta\tau-\Delta t)}{\pi\Delta\nu(\Delta\tau-\Delta t)} \cos \omega_{IF} (\Delta\tau-\Delta t), \qquad \text{II-1}$$

can be kept near unity. By delay switching with times as short as 2 nanoseconds $F(\Delta t-\Delta\tau)$ can be kept to between 0.98 and 1.0.

Although the changes in delays are maintained to this accuracy by the computer, each telescope pair, when the cable lengths are altered during a move, has a change in the travel time from telescope to the multiplier. Because of this the cable lengths for each pair must be adjusted so that, when tracking, the observations are made with maximum $F(\Delta t-\Delta\tau)$. This can be determined by letting untracked sources drift through the beam. The characteristic "sausage" pattern (see Fig. I-3) observed on all correlators on the analog output is then used to adjust the delays for each pair. In general only NRAO staff or experienced observers will be responsible for carrying out this important calibration.

4. Baseline Calibration

There is another important calibration which will also usually be carried out by NRAO staff or experienced observers after the above-mentioned calibrations are finished. This is the determination of the baseline constants, B_x, B_y, and B_z (cf. Chapter I). Observations of a number of calibrators over a range of hour angles and declinations permit one to determine errors in any assumed set of baseline constants as follows. The interferometer response for a point source at the reference position is

$$R = S \cos 2\pi \underset{\sim}{B} \cdot \underset{\sim}{s}_o$$

Earlier we discussed the fact that one can determine the displacement vector $\Delta\underset{\sim}{s}$ from phase data for a point source. It is obvious that if

$$\underset{\sim}{B} = \underset{\sim}{B}_{true} + \Delta\underset{\sim}{B}, \qquad \text{II-(2)}$$

then the spurious phase shifts due to baseline errors are given by (cf. Equation I-(4)

$$\Delta\phi = \Delta\underset{\sim}{B} \cdot \underset{\sim}{s}_o = \Delta B_x \cos\delta \cos H - \Delta B_y \cos\delta \sin H + \Delta B_z \sin\delta. \qquad \text{II-(3)}$$

Obviously sufficient data in $\Delta\phi$ as a function of δ and H will permit a least squares solution for (ΔB_x, ΔB_y, ΔB_z). A special program called INTBCAL is used to obtain these solutions. Normally NRAO staff will update the baselines read into the DDP 116 after the calibration run for each move.

5. Practical Planning of Programs

If we assume that observing requirements of program sources are clearly known, the practical procedures of planning the observing for the interferometer is very straightforward. We assume the observer has in hand the following for all the sources he wishes to observe:

1. A name of ten characters or less with no imbedded blanks.
2. Right ascension and declination of epoch 1950.0.

The program then can be planned within the following limitations:

1. Mechanical limits:

   For sources with $\delta \geq 0°$, hour angles cannot exceed $\pm\ 5^h40^m$. For $\delta < 0°$, hour angles cannot exceed $\pm\ 4^h40^m$. In addition declinations greater than +86° and less than -46° are inaccessible.

2. Mountain limits:

   In the west, at large positive hour angles, the telescopes can begin observing the mountains. Figure II-3 shows an approximate outline of the mountains as seen by 85-2 on station 27. If the observer does observe a source into the mountains, he will see it clearly in the data because, firstly, the total powers increase rapidly and, secondly, the correlated signal begins decreasing in amplitude. When this occurs it is safest to delete all data with excessive total powers.

3. Atmospheric limits:

   The amount of atmosphere being observed through can affect the amplitude calibration slightly and the phase data a great deal. At low elevation angle, variations in the atmosphere clearly dominate the phase "noise", and these effects cannot be calibrated out. Therefore, one must adopt a minimum elevation angle below which no sources are observed. Where this limit is put depends upon how conservative the observer is, and how badly the observer needs the extra information at extreme hour angles. A moderately conservative limit is 15°. A less conservative limit is 10° and the observer flirts with trouble with a limit of 5°. Examination of Figure II-3 will allow the observer to translate these elevation limitations into hour angle limits for any declination.

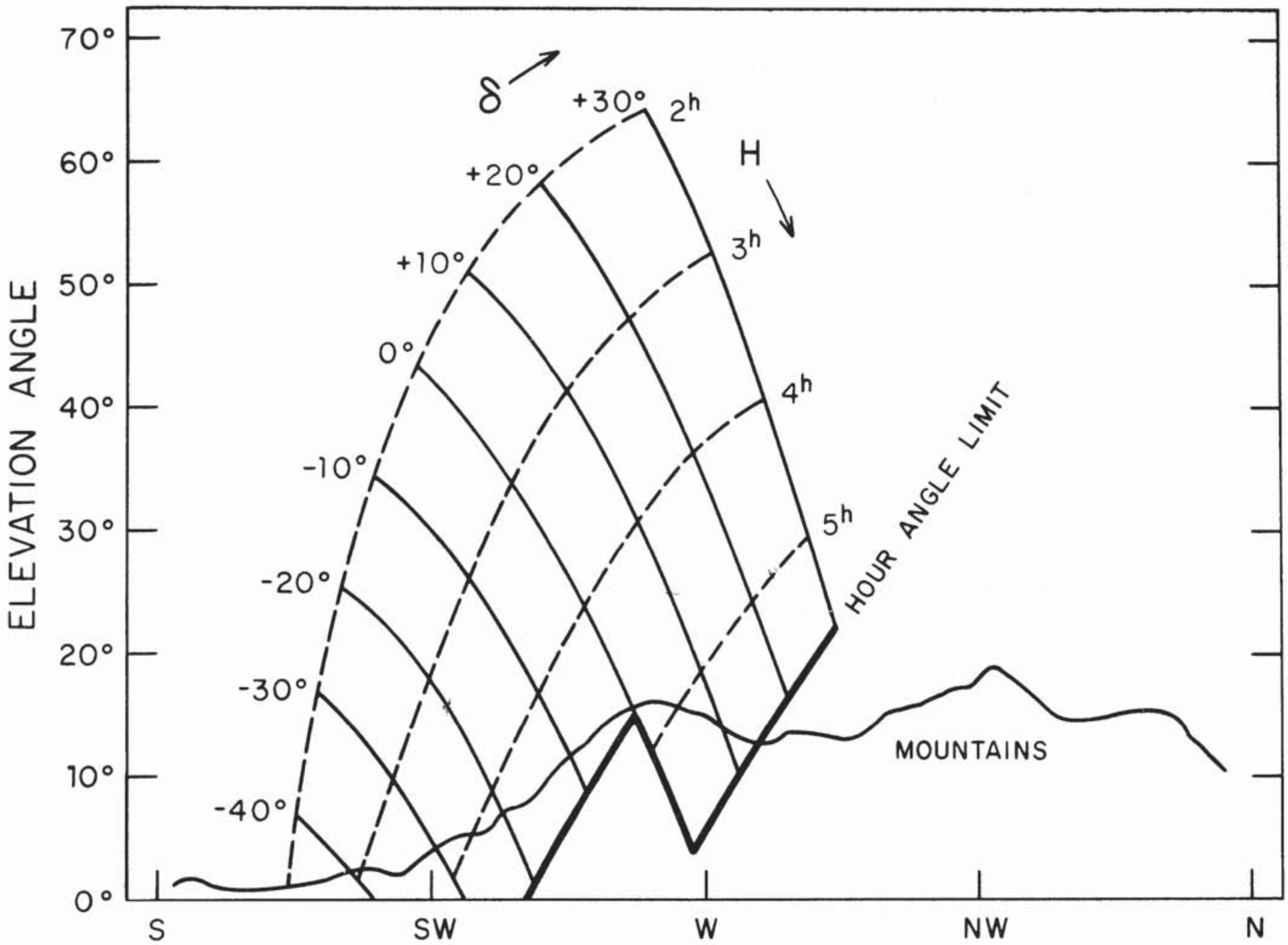

Fig. II-3. The elevation of the mountains, as seen from station 27, as a function of direction, with indication of possible hour angles and declinations for the telescopes.

The next step is to plan the times when program sources are to be observed. For various practical reasons it is useful to divide the observations into a number of 25 to 50 minute scans. Teletype printouts of the raw scan averages for a 2 minute scan will have rms' corresponding to roughly 0.01 f.u. (normally about 10 counts). This is also a convenient division to deal with when processing data in Charlottesville. For some purposes, when strong sources are involved, scan lengths of 10 or 15 minutes will be used. It is also recommended that the observer schedule an observation of a calibrator about once an hour. Some people prefer to observe a calibrator only once every two hours, but this can be inconvenient when system changes need to be monitored. A reasonable procedure is ten minutes per hour on a strong calibrator and 50 minutes per hour observing program sources. An observer may not want to spend this much time on calibrators, but it is wise to do so. Regrets occur when the observing time is used up and calibration is later found to be insufficient.

The two goals sought when monitoring calibrators are: (1) monitoring gain changes in the correlators used in observing the program sources; (2) monitoring for system phase changes (ϕ_s in Chapter II). There are now sufficient numbers of point sources with excellent positions that any of the many sources listed in Appendix 1 will provide good phase calibration. Appendix 1 also gives a list of flux densities of varying dependability. It is recommended that every day some observations of sources like 3C 48 and 3C 286 be included to tie down the flux and gain calibration. Whenever possible pick phase calibrators which are also good flux calibrators. It is important to use the calibrators given in Appendix 1, with exactly the same spelling of names and 1950.0 positions, so the automatic reduction programs will be able to recognize the calibrators.

Choice of calibrators is usually made on the basis of compromising between the best calibrators available and the closest ones to the program source being observed. If the sources and calibrators are too far apart, considerable time is spent just moving telescopes. It takes about one minute to move one hour in right ascension or 15° in declination. The network of calibrators listed in Appendix 1 is extensive enough that a good calibrator can almost always be found within a couple minutes moving time of any program source. The list of excellent flux calibrators is, however, much spottier; and polarization calibration (Appendix 2) suffers even more difficulty. In the last analysis the observer must judge advantages and disadvantages in terms of what he is trying to accomplish.

Finally, once the program is laid out and specified in terms of the LST of the stopping time for each scan on each source, the observer must assign a gain setting to each source. This is because of the basic limitation that the correlators saturate above roughly 5000 counts. Therefore gain steps must bring down the count level when the source is too strong. During operation between June 1970 and Janaury 1971, the counts per flux unit (CPFU) were typically 1000 to 1200 for the SBAND correlators and 600-800 for the XBAND correlators. Therefore, the following table gives rough rules of thumb for assigning gains:

FLUX DENSITY		NUMBER OF GAIN STEPS		
SBAND	XBAND	SBAND	XBAND	GAIN CODE
> 4 f.u.	> 4 f.u.	1	1	444
> 4	< 4	1	0	111
< 4	> 4	0	1	333
< 4	< 4	0	0	000

Higher gain codes can be assigned, but there are few sources with Fourier components stronger than 40 f.u. likely to be observed with the interferometer. The final gain is calculated from $G = G_s + 3G_x$ where $G_s = 0, 1,$ etc., and $G_x = 0, 1,$ etc. The amplitudes are to be reduced a factor of ten for each gain step. It is possible that under the rare circumstance of a very strong source at short spacing, which is very resolved at long spacings, gain codes like 014 could be used indicating no gain steps for the 12 correlators, one SBAND gain step for the 13 correlators, and one gain step for both SBAND and XBAND for the 23 correlators.

All of the calibrators in Appendix 1 have at least roughly known densities so that gain codes can be assigned. When cross-hand correlators are included, there are never any gain steps applied. It is not necessary since there are no strong sources that are sufficiently polarized.

The last step is punching the abovementioned information on the cards in the format shown in the example in Figure II-4. A C punched in column 40 indicates a calibrator; columns 66-80 can be used for comments. When column 38 is left blank, an epoch of 1950.0 is assumed for the punched position. If a D is punched in column 38, the precessed position may be punched on the card.

In normal operation the observer provides a deck of program cards covering all of the observations planned during any particular observing period. However, after the observing deck has been made up, there is one further detail that must be taken care of. As the data is collected, it is stored on disk in the DDP 116; however, no more than about 15 hours of data can fit on disk. It is the responsibility of the observer to indicate when the dump from disk to magnetic tape should be made. For 24 hours of data this is essentially twice a day. In addition, the observer must indicate at what point the data should be sent to Charlottesville for processing. Since the data tapes are picked up between about 0800 and 0830 local time in the morning, one usually designates a dump just before this. Normal procedure is to call for the first dump in the early evening by writing DUMP 1 on the observing card preceding the dump time; then the next dump is called for in the early morning by writing DUMP2 and SEND TO CV on an observing card.

6. The Green Bank Staff

With the exception of preparation of program cards and analysis of data output, the interferometer observer does nothing with the interferometer equipment. The observer should realize that dials are not to

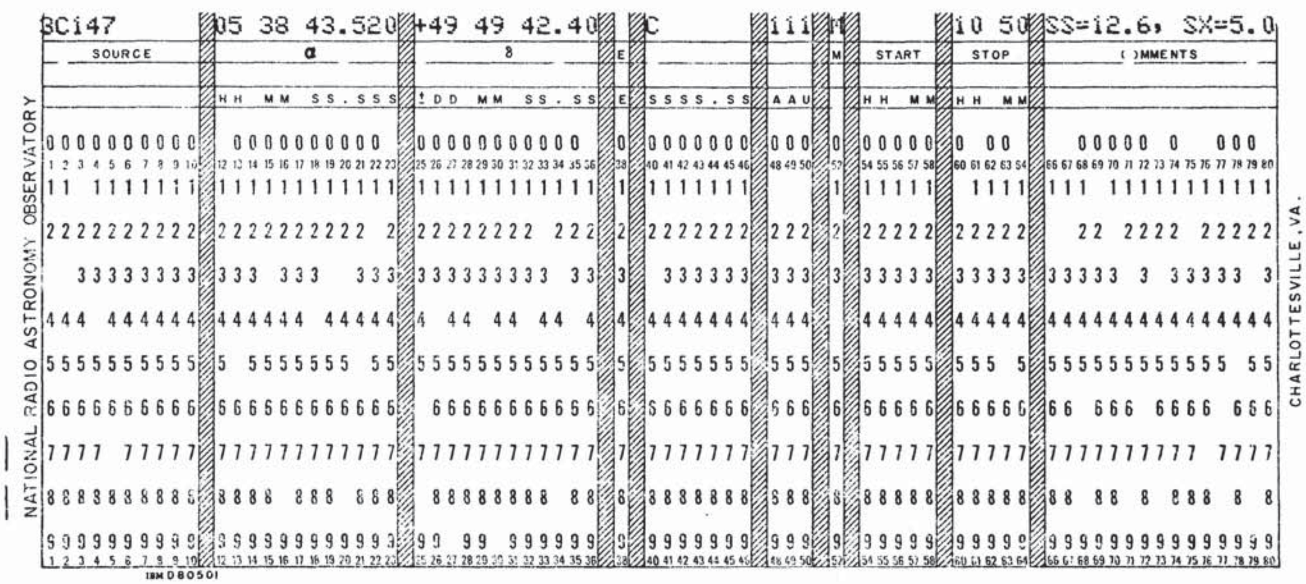

Fig. II-4. A sample program card gives the interferometer instructions that the calibrator 3C147 is to be observed in mixed mode, with one SBAND gain step and no XBAND gain steps, until 10:50 LST.

be twiddled and switches are not to be flipped, at least by him. The operation of all equipment is the sole responsibility of the operators who work under the direction of the head operator and in close collaboration with a group of electronic specialists, digital specialists, and programmers. The operators have the responsibility to: (a) See that the observer's program cards are properly loaded into the control system; (b) See that all proper data is being recorded normally; (c) Keep a log (see examples in Figure II-5) of observations carried out; (d) Monitor essential indicators to see that the instrument is functioning normally; (e) Call for the appropriate specialists when malfunctions are found; (f) Shut down part or all of the system in case of equipment problems, excessive snow or ice on dishes, or excessive winds; and (g) keep in close contact with the observer so that program decisions can be made where necessary and so the observer is at all times aware of possible problems with the instrument. The observer can always make requests or ask questions but the operators have final authority on the operation of the instrument. This is necessary because occasionally the safety of operation can conflict with the natural desire of the observer to not lose essential data. In most cases the operator will, if possible, talk over a problem with the observer before taking drastic action. It is strongly recommended that observers take the trouble to develop friendly and courteous relationships with the operators.

The operators are not expected to be able to diagnose subtle malfunctions of the interferometer which can be detected only by examination of the on-line output, particularly of the calibrators, although they are familiar with the way normal fringes on strong calibrators should look on the chart recorders. It is, therefore, the observer's responsibility to monitor the on-line output to detect subtle malfunctions. The most serious of these are: (a) A receiver or delay line malfunctions so that no signal is obtained for the appropriate correlators -- the operators will frequently notice this for the calibrators, but only the observer can judge how a particular program source should appear on-line;

INTERFEROMETER OBSERVING LOGS

PAGE NO.: 4815 DATE: 4/5 MAY 72 OPERATOR: DS LW OBSERVER: J. SPENCER PROGRAM: B73 RCVR. FREQUENCY: 2695 8085

TAPE NUMBER: 132

L.S.T. CLOCK ERROR: +73.2 ms Fast at 00:00 EST.

RCVR. WAVELENGTH: 11.1 3.7 cm

SCAN NO.	OBJECT	EST START	EST STOP	85-1 I RA H M S	85-1 I DEC ° ' "	85-2 I RA H M S	85-2 I DEC ° ' "	85-3 I RA H M S	85-3 I DEC ° ' "	TELESCOPE HOUR ANGLE	COMMENTS
4584	3C48	1644	1652	01 36 32	33 00 20	01 36 23	33 03 38	01 36 15	33 00 30	0540	DUMP
85	3C273	1705	1721	12 27 39	02 10 31	12 27 24	02 13 09	12 27 21	02 10 50	-0451	X BAND
86	"	1723	1728	12 27 42	02 10 31	12 27 27	02 13 19	12 27 24	02 10 21	-0432	S BAND
87	NCG5194	1731	1753	13 28 45	47 18 25	13 28 47	47 20 14	13 28 35	47 18 15	-0525	
88	H2N051SNR	1753	1818	13 28 58	47 17 46	13 29 00	47 19 24	13 28 48	47 17 16	-0503	
89	3C286	1819	1828	13 29 52	30 37 27	13 29 49	30 38 46	13 29 38	30 36 48	-0438	
4590	NGC5194	1829	1853	13 28 45	47 18 25	13 28 49	47 20 14	13 28 37	47 18 35	-0426	
91	H2N0515SNR	1853	1918	13 28 59	47 17 36	13 29 02	47 19 24	13 28 50	47 17 16	-0403	
92	3C286	1919	1928	13 29 56	30 37 37	13 29 51	30 38 56	13 29 40	30 36 38	-0338	
93	NGC5194	1929	1952	13 28 47	47 18 15	13 28 51	47 21 13	13 28 39	47 18 45	-0327	
94	H2N051SNR	1953	2017	13 29 02	47 18 15	13 29 03	47 19 54	13 28 53	47 17 06	-0303	
95	3C286	2019	2027	13 29 58	30 37 57	13 29 53	30 39 56	13 29 44	30 36 48	-0238	
96	NGC5194	2029	2052	13 28 48	47 19 24	13 28 52	47 21 53	13 28 41	47 19 15	-0227	
97	H2N051SNR	2053	2117	13 29 00	47 17 56	13 29 07	47 20 53	13 28 55	47 18 25	-0203	
98	3C286	2119	2127	13 29 57	30 37 27	13 29 56	30 40 06	13 29 46	30 37 08	-0138	
99	NGC5194	2129	2152	13 28 49	47 18 55	13 28 55	47 22 22	13 28 43	47 19 54	-0127	
4600	H2N051SNR	2153	2217	13 29 04	47 17 36	13 29 10	47 21 03	13 28 56	47 17 56	-0103	
01	3C286	2219	2227	13 30 00	30 37 37	13 29 57	30 40 06	13 29 47	30 37 27	-0033	
02	NGC5194	2228	2252	13 28 52	47 19 05	13 28 58	47 22 42	13 28 45	47 20 14	-0027	
03	H2N051SNR	2253	2317	13 29 06	47 17 26	13 29 13	47 21 13	13 28 58	47 17 56	-0003	
04	3C286	2318	2327	13 30 04	30 37 37	13 29 54	30 40 35	13 29 51	30 37 57	+0022	
4605	NGC5194	2328	2352	13 28 53	47 19 15	13 28 57	47 22 32	13 28 46	47 19 54	+0033	
06	H2N051SNR	2353	0017	13 29 09	47 18 15	13 29 10	47 22 13	13 28 59	47 19 15	+0057	

I-0-1

Fig. II-5. Sample observing log.

(b) Serious gain drifts on the time scale of hours indicating instabilities in the system; and (c) Serious drifts or discontinuities in phase centers for some or all correlators. All of these mean something happened or is happening in the system. Changes from one stable set of gains or phase centers to another set are not too serious, but the operator should be informed because it does mean that something happened, and this may be a first indication of further problems. Rapid, continuous drifts in gains or phase centers can mean worthless data and the causes must be fixed as soon as possible. In the frequent borderline cases the observer is wise to listen seriously to the advice of the operators and technical specialists. Frequently the observer is asked if he is willing to put up with a marginal situation until a maintenance period or until help presently unavailable arrives. Such decisions are up to the observer but two guidelines should be followed: (1) The honest recommendations of the operators and specialists are to be listened to and (2) it is better to fix a marginal system early before it suffers a massive failure.

7. Use of On-Line Data to Monitor System

The first and simplest use of the on-line interferometer data is monitoring the health of the system and the data. This is done by noticing how well the calibrators, observed exactly at the reference position, match the theoretical ideal response. Let A be the amplitude, in counts, for a particular correlator and ϕ be the phase, where both are obtained from the scan averages printed out by the teletype. Let us assume that we know that 3C 48 is 9.0 f.u. at SBAND and 3.3 f.u. at XBAND. By dividing the raw amplitudes by the known fluxes the appropriate counts per flux unit (CPFU) can be obtained. The raw data for three of the scans, recorded on the teletype output as shown in Figure II-6, can be summarized as follows:

3C48 SCAN 16880
01 36 06.247 + 33 01 20.406
OBSERVE UNTIL 00 10
MODE M GAIN 0

000140 3C48

	2448008	001011	SECT	00125	RETURN 00001
0	224	-2	-22	49	16
1	1363	-131	-34	93	16
2	290	173	-6	47	16
3	1013	26	-57	70	16
4	271	5	41	46	16
5	1073	19	24	77	16

3C48 SCAN 16883
01 36 06.247 + 33 01 20.406
OBSERVE UNTIL 01 10
MODE M GAIN 0

010208 3C48

	2448008	011011	SECT	00243	RETURN 00001
0	217		-21	49	15
1	1343		-46	85	15
2	291	155	-7	47	15
3	906	22	-69	72	15
4	277	9	45	47	15
5	1178	22	14	80	15

3C48
01 36 06.247 + 33 01 20.406
OBSERVE UNTIL 02 10
MODE M GAIN 0

020136 3C48

	2448008	021011	SECT	00362	RETURN 00001
UNEXPECTED TRAP ON LINE 5					
0	216	-24	-21	48	17
1	1350	-136	-49	84	17
2	272	153	-6	45	17
3	771	21	-73	67	17
4	274	0	46	47	17
5	1087	18	13	80	17

Fig. II-6. Three scan averages of observations of 3C48 as typed out by the teletype.

	Band	XBAND			SBAND		
	Corr. Number	0	2	4	1	3	5
	Pair	1R2R	1R34	2R3R	1L2L	1L3L	2L3L
Raw Scan Average Amplitudes	Scan 16880	224	290	271	1363	1013	1073
	Scan 16883	217	291	277	1343	906	1178
	Scan 16886	216	272	274	1350	771	1087
Raw Scan Average Phases	Scan 16880	- 2	173	5	-131	26	19
	Scan 16883	-14	155	9	-132	22	22
	Scan 16886	-24	153	0	-136	21	18
Approx. System Phase Center		-13	160	5	-133	23	20

For the data in Figure II-6, the scan average phases have been used to determine approximate system phase centers.

Now, dividing the amplitudes in counts by the appropriate flux densities for 3C 48 and multiplying by factors of ten to remove the effect of the gain steps, we obtain

CPFU

BAND		XBAND			SBAND	
Pair	1R2R	1R3R	2R3R	1L21	1L3L	2L3L
Scan 16880	679	879	811	1514	1126	1192
Scan 16883	658	882	839	1492	1007	1309
Scan 16886	655	824	830	1500	857	1208
Approx. CPFU	664	862	827	1502	997	1236

As long as the gains are stable, the CPFU remain about the same*. The CPFU obtained from edited and corrected data usually changes by only a small amount. The major correction to be applied is that for attenuation by the atmosphere. This correction involves multiplication by $(1 + k \sec z)/(1 + k)$ to correct to "outside the atmosphere." For SBAND data $k \cong 0.035$ and for XBAND data $k \cong 0.11$, where z is the zenith angle

* The above numbers are fairly typical. There is more variation for the SBAND 1L3L correlator than one would like; this may be due to problems with the delay setting that were not caught earlier.

and sec z is what is frequently called the "air mass." This correction is important only for large sec z, so it can be ignored in the raw data by paying less attention to raw data for calibrators at large zenith angles (extreme hour angles).

The system phase centers from raw data will also be approximately constant for all calibrators if three conditions are met: (1) The calibrators are at the reference position; (2) The baseline constants (B_x, B_y, B_z) read into the DDP are accurate enough; and (3) Extreme zenith angles are counted as exceptions. The atmosphere induces a phase shift ($\Delta\phi$) proportional to sec z, therefore when sec z is large the raw phase can shift from the phase centers by a significant amount. Unfortunately, it is a fact that in the relationship $\Delta\phi$ = c sec z, the value of c varies so much with the changes in the weather that it cannot be determined as a function of known parameters either theoretically or empirically.

With the rough rules we have outlined, the observer can tell whether the gains and phase centers are remaining roughly stable. It is recommended that the observer pay attention to such monitoring to a reasonable extent.

8. Amplitude and Phase Noise

As for all radio telescope instrumentation there are limitations due to noise* that affect the data from the interferometer. The rms noise fluctuations in the amplitudes can be determined either from the parameters of the system or empirically from examination of the variations in determinations of fluxes of very weak sources.

Let

$\Delta\nu$ = I.F. bandwidth (= 30 MHz)

T_s = system noise temperature ($\sim$ 125° K)

D = diameter of each antenna (= 2590 cm)

ε_a = aperture efficiency ($\simeq$ 0.5)

---

* We limit this discussion to system noise, there will be additional amplitude and phase noise in real data due to atmospheric effects, pointing errors, imperfections in delay tracking etc.

then the theoretical rms noise fluctuation in the amplitudes for a single telescope pair is

$$A = \frac{8(2^{1/2})kT_s}{\varepsilon_a \pi D^2 \sqrt{\Delta\nu t}} \qquad \text{II-(4)}$$

where k = Boltzmann constant and t is the length of observing time involved.

Using the abovementioned values for the parameters, the rms for a single 30-second record for a telescope pair is

$$\sigma = (\bar{A}^2)^{1/2}_{\text{theoretical}} \sim 0.062 \text{ flux units.} \qquad \text{II-(5)}$$

Now system-noise temperatures vary and the aperture efficiencies differ slightly at 3.7 and 11.1 cm; therefore a single value of $(\bar{A}^2)^{1/2}$ is not always applicable to all telescope pairs at both frequencies at all times.

Empirical evaluations of the noise in the amplitudes indicate that on the average

$$\sigma \sim 0.070 \text{ f.u.}$$

for a 30-second record for a single telescope pair. This is quite consistent with the theoretical result. Therefore, barring circumstances when the noise is unusually low or high, one can use the following formula to predict the amplitude rms for a combination of N different records and correlators:

$$\sigma \sim \frac{0.07}{\sqrt{N}} \text{ f.u.} \qquad \text{II-(6)}$$

This results in the following table:

	σ (Flux Units)		
Time	1 Pair	3 Pairs	6 Pairs
30 sec.	$\sim$ 0.07	$\sim$ 0.04	$\sim$ 0.03
25 min.	$\sim$ 0.01	$\sim$ 0.006	$\sim$ 0.004

Let us now discuss the probability distributions for both amplitudes and phases. Let

A = true amplitude due to a real signal

A' = a measured amplitude

$P(A')dA'$ = the probability a measured amplitude will be between A and $A' + dA'$

ϕ = true phase due to a real signal

ϕ' = a measured phase

$P(\phi')d\phi'$ = the probability a measured amplitude will be between ϕ' and $\phi' + d\phi'$.

Following the discussion by Vinokur (<u>Ann. d'Ap.</u>, **28**, 412, 1965), the probability distribution for a measured amplitude is given by

$$P(A') = \frac{A'}{\sigma^2} I_o\left(\frac{AA'}{\sigma^2}\right) \exp\left\{-\frac{[A^2 + (A')^2]}{2\sigma^2}\right\} \qquad \text{II-(7)}$$

where $I_o(x)$ is the modified Bessel function of the first kind, of order zero. This function is unity when the argument is zero, corresponding to $A = 0$, i.e., no real signal is present. In Figure II-7, we show plots of $P(A')$ as a function of A'/σ for several values of signal to noise: A/σ = 0, 1, 2, 3, 5, and 10.

The probability distribution for the phases, $P(\phi'-\phi)$, is plotted in Figure II-8 as a function of $\phi'-\phi$ for A/ϕ = 0, 1, 2, 3, and 5.

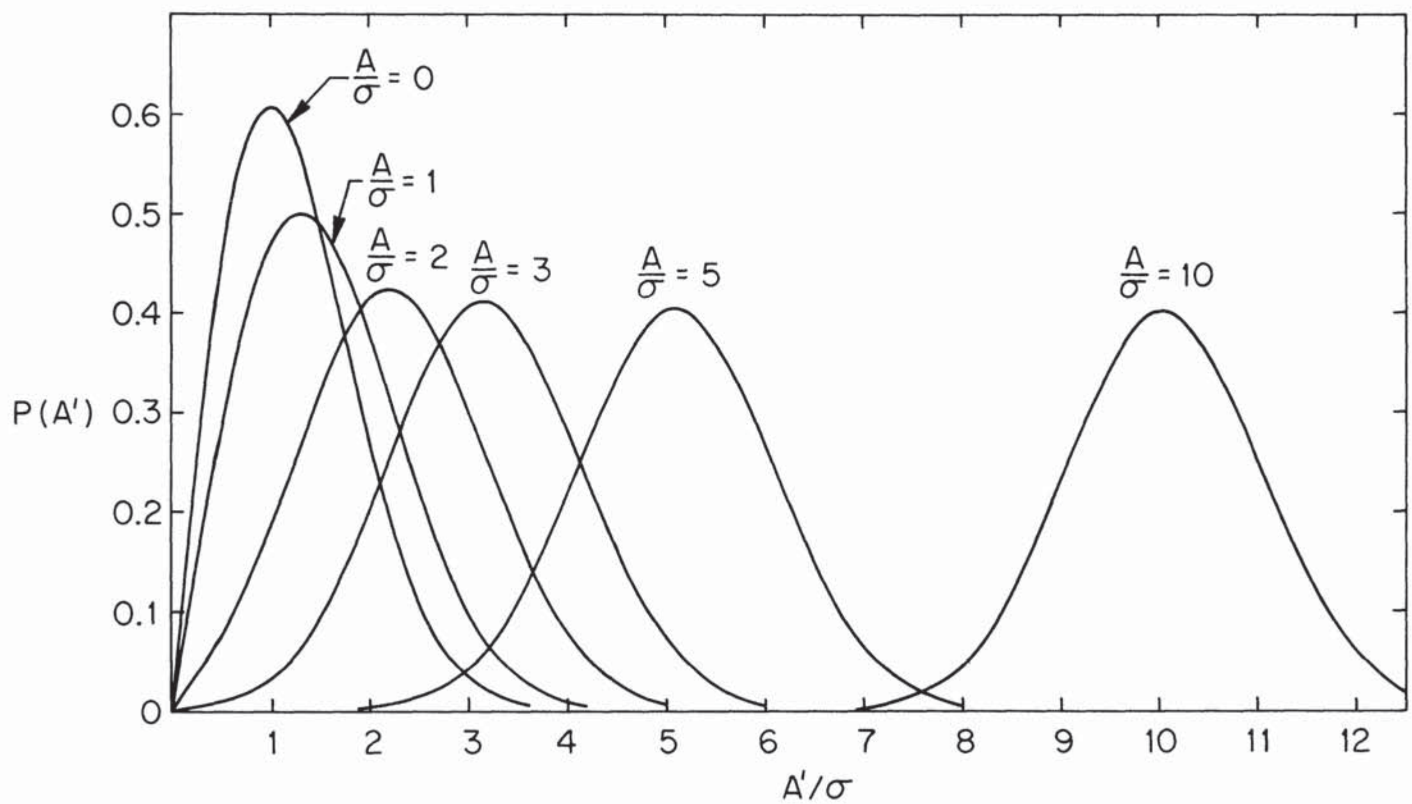

Fig. II-7. For a number of values of real signal to noise (A/σ), the probability distribution of measured amplitudes (A') is plotted as a function of A'/σ.

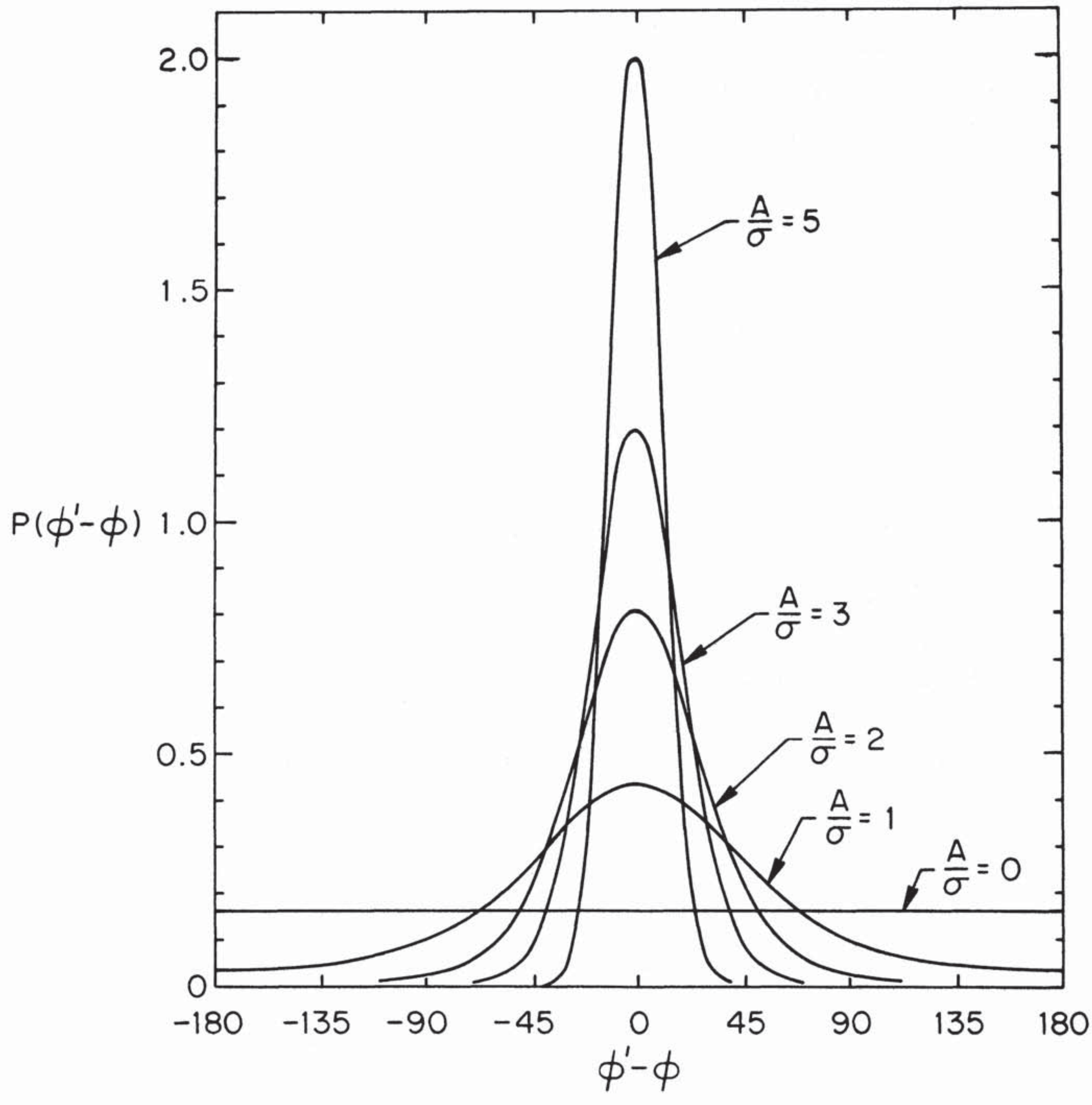

Fig. II-8. For a number of values of real signal to noise (A/σ), the probability distribution of measured phases (ϕ') is plotted as a function of $\phi'-\phi$.

We see that in the absence of a real signal all phases are in principle equally probable. As the signal-to-noise increases, the probability distribution has less and less deviation from the true phase, as seen from the following table.

A/σ	$(\phi'-\phi_o)_{P/P_{max}} = 1/2$
1	$\pm$ 55°
2	$\pm$ 35°
3	$\pm$ 22°
5	$\pm$ 13°

For large values of A/σ ($\gtrsim$ 2),

$$(\phi'-\phi_o)_{P/P_{max}} = 1/2 \; \frac{\cong \pm 65°}{(A/\sigma)} \; . \qquad \text{II-(8)}$$

Examination of Figures II-7 and II-8 reveals the basic reasons why the presence of a weak source will always show up most easily in the phase information. The difference between the phase distributions for A/σ = 0 and 1 are much more obvious than the differences between the associated amplitude distributions.

The user should realize that although A and ϕ obey statistics with the properties we have just discussed, the real and imaginary parts of the visibility function, R and I, each separately obey Gaussian statistics.

9. Confusion

We are still far from understanding the effects of confusion at flux levels as low as 10^{-2} to 10^{-3} flux units. Even less understood are the effects of confusion for an interferometer which has a very complex synthesized beam. However, two effects related to confusion have been fairly well established for the NRAO interferometer, based upon the experience of observers between June 1970 and February 1973. Although a detailed statistical discussion has not been made, it has been estimated that the probability of finding a single dominant point source at the 0.01 f.u. level in a 20' field at 11 cm is about 0.5. This means that detections of sources at or below this level must be based upon sufficient information to establish position coincidences with other objects.

There is also a clear effect of an apparently spurious "detection" of radio emission in the shorter spacings ($\lesssim$ 900 m) at 11.1 cm. Quite frequently a 15-20 minute observation at these short spacings will show an apparent flux of 0.02 to 0.03 f.u. However, repeated observations do not clearly delineate any sources and maps do not clearly reveal the location of the radiation in the field. Possible interpretations range from the common occurrence of radiation sources with size scales of the order of a few arcminutes to it being a completely spurious response. In any case, an observer should, at the present time, be cautious about interpreting apparent detections from short spacing data on just a few observations.

10. Use of On-Line Data for Preliminary Evaluation of Scientific Results

In some programs rough scientific results can be obtained from the on-line data. The first questions that can be sometimes answered from the on-line data are: (1) Are there any radiation sources in the field being observed? (2) Is there a single point source in the field and if so what is its strength and rough position offset from the reference position? and (3) Is the radiation in the field more complicated than a single point source?

When the scan averages show amplitudes considerably above the rms noise level for some length of time, the situation is simple. The question of whether the field is dominated by a point source or by a distribution of radiation can be answered first. If, for a number of scans at different hour angles, all correlators give the same flux density, within the noise limits, at all hour angles, then a point source is being observed at that frequency. Significant differences in the indicated flux densities, particularly if there are systematic changes with hour angle or with the different correlators at one frequency,means there is some distribution of sources in the field. Most of the time further on-line analysis is then not useful except to answer questions concerning what size scales are being resolved out and how much flux is in different Fourier components. When the observer has attained a certain amount of familiarity with the meaning of the fact that every measurement of amplitude and phase is a measurement of the properties of a particular Fourier component of the observed brightness distribution, then a considerable amount can be guessed about the nature of the brightness distribution by examining the amplitudes at different times for different correlators.

If the amplitudes indicate a single point source dominates the field, it can then be asked whether the source is on the reference position or somewhere else. A simple way to evaluate this is to write down the scan average phases alternating the source in question and the calibrator observed in between. The following shows the result for a series of observations of the radio star β Persei and 3C 48:

Raw Phases

Source	LST	XiR2R	X1R3R	X2R3R	21L21	S1L3L	S2L3L
β Persei	2213	-102	152	-79	46	14	-155
β Persei	2238	-119	147	-89	36	-3	-147
3C 48	2256	- 89	167	-73	48	9	-141
β Persei	2213	-121	137	-81	45	2	-140
β Persei	2378	-110	150	-81	49	3	-138
3C 48	2356	- 91	171	-78	50	12	-142
β Persei	0013	-129	139	-85	40	13	-151
β Persei	0038	-113	159	-92	44	11	-147

These data clearly show a point source at the reference position to within a few arcseconds. Remembering that the calibrator gives the status of the phase centers, it is impossible for another source to have this degree of phase agreement with the calibrator without the source being within a few arcseconds of the reference position. It is noteworthy that this method of comparing phase will always be relatively valid if source and calibrator are close to each other, <u>even if there are serious</u>

baseline errors or serious phase drifts. In the latter case the criterion is whether the program source is showing the same drift as a calibrator at the pointing position.

If the observer knows the source is a point source from the amplitude information but the source's raw phases vary considerably, he can verify that it is a point source off position by doing one of the following tricks.

Assume six successive scan averages have been measured with raw amplitudes A_i and phase ϕ_i, i = 1, ..., 5. Using a protractor with a graphical scale taped to the appropriate spot, make the plot as shown in Figure II-9, which is basically a plot of the real vs the imaginary part of the raw visibility function. The spiral behavior shown in Figure II-9 is characteristic of a point source off-position, and this change in phase is characteristically called phase "wind". For a source on position the vectors, placed head-to-tail, move out in almost a straight line in a direction corresponding to a single angle ϕ_s which is the raw system phase center. One feature of this is that the amount of phase wind should be proportional to both the baseline length and the observing frequency. In this case, except for the effects of phase noise, one gets the result, for example, that

$$\Phi_{S23} = \frac{\Phi_{S13}}{2} = \frac{\Phi_{S12}}{3} = \frac{\Phi_{X23}}{3} = \frac{\Phi_{X13}}{6} = \frac{\Phi_{X12}}{9} \qquad \text{II-(9)}$$

if the spacings are 2700, 1800, and 900 meters, where $\Phi = \phi_i - \phi_s$. In this case data on all correlators can be reduced to a common baseline, say Φ_{S23}, and averaged together to get mean $\bar{\Phi} = \bar{\Phi}$ (H). Remember that all phases have 360° ambiguities, hence reduction of phase to a common baseline often involves addition or subtraction of multiples of 360°. A quick and dirty solution for $\Delta\alpha \cos \delta$ and $\Delta\delta$ (cf. Eqn. I-(12)) can be obtained from

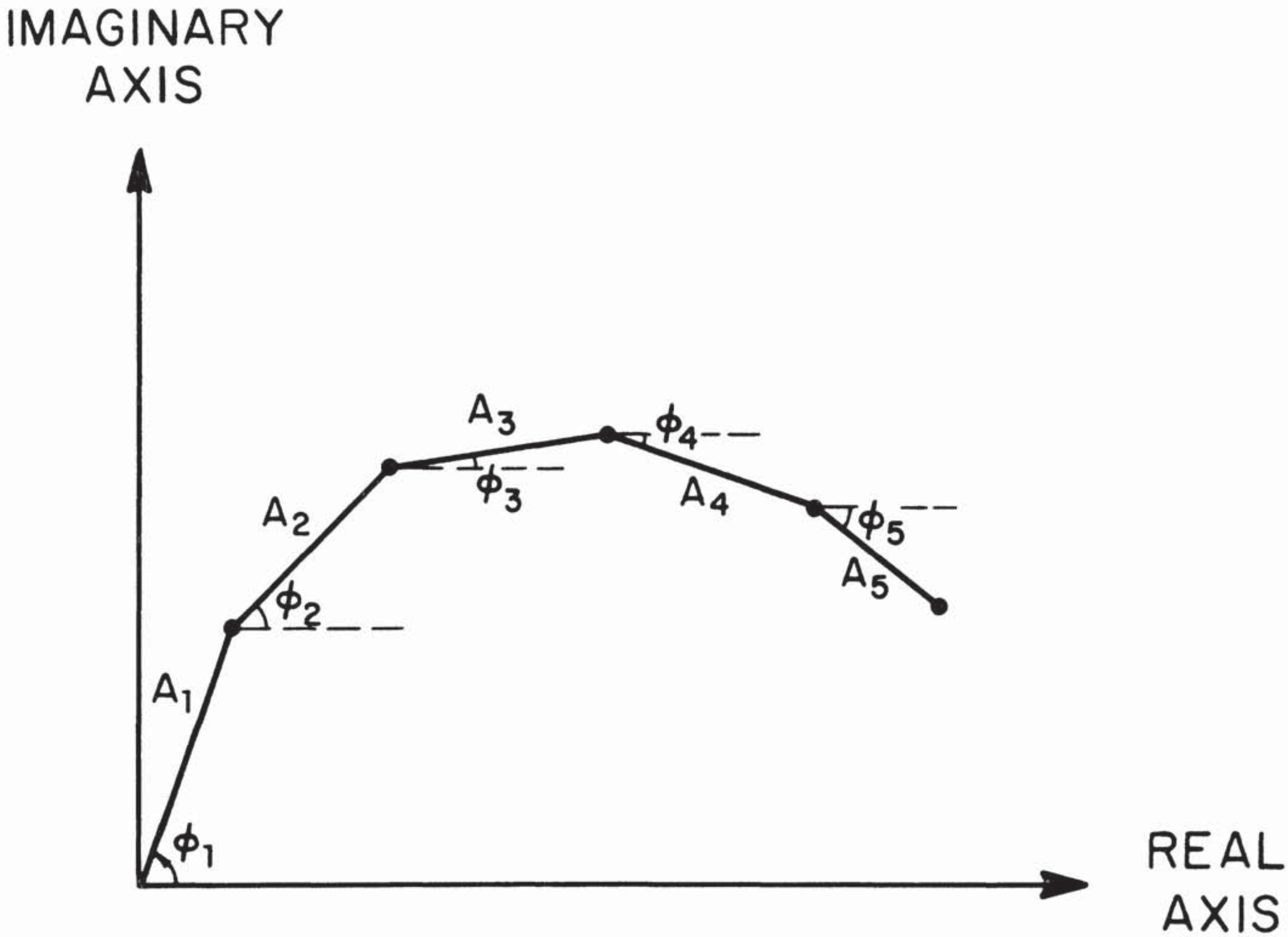

Fig. II-9. Phase and amplitude data for successive records (or scans) are schematically plotted in the real-imaginary plane to show the effects of phase wind for a point source off the reference position when observed.

$$\Phi(H) = 2\pi[u \cdot \Delta\alpha \cos\delta + v \cdot \Delta\delta]$$

$$= 2\pi[B_x \cos\delta \sin H - B_y \cos\delta \cos H]\,\Delta\alpha \qquad \text{II-(10)}$$

$$+ 2\pi[B_x \sin\delta \cos H - B_y \sin\delta \sin H + B_z \cos\delta]\Delta\delta$$

Note that if a measurement is made where u or v are zero (see typical u-v plane plots in Fig. I-8) then the solution for $\Delta\alpha$ and $\Delta\delta$ can be obtained very easily.

The above procedure is a crude version of what is used to obtain accurate positions for point sources from data which has been properly phase calibrated.

Judgment concerning some data with amplitudes typically less than three times the rms noise level can be made using the above-mentioned methods if the observer is conversant with the properties and statistics of Rayleigh noise. The principles are the same, but virtually all reliance is placed upon the phase data only, and some feeling for what is noise and what is not must be developed. For the previous example involving β Persei and 3C 48, β Persei was of the order of 0.16 f.u. at XBAND and 0.1 f.u. at SBAND. The following examples show the case of β Persei when it was 0.012 ± 0.005 f.u. at XBAND but marginally present at 0.006 ± 0.005 f.u. at SBAND.

RAW PHASES

Source	XBAND			SBAND		
	X12	X13	X23	S12	S13	S23
β Persei	159	-155	-156	- 81	150	33
β Persei	-110	107	-165	1	-150	-82
NRAO 140	-146	156	-118	-145	32	2
β Persei	-166	- 99	- 87	-157	-146	18
β Persei	-166	-137	149	-106	124	-97
NRAO 140	-133	170	-118	-140	37	2
β Persei	- 45	-154	-151	-153	- 91	43
β Persei	-115	-148	- 62	-161	91	114
NRAO 140	-116	-173	-119	-134	43	2
β Persei	- 83	- 40	- 65	-134	- 31	-97

The phase coherence at XBAND is quite good, but only marginal at SBAND.

Another example showing the difference between the appearance of a source at a mean level of about 0.01 f.u., and when it is below a detection limit of 0.005 f.u., is shown in Figure II-10, where the mean amplitudes and mean phases for the variable radio X-ray star, GX17+2, are shown for two different days. On May 27, 1971, the source was clearly present with a phase drift expected for a source $\sim$16" from the pointing position. The mean amplitudes are typically only one rms above the expected mean noise level, but the phases, reduced to a common baseline, could be produced only by the source being really present. On May 30, 1971 the amplitudes are close to the constant bias level for the Rayleigh statistics of the amplitudes, and the phases scatter randomly.

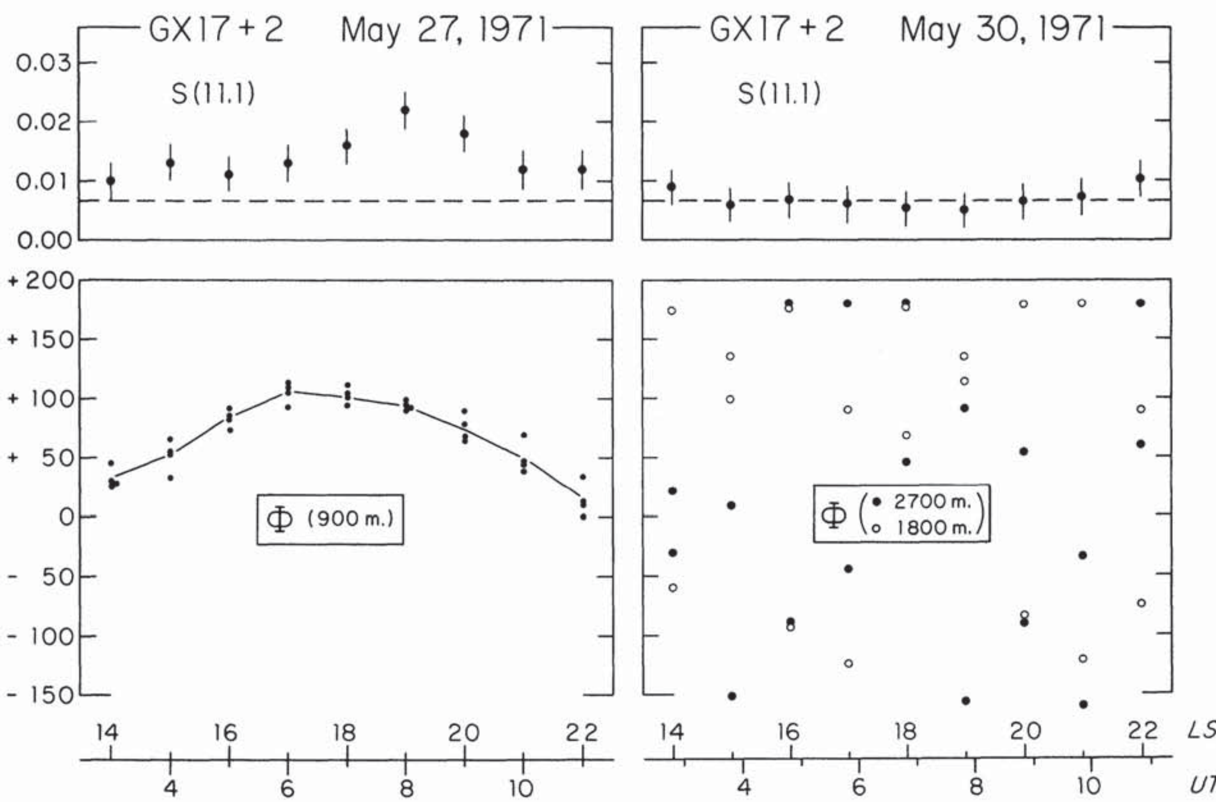

Fig. II-10. Data for the variable radio and X-ray star GX17+2, taken on a day when it was present (May 27, 1971) and a day when it was below the detection limit (May 30, 1971), are plotted as a function of LST and UT to show the difference in apparent amplitude and phase for a very weak source and complete absence of a source.

CHAPTER III

PROCESSING OF INTERFEROMETER DATA

1. Theory of Data Processing for LL and RR Correlators

(a) Objectives to be Accomplished.

Interferometric data requires a great deal of cleaning, correcting, and calibrating. We will now discuss the theory of what is necessary to obtain fully calibrated visibility functions for all LL and RR correlations; in later sections, where we discuss programming details, we will further discuss how to put these principles to practical use.

It is convenient to identify three distinct stages that the data attains during the whole process of observing, cleaning, correcting, and calibrating. We will identify the uncleaned, uncorrected, and uncalibrated data, as recorded on magnetic tape in Green Bank, by double primed quantities. For example, the raw visibility function will be denoted by $V'' = A'' \exp(i\phi'')$ where A'' and ϕ'' are the raw fringe amplitude and fringe phase, respectively. We will identify the final cleaned, corrected, and calibrated data by unprimed quantities, e.g., $V = A \exp(i\Phi)$. We will reserve the single prime to identify a very important stage in the processing where all cleaning and correcting has been carried out, but not amplitude and phase calibration.

For the LL and RR correlators, the process of cleaning, correcting, and calibrating can be described as determination of a single complex function, G, that we will call the complex gain of a correlator, i.e.,

$$V = G\,V'' . \qquad \text{III-(1)}$$

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* Note that we will always use the word "calibration" in the strict sense whereby instrumental parameters are determined from observations of point sources with known flux densities located at the reference position.

The complex gain, G, is determined, in practice, partly from cleaning, partly from corrections for known effects, and partly from observations of calibrators. As discussed in Chapter I, in the absence of noise a calibrator observed at the reference position has

$$V = S$$

where S is the flux density. In fact, of course, one can never remove noise from real data, so the objective of calibration is to make the complex visibility function of calibrators observed at the reference position describable by

$$V = (S + \sigma_A) \exp (i\sigma_\phi)$$

where σ_A and σ_ϕ describe the amplitude and phase noise, respectively.

Let us further define a quantity g that we will call the <u>gain factor</u> and a phase correction $\Delta\phi$ such that

$$G = g \exp (i\Delta\phi). \qquad \text{III-(2)}$$

Obviously g and $\Delta\phi$ are the amplitude and phase of the complex gain of a correlator. By definition, data have been cleaned, corrected, and calibrated when G has been determined for each correlator and all raw visibility functions have been multiplied by G to give

$$V = g A'' \exp [i \phi'' + i\Delta\phi] \qquad \text{III-(3)}$$

or

$$A = g A'$$

$$\Phi = \phi'' + \Delta\phi.$$

The complex gain, G, may be a time-dependent quantity and the observer should think of it as a slowly varying function.

As we will be discussing in great detail, the last stages in the determination of g and $\Delta\phi$ are based upon observations of calibrators. We must distinguish between flux (or gain) calibrators, which are point sources with well known flux densities, and phase calibrators, which are point sources with accurately known positions observed at the reference position. It turns out that all flux calibrators are also phase calibrators, but only a small fraction of the available phase calibrators are good flux calibrators.

(b) Steps to Accomplish in LL and RR Data Processing.

The determination of G and its application to the data require four distinct steps to be carried out. The first is what we have referred to as cleaning; the next two involve application of corrections that are either previously known or easily determinable; and the fourth is what we call calibration because it involves empirical determination of instrumental constants from data for sources of known flux density (amplitude calibrators) and sources with known accurate positions observed at the reference position (phase calibrators).

(1) Cleaning.

Malfunctions of part or all of the interferometer system require complete deletion of portions of the data. Fortunately, in most cases, only a small part of the data requires major surgery.

At every stage in the processing of data one may discover faults which require cleaning. The causes of bad data are sometimes obvious and sometimes never understood. For example, it is easy to identify bad data if: the LO is out of lock; a receiver suffers a massive failure; a delay bank malfunctions; a telescope is observing part of a mountain; or snow and ice on an antenna attenuate the signal too much. More difficult to identify, and sometimes never traceable to a known cause, are cases where: excessive rms' indicate something was wrong; or there are apparent changes in gain or phase center too erratic to make the determination of g and $\Delta\phi$ possible. Unfortunately, detection of some problems may depend partly on luck and heavily on whether inconsistent results are blamed more on faulty data than on "things" in the sky. In this category are all sporadic equipment malfunctions, erratic variations of system "constants", brief interference, etc., which occur only during observations of program sources about which you have little idea of expected behavior. The observer is advised to be very suspicious of the unusual, and to believe interesting results only when independent parts of the system or independent observations tell the same story.

As an aid in describing the steps to be accomplished, we can describe the cleaning process in terms of determining a function g_D which is a factor in the general gain factor g; therefore we can say $g_D = 0$ for data records that are to be deleted, and $g_D = 1$ otherwise. (The subscript D stands for delete.)

Under some circumstances bad data concerning the state of the system or the observing parameters (particularly baseline parameters) can be replaced by the proper data parameters; this is a natural part of the cleaning process.

(2) Automatic Corrections.

There are a number of corrections, due to well-understood effects, that can be automatically applied to the data.

Several automatic corrections are lumped together in the so-called PHASE* correction: diurnal aberration; deviation of the LO from its nominal value; phase and amplitude corrections for the effects of the correlator filters and system time constants; and, the biggest of all, differential retardation of wave fronts due to passage through different path lengths in the atmosphere. The latter effect is dominated by effects that are proportional to the secant of the zenith angle, z, but one also accounts for the effects of sphericity of the earth.

The effects of the PHASE correction are: (1) to provide a factor g_P to the gain factor g, where g_P is very close to unity; and (2) to provide a substantial correction to the phase that we will denote by $\Delta\phi_P$. Because of the dominance of the sec z dependent atmospheric terms,

* Completely capitalized words will be used to identify programs or components of programs that accomplish particular purposes.

to first order $\Delta\phi_P \propto \sec z$. The corrections g_P and $\Delta\phi_P$ are calculated and applied to the data on the basis of known parameters (hour angle, declination, temperature, dew point, barometric pressure, deviations of the LO, etc.).

Corrections to the amplitudes due to attenuation in the earth's atmosphere are associated with a program component called AMPCOR. AMPCOR calculates and applies a component of the gain factor g given by

$$g_A = ((1 + k \sec z)/(1 + k))$$

which effectively corrects the amplitudes to outside the atmosphere. Normally $k \cong 0.07$ for SBAND and $k \cong 0.19$ for XBAND.

The third automatic correction is associated with a program component called CLOCK. The internal clock in the interferometer system has a small, well-understood error which we will call Δt. This error has the effect of making the hour angle (H) in error by Δt. Therefore, the CLOCK correction applies adjustment to the phases by an amount $\Delta\phi_C$, where

$$\Delta\phi_C = [(B_y \cos H - B_x \sin H) \cos \delta] \, \Delta t.$$

(3) Baseline Corrections.

As discussed in Chapter I, a key element in interferometric observing is the correction for the delay, D, which describes the extra time (or extra travel path) it takes for the same wave front to reach the second telescope in a pair after it has reached the first telescope. During the observing process this delay is compensated for based upon the equation

$$D = \underset{\sim}{B} \cdot \underset{\sim}{s}_o$$

where $\underset{\sim}{B} = (B_x, B_y, B_z)$ is the assumed baseline vector and $\underset{\sim}{s}_o$ is the unit vector pointing at the reference position. Because the assumed baselines may differ from the true ones, errors in the assumed $\underset{\sim}{B}$ result in sinusoidal phase error terms.

Whenever telescopes are moved, the observing begins with baseline parameters based upon previous experience at the same configuration; hence there are always small errors described by $\Delta\underset{\sim}{B} = (\Delta B_x, \Delta B_y, \Delta B_z)$ resulting in a phase error given by*

$$\Delta\phi_B = 2\pi\ \Delta\underset{\sim}{B} \cdot \underset{\sim}{s}_o.$$

Observations of calibrators at the reference position give measurements of the sinusoidal variation in phase due to $\Delta\phi_B$; hence these data can be used to solve, in a least squares sense, for $\Delta\underset{\sim}{B} = (\Delta B_x, \Delta B_y, \Delta B_z)$. This solution is carried out on data for which PHASE has already been applied. At this stage in the data processing the residual phase variations of the calibrators observed at the reference position should be given by

$$2\pi\ \Delta\underset{\sim}{B} \cdot \underset{\sim}{s}_o + \phi_s + \text{noise},$$

where ϕ_s is the system phase center for the correlator in question. One must be careful to use data from calibrators covering a wide range of hour angles and declinations. Furthermore, one must be sure that changes of phase centers and short-term atmospheric fluctuations (which cannot be corrected for as yet) do not invalidate this solution. We will discuss further practical details while describing the usage of the program called INTBCAL.

In general, NRAO staff will determine the true baselines after each move, and the observer need not worry about determining them himself--unless his program requires more accurate determinations than "usual".

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* Small corrections due to non-identical telescopes and polar axes not being aligned are to be included in $\Delta\phi_B$ if unusually great accuracy in phases is desirable, but we will not discuss them (see Wade, C. M., Ap. J., 162, 381, 1970).

(4) Summary of (1), (2), and (3).

Let us summarize the effects of the cleaning and automatic correction processing in terms of equations.

The net effect on the gain factor g due to cleaning and correcting can be described as contributing a complex gain factor

$$G'' = g_D\ g_P\ g_A\ \exp\ [i(\Delta\phi_P + \Delta\phi_C + \Delta\phi_B)].$$

The effect of this cleaning and correcting is to produce data which need only gain calibration and phase centering. We denote the visibility function at this stage by

$$V' = A'\ \exp\ (i\phi')$$

and it is obtained from V'' by

$$V' = G'' \cdot V'' = g_D\ g_P\ g_A\ A''\ \exp\ [i\ (\phi'' + \Delta\phi_P + \Delta\phi_C + \Delta\phi_B)], \qquad \text{III-(4)}$$

or

$$A' = g_D\ g_P\ g_A\ A''$$

and

$$\phi' = \phi'' + \Delta\phi_P + \Delta\phi_C + \Delta\phi_B.$$

(5) Determination of System Gain Factor and Phase Center.

After all cleaning and correcting have been accomplished, there should be only six effects still marring the data: (i) amplitude and phase variations due to system noise; (ii) phase variations due to atmospheric fluctuations; (iii) amplitude fluctuations due to imperfections in delay compensation; (iv) amplitude variations due to residual pointing errors for individual telescopes; (v) system gain effects; and (vi) non-zero system phase centers.

No one can remove system noise from data, and no one has yet figured out a way to empirically remove the effects of atmospheric fluctuations. In addition one ordinarily considers the amplitude variations due to imperfect delay compensation or pointing error to be part of the "noise" in the amplitudes; but if the effects are too large one can attempt to use observations of calibrators to determine empirical amplitude corrections.

Thus, in most cases we now need only worry about corrections for system gains and phase centers. This can be called calibration because it depends empirically upon the results of known calibration sources observed at the reference position. We must determine from these observations a system gain factor that we will call g_S and a system phase center that we will call ϕ_S. In principle, then,

$$V = G' V' = g_S A' \exp [i (\phi' - \phi_S)] \, , \qquad \text{III-(5)}$$

so that

$$G' = g_S \exp (-i\phi_S).$$

One should consider g_S and ϕ_S to be system "constants" that may change slowly with time, or may change abruptly due to changes (malfunctions?) in the electronics.

Only now, in discussing the transformation of the data from the V' state to the V state, are we finally at the stage assumed for much of the discussion in Chapter I. One now uses observations of good flux (or amplitude) calibrators (see Appendix 1) with flux densities denoted by S to determine, by a fit to the data,

$$g_S = \overline{S/A'} \, .$$

By observations of good phase calibrators (see Appendix 1), one determines, by a fit to the data,

$$\phi_S = \overline{\phi'} \, .$$

Once g_S and ϕ_S have been determined, in principle as a function of time where necessary, all data may be calibrated by using Equation III-(5).

(c) Summary of LL and RR Data Processing.

If

$$V'' = A'' \exp (i\phi'')$$

represents the raw visibility function for a particular LL or RR correlator, as recorded on magnetic tape in Green Bank, then the fully cleaned, corrected, and calibrated visibility function,

$$V = A \exp (i\Phi)$$

is obtained from

$$V = G' \, G'' \, V''$$

$$= g_D \, g_P \, g_A \, g_S \, A'' \exp [i \, (\phi'' + \Delta\phi_P + \Delta\phi_C + \Delta\phi_B - \phi_S)] \qquad \text{III-(6)}$$

or

$$A = g \, A'' = g_D \, g_P \, g_A \, g_S \, A''$$

and

$$\Phi = \phi' + \Delta\phi = \phi'' + \Delta\phi_P + \Delta\phi_C + \Delta\phi_B - \phi_S \, ,$$

where

g_D = 0 or 1 depending upon whether the item of data is to be deleted or not

g_P = minor contribution to gain factor due to PHASE

g_A = contribution to gain factor due to AMPCOR

g_S = contribution to gain factor due to instrumental gain of system

$\Delta\phi_P$ = phase correction due mainly to atmospheric effects, applied by PHASE

$\Delta\phi_C$ = phase correction due to clock error, applied by CLOCK

$\Delta\phi_B$ = phase correction for errors in assumed baseline parameters (applied using a program component called BASELINE)

ϕ_S = system phase center.

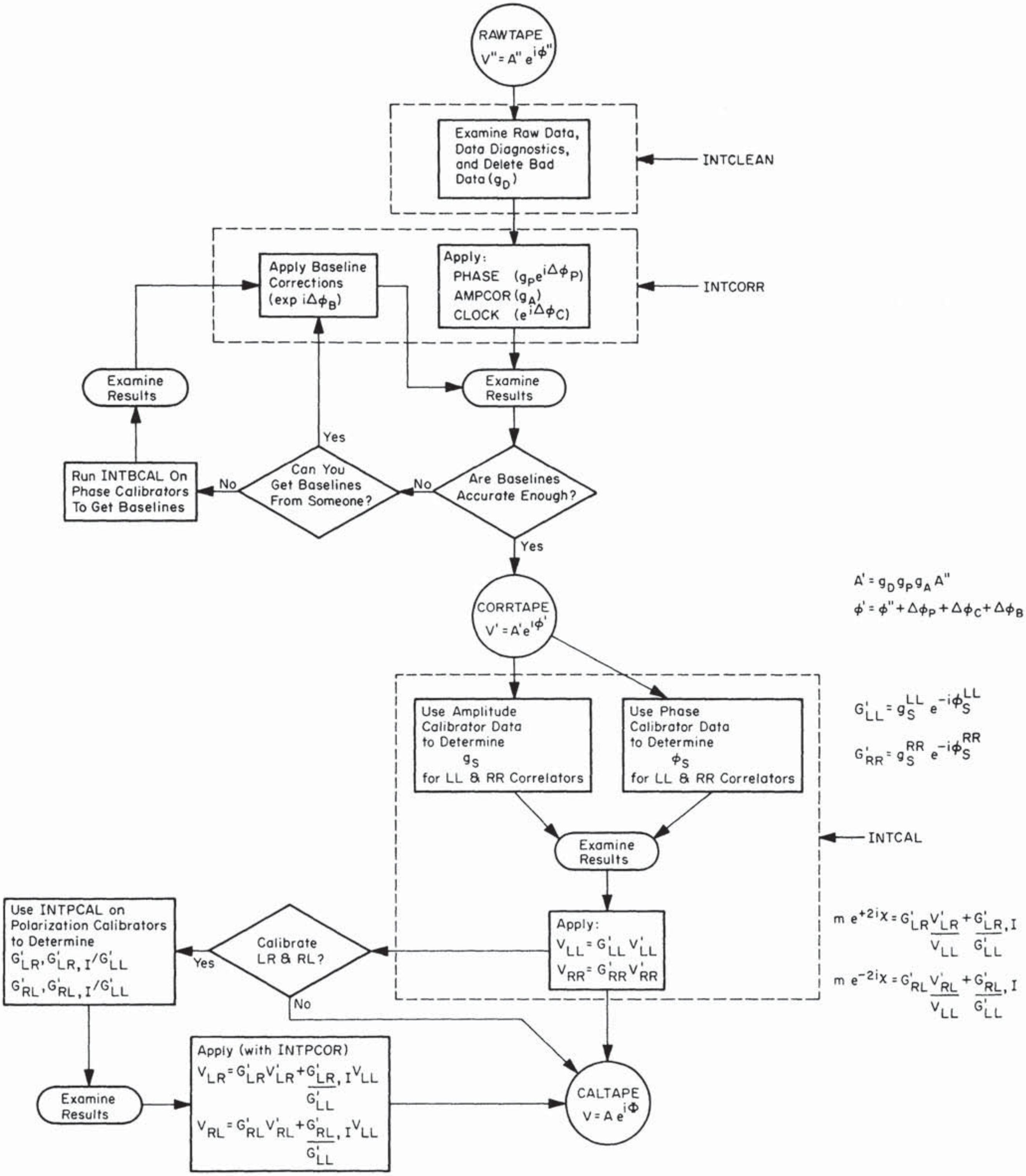


Fig. III-1. A schematic flow diagram showing the successive steps involved in interferometric data processing.

A logical flow chart showing the data processing is presented in Figure III-1. The portions of the flow chart not yet defined will be explained in forthcoming sections.

2. Theory of Data Processing for LR and RL Correlators

(a) Stokes Parameters from Measurements with Circularly Polarized Feeds.

When the NRAO interferometer operates in D, S, or X mode, one obtains data on not only LL and RR pairs but also data on LR and RL pairs which suffice to determine all four Stokes parameters:

I = total intensity visibility function

Q = linear polarized visibility function for one orientation

U = linearly polarized visibility function for 90° rotation from first orientation

V_{circ} = circularly polarized visibility function

assuming the appropriate calibration has been carried out. The user should note that, because interferometric measurements are being discussed, the Stokes parameters take the form of visibility functions rather than just intensities.

When complete polarization information is being obtained for a particular telescope pair at a particular frequency, each of the two circularly polarized feeds, one with a right-hand (R) sense and the other with a left-hand (L) sense, produce signals which are cross-correlated to obtain the visibility functions

$$V_{LL},\ V_{RR},\ V_{LR},\ \text{and}\ V_{RL}\ .$$

The four Stokes parameters are obtained from

$$\begin{aligned} I &= \frac{1}{2}\,(V_{LL} + V_{RR}) \\ V_{circ} &= \frac{1}{2}\,(V_{LL} - V_{RR}) \\ Q &= \frac{1}{2}\,(V_{LR} + V_{RL}) \\ U &= \frac{i}{2}\,(V_{LR} - V_{RL})\ , \end{aligned} \qquad \text{III-(7)}$$

or, turning the problem around,

$$\begin{aligned} V_{LL} &= I + V_{circ} \\ V_{RR} &= I - V_{circ} \\ V_{LR} &= Q + i\,U \\ V_{RL} &= Q - i\,U\ . \end{aligned} \qquad \text{III-(8)}$$

One also commonly uses the notation whereby P is the complex linearly polarized visibility function, m is the degree of linear polarization and χ is the position angle, where

$$\begin{aligned} P &= V_{LR} = Q + i\,U = m\,I\,\exp\,(2i\chi) \\ P^* &= V_{RL} = Q - i\,U = m\,I\,\exp\,(-2i\chi) \\ |P| &= (Q^2 + U^2)^{1/2} = m\,I, \end{aligned} \qquad \text{III-(9)}$$

and

$$\chi = \frac{1}{2}\tan^{-1}\,(U/Q)\ ,$$

where the asterisk denotes complex conjugation. Although m and χ are always definable by Equation III-(9), they will be constants for a particular source only if it is an unresolved point source which does not vary with time; otherwise they would be variable functions of hour angle, baseline separation and/or perhaps time.

(b) Measurement of Circular Polarization.

Although most radio sources have little or no circular polarization, it is simple to detect and measure such polarization with the NRAO interferometer if there is a sufficient circularly polarized flux. The normal calibration discussed previously for the LL and RR correlators is sufficient, and one need not have circularly polarized calibrators. Hence

$$V_{circ} = \frac{1}{2} (V_{LL} - V_{RR})$$

gives the circularly polarized visibility function and

$$|V_{circ}/I| = |(V_{LL} - V_{RR})/(V_{LL} + V_{RR})|$$

gives the degree of circular polarization.

(c) Causes of Instrumental Polarization.

Unlike the calibration problem for LL and RR correlators, the calibration of LR and RL correlators is dominated by the fact that inherent instrumental polarization is frequently much larger than the true polarized signal--even for the strongest calibrators.

The instrumental polarization arises from the fact that the R and L circularly polarized feeds contain imperfections whereby signals for each polarization sense are contaminated with signals of the opposite polarization sense. For example, Let E_R and E_L be the incident right and left circularly polarized components of the electric field, then the voltage outputs from the R and L receivers of telescopes 1 and 2 are

$$e_{1R} \propto E_R + \varepsilon_1 E_L$$

$$e_{1L} \propto E_L + \varepsilon_2 E_R$$

$$e_{2R} \propto E_R + \varepsilon_3 E_L$$

$$e_{2L} \propto E_L + \varepsilon_4 E_R$$

where the ε's are small quantities usually of the order of a few percent. The output signals from the 1L2L and 1L2R correlators, for example, are then

$$V_{1L2L} \propto E_L E_L^* + \varepsilon_2 E_R E_L^* + \varepsilon_4^* E_L E_R^* + \varepsilon_2 \varepsilon_4^* E_R E_L^*$$

and

$$V_{1L2R} \propto E_L E_R^* + \varepsilon_2 E_R E_R^* + \varepsilon_3^* E_L E_L^* + \varepsilon_2 \varepsilon_3^* E_R E_L^*$$

so that, since the ε's are of the order of a few percent, and terms like $E_R E_L^*/E_L E_L^*$ are typically several percent or less, one can drop second order terms to get

$$V_{1L2L} \propto E_L E_L^*$$

and

$$V_{1L2R} \propto E_L E_R^* + \varepsilon_2 E_R E_R^* + \varepsilon_3^* E_L E_L^* .$$

Obviously the RR and LL correlators will have contamination of a few percent only when the signals are almost completely linearly polarized; and with typical linear polarizations being a few percent or less, the contamination will amount to no more than a few tenths of a percent. That is why we have not even mentioned these effects before.

However, for the LR and RL correlators, even in the case of a strongly polarized source, the terms involving ε's are of the same order or greater than the true polarized signal. Therefore the ε's must be determined as accurately as possible so that such terms can be subtracted from the data.

(d) Linear Polarization Calibration.

To emphasize the nature of the problem, let us define the calibration in terms of complex gains by which raw visibility functions are transformed into calibrated visibility functions.

We assume that all cleaning and correcting has been accomplished, i.e.,

$$V'_{LR} = G''_{LR} \cdot V''_{LR} = g_D^{LR} \cdot g_P^{LR} \cdot g_A^{LR} \; A''_{LR} \; \exp\;[i(\phi''_{LR} + \Delta\phi_P^{LR} + \Delta\phi_C^{LR} + \Delta\phi_B^{LR})]$$

and

$$V'_{RL} = G''_{RL} \cdot V''_{RL} = g_D^{RL} \cdot g_P^{RL} \cdot g_A^{RL} \; A''_{RL} \; \exp\;[i(\phi''_{RL} + \Delta\phi_P^{RL} + \Delta\phi_C^{RL} + \Delta\phi_B^{RL})]$$

in a manner identical to that for the LL and RR correlators. However, whereas for the LL and RR correlators we calibrate the data by determining G_{LL} and G_{RR} such that

$$V_{LL} = G'_{LL} \cdot V'_{LL} = g_S^{LL} \; A'_{LL} \; \exp\;[i(\phi'_{LL} - \phi_S^{LL})]$$

and

$$V_{RR} = G'_{RR} \cdot V'_{RR} = g_S^{RR} \; A'_{RR} \; \exp\;[i(\phi'_{RR} - \phi_S^{RR})],$$

because of the terms involving the ε's there are contributions to the LR and RL correlators proportional to both V'_{LL} and V'_{RR}, therefore we have

$$V_{LR} = G'_{LR} \cdot V'_{LR} + G'_{LR,LL} \cdot V'_{LL} + G'_{LR,RR} \cdot V'_{RR}$$

and III-(10)

$$V_{RL} = G'_{RL} \cdot V'_{RL} + G'_{RL,LL} \cdot V'_{LL} + G'_{RL,RR} \cdot V'_{RR}$$

We see from Equation III-(10) that in general the calibration of each LR and RL correlator will involve determination of three complex gains. By making one further simplifying assumption the problem can be reduced to more manageable proportions. If we can assume

$$V'_{RR} = C \cdot V'_{LL} ,$$

which will be true for any source with negligible circular polarization, then we can define

$$G'_{LR,I} = G'_{LR,LL} + C \cdot G'_{LR,RR}$$

and

$$G'_{RL,I} = G'_{RL,LL} + C \cdot G'_{RL,RR}$$

reflecting that $G'_{LR,I}$ and $G'_{RL,I}$ are special complex gains describing the contamination of LR and RL correlators by the total intensity.

Equation III-(10) then becomes

$$V_{LR} = G'_{LR} \cdot V'_{LR} + G'_{LR,I} \cdot V'_{LL}$$

and III-(11)

$$V_{RL} = G'_{RL} \cdot V'_{RL} + G'_{RL,I} \cdot V'_{LL}$$

We will assume that Equations III-(11) are applicable from now on; therefore, the user should be forewarned that the reduction procedure, and the programs discussed later, do not apply to the rare cases where circular polarization is important.

Typical strong polarization calibrators (see Appendix 2) show only a few percent linear polarization. This means that even a very strong calibrator at the 10 f.u. level will have only a few tenths of a flux unit polarized flux density. Therefore calibration of LR and RL correlators amounts to determining twice as many instrumental constants as are determined for LL and RR correlators from calibrator data with much poorer signal to noise.

To carry out calibration of LR and RL correlators one uses data from at least two (and preferably more) polarization calibrators that are observed regularly throughout the observing program. To get adequate signal-to-noise for the polarized fluxes the integration time per scan should be a factor of two, three, or more longer than usual for calibrator observations.

For reasons of convenience one does not work directly with Equations III-(11), but with a form of these equations divided by $V_{LL} = G'_{LL} \cdot V'_{LL}$, i.e.,

$$V_{LR}/V_{LL} = m \exp(2i\chi) = \frac{G'_{LR}}{G'_{LL}} \frac{V'_{LR}}{V'_{LL}} + \frac{G'_{LR,I}}{G'_{LL}}$$

and III-(12)

$$V_{RL}/V_{LL} = m \exp(-2i\chi) = \frac{G'_{RL}}{G'_{LL}} \frac{V'_{RL}}{V'_{LL}} + \frac{G'_{RL,I}}{G'_{LL}} .$$

Knowing the values of m and χ for each calibrator, the problem, in principle, is to determine G'_{LR}/G'_{LL}, $G'_{LR,I}/G'_{LL}$, G'_{RL}/G'_{LL}, and $G'_{RL,I}/G'_{LL}$ from a least square fit to date on V'_{LR}/V'_{LL} and V'_{RL}/V'_{LL}.

In practice the calibration is most conveniently carried out in a two-stage process where one begins with completely calibrated LL and RR correlators, but with LR and RL correlators in the V'_{LR} and V'_{RL} stages. One then uses Equations III-(12) to solve for G'_{LR}, $G'_{LR,I}/G'_{LL}$, G'_{RL} and $G'_{RL,I}/G'_{LL}$ given data on $V'_{LR}/V_{LL} = V'_{LR}/(G'_{LL} \cdot V'_{LL})$ and $V'_{RL}/V_{LL} = V'_{RL}/(G'_{LL} \cdot V'_{LL})$. The determination of V_{LR} and V_{RL} for all sources is made by first applying Equations III-(12) to determine V_{LR}/V_{LL} and V_{RL}/V_{LL}; then one multiplies by V_{LL} to obtain the final visibility functions.

There are a number of pitfalls involved in applying LL and RR calibration before determining the LR and RL polarization "constants"-- all of them related to the difficulty of identifying changes of instrumental parameters with time. We will discuss these details further when we discuss the use of the programs for processing polarization data.

3. Programs for Display and Manipulation of Data

In this section, and the subsequent sections of this chapter, we will attempt to introduce the methods by which one can examine the data and the programs with which one edits, corrects, and calibrates the data. For a more comprehensive description of these programs the reader should consult the "Users Guide to the Dual-Frequency Interferometer Programs", hereinafter called the "Users Guide".

(a) Form of Data on Magnetic Tape or Disk Data Set.

All of the data gathered by the interferometer undergo the fringe-fitting process and are then written on seven-track magnetic tapes by the DDP116 in Green Bank. The data on the seven-track tapes are transferred to nine-track magnetic tapes by the 360/50 in Charlottesville. Once the raw data are available on nine-track tapes, the user, either by his own use of standard programs or by use of certain "automatic" programs, then carries out a process of data display, manipulation, cleaning, correcting, calibrating, etc. In doing this one frequently takes data off one tape, modifying it as desired, then writes the resulting data onto other magnetic tapes, or occasionally onto disk data sets kept in disk storage by the 360/50. As a result, the basic processing we will be discussing during the remainder of this chapter involves three steps: (i) displaying and examining the data; (ii) taking it off tape or disk, modifying it as desired, and writing it on another tape or disk data set; and (iii) displaying and examining the results.

What type of data are we to display, examine, modify, etc.? For every data scan, with length and data content chosen by the observer when making up the observing cards, the data format consists of three parts:

(1) The <u>header</u> in which scan number, source name, right ascension and declination of reference position precessed to date of observation, baselines, date (local sidereal day number), LST (local sidereal time), observing mode, baseline parameters, etc., are recorded;

(2) The <u>A/D records</u> (analog to digital) which contain information about temperature, dew point, barometric pressure, cable pressure, LO setting, etc.; and

(3) The <u>data records</u>, containing, for each successive 30-second period during the scan, the real (R'') and imaginary (I'') parts of the raw visibility function for each correlator, the rms of the fringe-fit for each correlator, the gain settings, LST, total powers, and other diagnostics of the system. For further details the reader should consult the "Users Guide".

<u>(b) Need for Data-Handling Programs</u>.

The user must become familiar with how to use a large number of standard programs (stored on disk in the 360/50) which give him access to and manipulative control of the data recorded on tape or disk. All extensive details are to be found in the "Users Guide", but we will attempt to introduce the reader to some aspects of the most important programs. In doing so we will frequently give examples of the needed computer cards and, whenever possible, display the relevant computer output in figures.

(c) Use of INCLUDE/EXCLUDE/END cards.

The data to be processed by many of the programs are specified by use of input cards called INCLUDE, EXCLUDE, and END cards; therefore before we can begin discussion of programs, we must explain their usage.

By use of these cards one can specify in a very flexible manner what data are to be processed by a particular program. Each card begins, in column one, with one of the three key words INCLUDE, EXCLUDE, or END. Following the key word one then lists, in any order, attributes describing the data to be included, excluded, etc. At least one blank space must occur between each attribute listed.

The attributes that can be specified are of six kinds:*

(1) Scan Range.

e.g., INCLUDE_1570_1580

(include all scans from 1570 through 1580)

e.g., EXCLUDE_1570

(exclude scan 1570)

e.g., INCLUDE

(default option whereby all data found on tape or disk data set are to be processed)

(2) Source Name.

e.g., INCLUDE_3C48

(3) Frequency.

e.g., INCLUDE_XBAND

e.g., INCLUDE_SBAND

* Here and in the following sections we will indicate places where at least one blank space must be present by an underline (_) which, needless to say, is not to be punched on the cards. It is wise to assume that if no space is indicated, then insertion of a space will cause an error.

(4) Correlator.

e.g., INCLUDE_1R3R

possible designations:				
	1R2R	2R3R	1R3L	RR
	1L2L	2L3L	1L3R	LL
	1R3R	1R2L	2R3L	LR
	1L3L	LL2R	2L3R	RL

(5) Telescopes.

e.g., EXCLUDE_85-1

possible designations: 85-1
85-2
85-3

(6) Receivers.

e.g., EXCLUDE_1R

possible designations:		
	1R	1L
	2R	2L
	3R	3L

Any combination of these six types of attributes may be used to describe what data is to be included or excluded; if a particular type of attribute is not specified, then all data possessing that attribute are processed.

e.g., INCLUDE 3C48_15841_1580_XBAND_1R2R
INCLUDE_15841_15845_85-1

The purpose of the END card is to cause the program to begin again under the control of different INCLUDE/EXCLUDE cards that follow afterwards. This is used in two forms:

END_(Scan Number)

and

END_REWIND.

e.g.,
INCLUDE_1500_1700_SBAND
END_1700
INCLUDE_1500_1700_XBAND

(first run is executed for scan range 1500 through 1700 on SBAND data, then program is rerun for the same scan range on XBAND data)

e.g., INCLUDE_SBAND
END_REWIND
INCLUDE_XBAND

(first run processes all SBAND data, then it goes back to beginning of tape (or disk data set) and processes all XBAND data.)

(d) Use of Job Control Language (JCL).

The user controls what programs are to be used, what data are to be processed, and how this is to be done by means of JCL cards--with input data where necessary. We will give a minimal, abbreviated introduction to JCL usage so the user can get started.

To run any program on the 360/50 you must supply:

(1) a JOB card*

e.g.: //INTDATA_JOB_(79,P,6,8,4),MSGLEVEL=1,CLASS=C

(note that slashes in columns 1 and 2 are the identifying characteristics of JCL cards).

(2) An EXEC card which

(i) names the program to be executed

(ii) specifies details on input and output data, either in detail or by default

(iii) specifies parameter options (PARM = '...'), to be used in program, either in detail or by default

e.g.: //_EXEC_INTAVG,INTAPE=1817,INNAME=DATA,PARM='ARITH'

and, depending upon the nature of the program to be executed, you may need to supply data to data files:

for programs controlled by INCLUDE/EXCLUDE cards

---

* The number 79 is an example of a user number; every observer should see to it that the computer division has assigned him or her a user number before running on the 360/50.

(3) A card indicating a set of INCLUDE/EXCLUDE cards is to be read

e.g., //SYSIN_DD_*

where SYSIN is the name of the data file

(4) The INCLUDE/EXCLUDE cards which specify the contents we wish to read into the data file SYSIN

e.g., INCLUDE_SBAND
END_REWIND
INCLUDE_XBAND

<u>or, for programs requiring special data input</u>

(3) A card identifying a particular data file which is to be supplied with data

e.g., //BASLINES_DD_*

where a data file named BASLINES is to be supplied with data.

(4) The necessary data, usually in a particular format defined by the program being executed.

The only further details the user need be conversant with at the moment concern the EXEC card.

The PARM specification on an EXEC card is simple and straightforward. Many programs allow the user to specify certain options in executing a program. For example, we will soon describe a program that can average together a specified number of 30-second data records. One can control the length of the average by specifying PARM='LENGTH=(time in minutes)'; and one can average the amplitudes arithmetically rather than vectorially by specifying PARM='ARITH'.

e.g., //_EXEC_INTAVG,PARM='ARITH,LENGTH=12'.

The more complicated part of the EXEC card involves specification of properties, numbers, and names for all input and output devices. One can supply:

(1) Information concerning whether data are on tape or disk

e.g., INUNIT=DISK

if the device name is not specified it is assumed to be TAPE.

(2) A tape number which must be supplied whenever a tape is to be either read or written upon

e.g., INTAPE=3359
OUTTAPE=1720

(3) The name of the tape or disk data set

e.g., INNAME=RAWTAPE
OUTNAME=CORRTAPE
INNAME='&&TEMP'

Note that each word used for a name can contain no more than 8 letters (or numbers, as long as both alphameric and numeric are present in the name); all names for disk data sets are surrounded by single quotes.

(4) Disposition of the tape or disk data set; usually whether you want to start a new one* (NEW) at the beginning of the tape or disk data set, add to the end of an old one (MOD), or share a data set on disk with other programs (SHR),

e.g., INDISP=SHR
OUTDISP=MOD
OUTDISP=NEW

Putting it all together for a sample EXEC card:

```
//_EXEC_INTAVG,PARM='ARITH,LENGTH=10',
//_INUNIT=DISK,INNAME='&&DATA',
//_INDISP=SHR,OUTTAPE=1137,OUTNAME=AVDATA1,
//_OUTDISP=MOD
```

Note that an EXEC instruction can be continued on as many cards as needed by making the last symbol, on all cards but the last, a comma. Remember also that columns 72-80 cannot be used; and the order in which one indicates PARM or unit specifications is arbitrary.

One special detail concerning disk data sets is very useful. Frequently one wants to write some data on disk for one program, then

* Warning, with DISP=NEW, anything already on a tape or disk data set is written over and destroyed.

call another program which uses these data. One can do this by using temporary disk data sets which are identified by a double amphersand preceding a name (of six or less letters and numbers),

e.g., OUTNAME='&&DATA'.

An example of such common usage, involving programs we will discuss shortly, is*

```
//_EXEC_INTAVG,INTAPE=1100,INNAME=SDATA,
//_OUTUNIT=DISK,OUTNAME='&&DATA'
//SYSIN_DD_*
INCLUDE_SBAND
END_REWIND
INCLUDE_XBAND
//_EXEC_INTSCRIB,INUNIT=DISK,INNAME='&&DATA'
```

When the job is finished, the data set &&DATA is erased. No OUTDISP specification is necessary when the double amphersand is used.

For many programs, default specifications exist for both input and output so they can be coupled together without specifying details. For example, the default output of INTAVG is the same as the default input to INTSCRIB; therefore the above program may be written in the more compact form:

```
//_EXEC_INTAVG,INTAPE=1100,INNAME=SDATA
//SYSIN_DD_*
INCLUDE_SBAND
END_REWIND
INCLUDE_XBAND
//_EXEC_INTSCRIB
```

A list of the input and output default specifications for a number of important programs can be found in Appendix 3.

(e) Display and Examination of Data

Obviously the first requirement is for programs to allow the user to examine all or part of the data. One examines the data for

* In listing programs we will hereinafter not write out the JOB card.

many reasons at many different stages of processing. There are two utility programs that can be used for direct display of data records: INTLOOK and INTSCRIB.

(1) INTLOOK

The first display program is called INTLOOK. With INTLOOK one can examine virtually every piece of information written on a tape or disk data set. As a result of this, indiscriminant application of INTLOOK to all data with all possible options gives the user an enormous amount of computer output. For this reason INTLOOK is best used only to diagnose serious problems or to examine details on small amounts of data.

Two examples of the use of INTLOOK are shown in Figure III-2 where the essential outputs for the following programs are shown:

```
//_EXEC_INTLOOK,INTAPE=1547,INNAME=RAWDATA,PARM='RCVR,DELAYS'
//SYSIN_DD_*
INCLUDE_3C48_15954
```

(resulting output shown in Figure III-2a)

and

```
//_EXEC_INTLOOK,INTAPE=1548,INNAME=CALDATA
//SYSIN_DD_*
INCLUDE_3C48_15954
```

(resulting output shown in Figure III-2b).

The first program (see result in Figure III-2a) gives us a display of the raw data for scan 15954 of 3C48, with a request for print-out of receiver parameters (RCVR; total powers, synchronous detector output) and delay setting (DELAYS). The second program (see result in Figure III-2b) displays the final calibrated data for the same scan, but without the extra diagnostic information. For both examples the data between rows of asterisks are the header contents. We see that most of the header contents are the same in Figures III-2a and III-2b, but there are small differences in baseline parameters indicating corrections have been applied. The next line in Figure III-2a tells us that

(a)

```
*****************************************************************************************************************

   3C48      ( 01 36 10.171, 033 01 30.55)   LOCAL SID DAY  2448287, LST 02 53 07, HA  01 16 56                 3C48
      RH IS OBSERVING WITH DS AS OPERATOR         RETURN CODE WAS  1, CONSOLE SWITCHES  0000 0000 0000 0000     SCAN 15954

              85-1/85-2                       85-1/85-3                        85-2/85-3                  85-1/42'
 BX        -4785.590    -14356.770     -4533.359    -13600.078       -252.229      -756.688     40491.079   121473.237
 BY       -15086.944    -45260.833    -14292.725    -42878.174       -794.220     -2382.659     74762.689   224288.068
 BZ         6421.510     19264.529      6083.550     18250.649        337.960      1013.880    -55965.279  -167895.838
KTERM          0.0           0.0           0.0           0.0            0.0           0.0         58.800        0.0

*****************************************************************************************************************

HDR CLOCK ERROR (MSEC) IS    0.0 EDITING DONE IS (      ) WD22= 0000

   TEMP   -4.          -8       -12       60     -9312     -9296    -11616    -16460       40        44        36
   DEW    -5.          -8     14752    12452      7536        40      4272      6376      992      6136      5604
   BARO  949.         752        32       -4        -4      7500        30    -28096    10240      1567      8906
   CABLE  7.9      -30131     16696    12016      7024     12036      7031     12023     7030         7     27751
   LO 7500030       28959         0        0         0      4520      5732         6    30128       175     16384

                                 1R2R               1L2L              1R3R               1L3L               2R3R               2L3L
   LST      TPOWER BAND    AMP  PHI  RMS     AMP  PHI  RMS     AMP  PHI  RMS      AMP  PHI  RMS      AMP  PHI  RMS      AMP  PHI  RMS      HA
 02 53 26   557655   S    1398  -22  126    1384 -108  101    1188 -114   99     1228   18  121     1139  -87   86     1094   53  126    1.29
 02 53 56   666656   X     327 -139   60     304  174   46     278 -121   42      341  -91   47      269  164   37      287   86   43    1.30
 02 54 26   557655   S    1451  -22   89    1394 -108   72    1215 -115   85     1261   18   97     1140  -87   70     1115   52   90    1.30
 02 54 56   666656   X     342 -142   54     304  172   46     275 -123   42      348  -93   49      260  162   40      285   85   43    1.31
 02 55 26   557655   S    1365  -21  111    1386 -107  101    1160 -114   70     1260   19   87     1139  -87   68     1117   53   88    1.32
 02 55 56   666656   X     333 -143   60     300  173   52     276 -124   45      342  -94   54      269  163   40      285   86   41    1.33
 02 56 27   557655   S    1100    0  454    1079  -85  442     844  -90  417      890   44  455     1150  -91   92     1127   49  106    1.34
 02 56 57   666656   X     346 -141   55     300  171   45     272 -126   40      336  -96   49      249  163   34      294   86   38    1.35
 02 57 27   557655   S    1473  -22  105    1394 -107   95    1215 -115   61     1272   18   78     1109  -86   76     1122   53   79    1.35
 02 57 57   666656   X     338 -140   59     295  173   45     283 -125   42      335  -96   48      272  164   32      291   88   38    1.36
 02 58 27   557655   S    1455  -22  100    1393 -108   79    1212 -116   76     1251   18   88     1119  -86   88     1102   53   91    1.37
 02 58 57   666656   X     344 -140   55     298  172   47     278 -125   42      336  -96   50      261  163   34      292   89   38    1.38
 02 59 27   557655   S    1384  -22   99    1383 -108   81    1202 -116   73     1238   17   90     1131  -85   81     1115   54   93    1.39

S/X GAINS =  111111 / 111111

                       1R                 1L                 2R                  2L                 3R                 3L               DELAYS
   LST           TP      SYNC       TP      SYNC       TP      SYNC        TP      SYNC       TP      SYNC       TP      SYNC   85-1  85-2  65-3
 02 53 26     -10580    29708    -10124    28592    -13152   -32632    -11844    32764     -9884    20996    -10700    20844   0000  0C27  0F58
 02 53 56     -11606    10812    -11724    21244    -12752   -32632    -12576    32764    -10080    14028    -11668    17644   0000  0C2C  0F5C
 02 54 26     -10564    29764    -10140    28660    -13076   -32632    -11808    32764     -9880    20916    -10720    20860   0000  0C30  0E61
 02 54 56     -11768    10748    -11680    21248    -12748   -32632    -12572    32764    -10072    13952    -11680    17588   0000  0C34  0F65
 02 55 26     -10516    29772    -10076    28672    -13088   -32632    -11808    32764     -9816    21004    -10704    20856   0000  0C38  0E69
 02 55 56     -11784    10824    -11664    21352    -12756   -32632    -12564    32764    -10072    13880    -11716    17700   0000  0C30  0E6D
 02 56 27     -10520    29880    -10052    28868    -13064   -32632    -11784    32764     -9820    20852    -10696    21048   0000  0C41  0E71
 02 56 57     -11808    10760    -11664    21356    -12820   -32632    -12572    32764    -10064    13828    -11660    17700   0000  0C46  0E75
 02 57 27     -10524    29688    -10016    28732    -13084   -32632    -11804    32764     -9816    20848    -10720    20976   0000  0C4A  0E7A
 02 57 57     -11800    10808    -11660    21380    -12832   -32632    -12552    32764    -10056    13948    -11672    17768   0000  0C4E  0F7E
 02 58 27     -10500    29816    -10060    28676    -13064   -32632    -11784    32764     -9804    19980    -10708    20848   0000  0C53  0E82
 02 58 57     -11796    10816    -11680    21316    -12760   -32632    -12564    32764    -10080    13176    -11680    17716   0000  0C57  0E86
 02 59 27     -10460    29756    -10016    28728    -13076   -32632    -11800    32764     -9812    19968    -10712    20772   0000  0C58  0E8A

NO MORE CARDS
```

(b)

```
*****************************************************************************************************************

   3C48      ( 01 36 10.171, 033 01 30.55)   LOCAL SID DAY  2448287, LST 02 53 07, HA  01 16 56                 3C48
      RH IS OBSERVING WITH DS AS OPERATOR         RETURN CODE WAS  1, CONSOLE SWITCHES  0000 0000 0000 0000     SCAN 15954

              85-1/85-2                       85-1/85-3                        85-2/85-3                  85-1/42'
 BX        -4785.609    -14356.828     -4533.382    -13600.146       -252.230      -756.691     40491.079   121473.237
 BY       -15086.926    -45260.778    -14292.714    -42878.142       -794.215     -2382.645     74762.689   224288.068
 BZ         6421.534     19264.604      6083.563     18250.689        337.974      1013.922    -55965.279  -167895.838
KTERM          0.0           0.0           0.0           0.0            0.0           0.0         58.800        0.0

*****************************************************************************************************************

HDR CLOCK ERROR (MSEC) IS  -40.0 EDITING DONE IS (PACB) WD22= 00F2

   TEMP   -4.          -8       -12       60     -9312     -9296    -11616    -16460       40        44        36
   DEW    -5.          -8     14752    12452      7536        40      4272      6376      992      6136      5604
   BARO  949.         752        32       -4        -4      7500        30    -28096    10240      1567      8906
   CABLE  7.9      -30131     16696    12016      7024     12036      7031     12023     7030         7     27751
   LO 7500030       28959         0        0         0      4520      5732         6    30128       175     16384

                                 1R2R               1L2L              1R3P               1L3L               2R3P               2L3L
   LST      TPOWER BAND    AMP  PHI  RMS     AMP  PHI  RMS     AMP  PHI  RMS      AMP  PHI  RMS      AMP  PHI  RMS      AMP  PHI  RMS      HA
 02 53 26   557655   S     866    0  127     912    0  103     879    1  100      893    0  122      925    0   88      898    0  127    1.29
 02 53 56   666656   X     322    3   61     350    2   48     327    6   44      338    6   49      347    0   40      337   -1   45    1.30
 02 54 26   557655   S     899    0   91     918    0   74     899    0   87      916    0   99      926    0   73      914    0   92    1.30
 02 54 56   666656   X     338    0   55     349    1   48     324    4   44      345    5   51      335   -2   42      336   -2   45    1.31
 02 55 26   557655   S     846    0  112     913    0  103     858    1   72      915    1   89      925    0   71      917    0   90    1.32
 02 55 56   666656   X     328    0   61     345    2   54     324    3   47      340    4   55      346   -1   43      336   -1   43    1.33
 02 56 27   557655   S      -1    0   -1      -1    0   -1      -1    0   -1       -1    0   -1      933   -4   94      924   -3  108    1.34
 02 56 57   666656   X     341    1   56     344    0   47     320    1   42      332    2   51      320   -1   37      347   -1   40    1.35
 02 57 27   557655   S     912    0  107     918    0   97     900    0   64      923    0   80      901    0   78      921    0   81    1.35
 02 57 57   666656   X     333    2   60     340    3   47     331    2   44      331    2   50      351    0   35      342    0   40    1.36
 02 58 27   557655   S     901    0  102     917    0   81     898    0   78      908    0   90      909    0   90      905    0   93    1.37
 02 58 57   666656   X     338    2   56     342    2   49     327    2   44      332    1   52      336   -1   37      343    1   40    1.38
 02 59 27   557655   S     858    0  100     912   -1   83     891    0   75      899    0   92      919    0   83      916    1   95    1.39

S/X GAINS =  111111 / 111111

NO MORE CARDS
```

Fig. III-2. INTLOOK display of all 30 second records for scan 15954 in the (a) raw data stage and (b) in the completely calibrated stage.

no CLOCK or other corrections have been applied; however we see from the corresponding line in Figure III-2b that PHASE, AMPCOR, CLOCK (-40 msec), and BASELINE corrections have been applied because PACB is present. The next series of lines for both Figures III-2a and III-2b give the same contents of the same A/D records: temperature, dew point, barometric pressure, cable pressure, an index of the LO setting (which should be close to 7500000), and other parameters of less interest.

Finally, under the appropriate column labels, the detailed data for each successive 30-second record in each scan are displayed in Figure III-2. The data was taken in dual (D) mode, so the display alternates S and X-band records. The columns showing LST, BAND, AMP (amplitude), PHI (phase), RMS, and HA (hour angle) are self-explanatory. The TPOWER column contains an index roughly describing the total power levels for each of the 6 receivers (1R, 1L, 2R, 2L, 3R, 3L) in a manner we will define in a moment.

The raw data in Figure III-2a appear normal except for unusually high rms' for the pairs involving 85-1 at LST = 02 56 27, and, indeed, something was wrong there because the amplitudes and phases are also anomalous. In the raw data stage the amplitudes are given in arbitrary units of counts. The calibrated data in Figure III-2b show the results of editing (the bad data are missing as shown by the combination of -1's and 0's in the AMP and PHI columns). In addition, the phases are very well centered on zero, as they should be; and the amplitudes tell us 3C48 is 9.0 f.u. at SBAND and 3.3 f.u. at XBAND, as it should be.

The next line in both Figures III-2a and III-2b gives the number of factors of ten (equipment gains) that the amplitudes must be multiplied by for each of the six correlators.

Next, under the appropriate column labels, we have in Figure III-2a the extra diagnostic information requested by the use of

PARM='RCVR,DELAYS' in the EXEC card. For each 30-second record we see the LST, total powers, synchronous detector outputs, and the delay setting between pairs (in hexadecimal form). The diagnostic data of primary interest are the total powers, because sudden changes in these are indicators of bad data. However, because only gross changes tell you very much, the detailed numbers are not essential, and the total power index displayed with the data records is frequently sufficient. The index is calculated in steps whereby: if TP = 10000 to 10999, the index is 5; if TP = 11000 to 11999, the index is 6, etc.

One can obtain a display of LR and RL correlators by specifying PARM = 'XPOL' in the PARM field of INTLOOK. Another option that is frequently used is the display of real and imaginary parts of the visibility function for each correlator, which one can obtain by specifying PARM = 'VISFUN'.

(2) INTSCRIB

The display program which is most often used is a very flexible program called INTSCRIB. The following program gives the INTSCRIB display shown in Figure III-3a for the same raw data displayed by INTLOOK in Figure III-2a:

```
//_EXEC_INTSCRIB,PARM='LIST',INTAPE=1547,INNAME=RAWDATA
```

(results shown in Figure III-3a)

The meaning of each column in the display is obvious from previous discussions, except for the NREC column which gives the number of 30-second records involved (as we shall see, one also uses INTSCRIB and INTLOOK to examine averaged data), and the RMS index. The RMS index is calculated as follows: if RMS = 0 to 99 counts, the index is 0, if RMS = 100 to 199, the index is 1, etc.; until, with RMS of 1000 or greater, an asterisk appears. Note that the equipment gain factors have been multiplied into the amplitudes before display by INTSCRIB.

---------- DATA FOR CONFIGURATION 1-18-19 ----------

SCAN	M	SOURCE	HA	RMS/100	AMP1R2R	PHI	AMP1L2L	PHI	AMP1R3R	PHI	AMP1L3L	PHI	AMP2R3R	PHI	AMP2L3L	PHI	NREC	TPOWER	LST
15954	SD	3C48	01 17	111101	8660	-1	9121	-1	8791	1	8930	1	9250	-1	8980	-0	1	557655	02 53 25
15954	XD	3C48	01 17	000000	3225	3	3504	3	3272	7	3383	7	3470	-1	3370	-1	1	666656	02 53 55
15954	SD	3C48	01 18	000000	8991	-1	9181	-1	8990	0	9160	-0	9260	-1	9140	-0	1	557655	02 54 25
15954	XD	3C48	01 18	000000	3380	0	3491	2	3242	5	3454	5	3353	-3	3362	-2	1	666656	02 54 55
15954	SD	3C48	01 19	110000	8460	1	9130	0	8583	2	9154	2	9250	-0	9170	-0	1	557655	02 55 25
15954	XD	3C48	01 19	000000	3280	-0	3452	2	3247	4	3400	5	3461	-2	3360	-1	1	666656	02 55 55
15954	SD	3C48	01 20	01		0		0		0		0	9334	-5	9249	-4	1	557655	02 56 26
15954	XD	3C48	01 20	000000	3411	2	3440	1	3201	2	3322	2	3201	-2	3471	-2	1	666656	02 56 56
15954	SD	3C48	01 21	100000	9120	-0	9180	-0	9000	0	9230	0	9010	0	9210	0	1	557655	02 57 26
15954	XD	3C48	01 21	000000	3333	3	3405	3	3313	3	3313	3	3510	0	3420	0	1	666656	02 57 56
15954	SD	3C48	01 22	100000	9010	-1	9171	-1	8980	-0	9080	0	9090	1	9050	-0	1	557655	02 58 26
15954	XD	3C48	01 22	000000	3383	3	3422	2	3273	3	3321	2	3360	-1	3430	1	1	666656	02 58 56
15954	SD	3C48	01 23	100000	8580	-1	9121	-1	8910	-0	8990	-1	9190	1	9161	1	1	557655	02 59 26

END

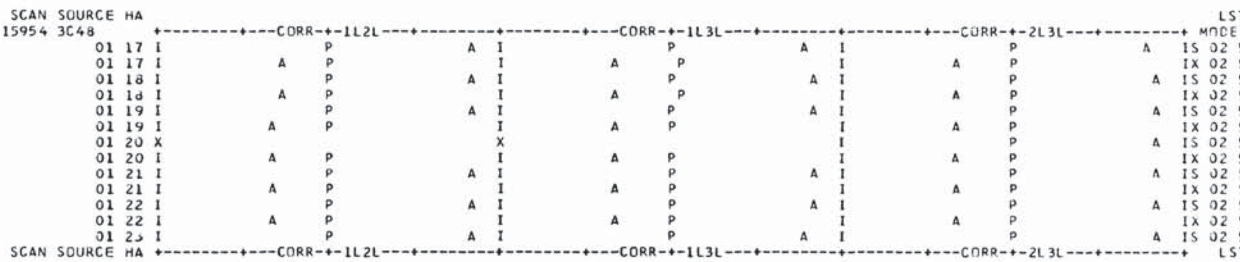
(a)

---------- DATA FOR CONFIGURATION 1-18-19 ----------

SCAN	M	SOURCE	HA	RMS/100	AMP1R2R	PHI	AMP1L2L	PHI	AMP1R3R	PHI	AMP1L3L	PHI	AMP2R3R	PHI	AMP2L3L	PHI	NREC	TPOWER	LST
15954	SD	3C48	01 17	110101	13980	-23	13847	-108	11887	-115	12285	19	11390	-88	10942	53	1	557655	02 53 25
15954	XD	3C48	01 17	000000	3271	-140	3045	174	2786	-121	3411	-92	2693	164	2875	87	1	666656	02 53 55
15954	SD	3C48	01 18	000000	14510	-23	13942	-108	12157	-116	12611	18	11400	-88	11152	53	1	557655	02 54 25
15954	XD	3C48	01 18	000000	3424	-143	3043	173	2759	-123	3485	-93	2602	162	2857	86	1	666656	02 54 55
15954	SD	3C48	01 19	110000	13654	-21	13863	-107	11609	-114	12605	20	11394	-87	11176	53	1	557655	02 55 25
15954	XD	3C48	01 19	000000	3336	-143	3000	173	2765	-124	3428	-94	2692	163	2854	87	1	666656	02 55 55
15954	SD	3C48	01 20	444401	11000	-1	10791	-86	8440	-90	8903	44	11505	-92	11271	50	1	557655	02 56 26
15954	XD	3C48	01 20	000000	3465	-141	3002	172	2724	-126	3360	-96	2496	163	2944	87	1	666656	02 56 56
15954	SD	3C48	01 21	100000	14730	-22	13943	-108	12156	-116	12721	18	11098	-87	11224	54	1	557655	02 57 26
15954	XD	3C48	01 21	000000	3381	-141	2957	174	2830	-126	3359	-96	2724	165	2911	88	1	666656	02 57 56
15954	SD	3C48	01 22	100000	14555	-23	13933	-109	12123	-117	12510	18	11196	-86	11026	53	1	557655	02 58 26
15954	XD	3C48	01 22	000000	3440	-141	2983	173	2786	-126	3365	-97	2614	164	2920	89	1	666656	02 58 56
15954	SD	3C48	01 23	000000	13846	-23	13838	-109	12021	-117	12385	17	11317	-86	11157	55	1	557655	02 59 26

END

LHAND AMPLITUDES AND PHASES FOR CONFIGURATION 1-18-19
PLOT RANGES FOR AMP: 0 -> 1000 PER SYMBOL, PHASE: -180 -> +180



(b)

RHAND AMPLITUDES AND PHASES FOR CONFIGURATION 1-18-19
PLOT RANGES FOR AMP: 0 -> 1000 PER SYMBOL, PHASE: -180 -> +180

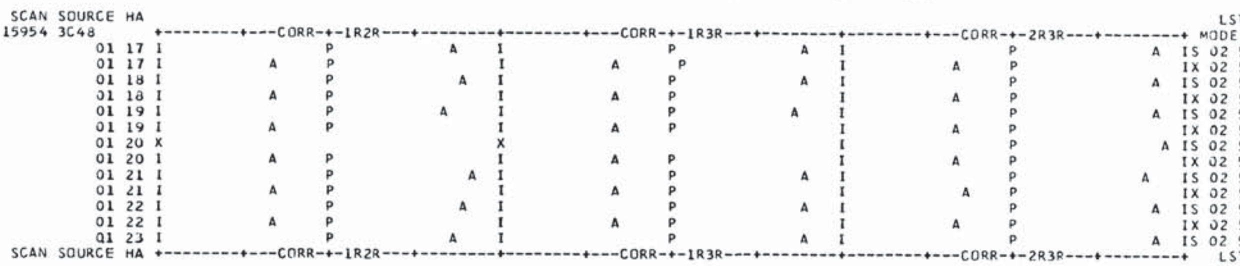


Fig. III-3. (a) INTSCRIB display, with PARM='LIST', for scan 15954 in raw data stage; and (b) INTSCRIB display, with PARM='LIST,PLOT', for scan 15954 in calibrated data stage.

There are a large number of PARM options that can be used with INTSCRIB, with the most important being the following:

PARM OPTION	DEFAULT*	USAGE
'LIST'	'LIST'	display of LL and RR data
'XPOL'	'NOXPOL'	display of LR and RL data
'SUM'	'NOSUM'	calculates and displays arithmetically averaged amplitudes and phases for all observations of each source within a particular configuration
'SORT'	'NOSORT'	data for each source displayed together, with sources appearing in order first observed
'PLOT'	'NOPLOT'	amplitudes and phases to be plotted as a function of time
'RANGE=...'	'RANGE=1000'	range for amplitude plot (RANGE=2000 useful when CPFU option invoked, RANGE=200 useful for very weak sources)
'NOGRID'	'GRID'	to use or not to use correlator labeling between plots for different sources
'CPFU'	'NOCPFU'	will calculate and display counts per flux unit in place of amplitudes

To illustrate the use of some of the INTSCRIB options, the following program was used to obtain the result shown in Figure III-3b:

```
//_EXEC_INTSCRIB,INTAPE=1548,INNAME=CALDATA,PARM='LIST,PLOT'
```

(result shown in Figure III-3b)

and to get the result shown in Figure III-4:

```
//_EXEC_INTSCRIB,INTAPE=1548,INNAME=CALDATA,
//_PARM='CPFU,SUM,PLOT,RANGE=2000'
```

(result shown in Figure III-4).

---

* Option invoked when nothing is specified.

Note that in the plots the symbol P ordinarily indicates the phase; however if phase and amplitude need to be plotted at the same point, an X appears. With RANGE = 1000, if AMP < 1000, an A is plotted. If 1000 ≤ AMP < 2000, a B is plotted, etc.

The use of the CPFU option is of special importance either to obtain or to check on the gain calibration. The INTSCRIB example displayed in Figure III-4 uses a default list of calibrator fluxes which is shown in the Figure. The program then takes the data for any sources included in this list (with the same spelling of name) and displays, not the amplitudes, but the amplitudes divided by the flux densities (CPFU is abbreviation for counts per flux unit). It is usual (but arbitary) to calibrate amplitudes so that point sources have 1000 counts per flux unit. We see that indeed the 3C48 scan being displayed is very well calibrated. Because the SUM option was invoked, we have a display of the averages for all amplitudes and phases; note that the average CPFU is off by only about 2 percent, and the average phase deviation from zero is about a degree. This is somewhat better than usual. The utility of RANGE=2000 for PLOT when using the CPFU option is obvious from Figure III-4, because one can get a quick visual impression of the quality of the calibration.

Use of the CPFU option requires that S and X-band fluxes be supplied. There is a default list stored on disk (use at your own risk); however, in general, the user will want to supply his own. This is accomplished as follows (to obtain the same result as Figure III-4, except only 3C48 would appear on the list):

```
//_EXEC_INTSCRIB,INTAPE=1548,INNAME=CALDATA
//_PARM='CPFU,SUM,PLOT,RANGE=2000'
//FLUXES_DD_*
3C48    9.0     3.3
```

where, after the //FLUXES_DD_* card, one supplies one card per source with: name, an SBAND flux, and an XBAND flux in (A(10), 2F(10,3)) format.

PARMS SPECIFIED ARE AS FOLLOWS: CPFU,SUM,PLOT,RANGE=2000

AMPLITUDES WILL BE IN UNITS OF COUNTS PER FLUX UNIT
SOURCES AND THEIR SBAND AND XBAND FLUXES HAVE BEEN SPECIFIED AS FOLLOWS:

3C48	9.000	3.300
CTA21	5.000	1.700
NRAO140	2.700	2.100
P0413-21	1.600	0.850
P0420-01	1.300	1.500
3C119	5.400	2.200
P0451-28	2.200	2.000
3C138	5.600	2.800
3C147	12.700	5.000
D0727-11	2.600	4.800
P0834-20	2.500	2.600
DA267	4.800	10.700
P1015-31	2.200	1.000
P1116+12	1.700	1.200
P1127-14	6.400	4.500
3C287	4.600	2.200
3C286	10.100	5.200
P1345+12	3.800	2.400
3C309.1	5.300	2.500
DA406	2.400	2.100
NRAO530	3.900	4.600
3C395	3.200	2.200
3C418	4.000	3.300
P2128-12	1.700	1.600

---------- DATA FOR CONFIGURATION 1-18-19 ----------

SCAN	M	SOURCE	HA	RMS/100	AMP1R2R	PHI	AMP1L2L	PHI	AMP1R3R	PHI	AMP1L3L	PHI	AMP2R3R	PHI	AMP2L3L	PHI	NREC	TPOWER	LST
15954	SD	3C48	01 17	111101	962	-1	1013	-1	976	1	992	1	1027	-1	997	-0	1	557655	02 53 25
15954	XD	3C48	01 17	000000	977	3	1062	3	991	7	1025	7	1051	-1	1021	-1	1	666656	02 53 55
15954	SD	3C48	01 18	000000	999	-1	1020	-1	998	0	1017	-0	1028	-1	1015	-0	1	557655	02 54 25
15954	XD	3C48	01 18	000000	1024	0	1058	2	982	5	1046	5	1016	-3	1018	-2	1	666656	02 54 55
15954	SD	3C48	01 19	110000	940	1	1014	0	953	2	1017	2	1027	-0	1018	-0	1	557655	02 55 25
15954	XD	3C48	01 19	000000	993	-0	1046	2	984	4	1030	5	1048	-2	1018	-1	1	666656	02 55 55
15954	SD	3C48	01 20	01		0		0		0		0	1037	-5	1027	-4	1	557655	02 56 26
15954	XD	3C48	01 20	000000	1033	2	1042	1	970	2	1006	2	970	-2	1051	-2	1	666656	02 56 56
15954	SD	3C48	01 21	100000	1013	-0	1020	-0	1000	0	1025	0	1001	0	1023	0	1	557655	02 57 26
15954	XD	3C48	01 21	000000	1010	3	1031	3	1004	3	1004	3	1063	0	1036	0	1	666656	02 57 56
15954	SD	3C48	01 22	100000	1001	-1	1019	-1	997	-0	1008	0	1010	1	1005	-0	1	557655	02 58 26
15954	XD	3C48	01 22	000000	1025	3	1037	2	992	3	1006	2	1018	-1	1039	1	1	666656	02 58 56
15954	SD	3C48	01 23	100000	953	-1	1013	-1	990	-0	998	-1	1021	1	1017	1	1	557655	02 59 26

********** AVERAGES FOR CONFIGURATION 1-18-19 **********
QTY-TYPE AVG: AMP,RMS = UNWTD ARITH, PHASE = VECTOR

SOURCE	RIGHT ASC	DECLINATION	AMP 1R2R	PHI	AMP 1L2L	PHI	AMP 1R3R	PHI	AMP 1L3L	PHI	AMP 2R3R	PHI	AMP 2L3L	PHI
3C48	01 36 10	+33 01 30	995	1	1032	1	987	2	1015	2	1025	-1	1023	-1

END

LHAND AMPLITUDES AND PHASES FOR CONFIGURATION 1-18-19
PLOT RANGES FOR AMP: 0 -> 2000 PER SYMBOL, PHASE: -180 -> +180

```
SCAN SOURCE HA                                                                                                      LST
15954 3C48      +---------+---CORR-+-1L2L---+---------+---------+---CORR-+-1L3L---+---------+---------+---CORR-+-2L3L---+---------+ MODE D
       01 17 I              X                 I                 X                 I                 X                 IS 02 53
       01 17 I              PA                I                 AP                I                 X                 IX 02 53
       01 18 I              X                 I                 X                 I                 X                 IS 02 54
       01 18 I              PA                I                  X                I                 X                 IX 02 54
       01 19 I              X                 I                 X                 I                 X                 IS 02 55
       01 19 I              PA                I                 PA                I                 X                 IX 02 55
       01 20 X                                X                                   I                 X                 IS 02 56
       01 20 I              PA                I                 X                 I                 PA                IX 02 56
       01 21 I              X                 I                 X                 I                 X                 IS 02 57
       01 21 I              PA                I                 X                 I                 PA                IX 02 57
       01 22 I              X                 I                 X                 I                 X                 IS 02 58
       01 22 I              PA                I                 X                 I                 PA                IX 02 56
       01 23 I              X                 I                 X                 I                 X                 IS 02 59
SCAN SOURCE HA  +---------+---CORR-+-1L2L---+---------+---------+---CORR-+-1L3L---+---------+---------+---CORR-+-2L3L---+---------+   LST
```

RHAND AMPLITUDES AND PHASES FOR CONFIGURATION 1-18-19
PLOT RANGES FOR AMP: 0 -> 2000 PER SYMBOL, PHASE: -180 -> +180

```
SCAN SOURCE HA                                                                                                      LST
15954 3C48      +---------+---CORR-+-1R2R---+---------+---------+---CORR-+-1R3R---+---------+---------+---CORR-+-2R3R---+---------+ MODE D
       01 17 I              AP                I                 X                 I                 PA                IS 02 53
       01 17 I              X                 I                 AP                I                 PA                IX 02 53
       01 18 I              X                 I                 X                 I                 PA                IS 02 54
       01 18 I              X                 I                 X                 I                 X                 IX 02 54
       01 19 I              AP                I                 AP                I                 PA                IS 02 55
       01 19 I              X                 I                 X                 I                 PA                IX 02 55
       01 20 X                                X                                   I                 PA                IS 02 56
       01 20 I              PA                I                 AP                I                AP                 IX 02 56
       01 21 I              X                 I                 X                 I                 X                 IS 02 57
       01 21 I              X                 I                 X                 I                 PA                IX 02 57
       01 22 I              X                 I                 X                 I                 X                 IS 02 58
       01 22 I              X                 I                 X                 I                 X                 IX 02 58
       01 23 I              AP                I                 X                 I                 X                 IS 02 59
SCAN SOURCE HA  +---------+---CORR-+-1R2R---+---------+---------+---CORR-+-1R3R---+---------+---------+---CORR-+-2R3R---+---------+   LST
```

Fig. III-4. INTSCRIB display, with PARM='CPFU,SUM,PLOT,RANGE=2000', for calibrated scan 15954.

The reader may have noticed that data input to INTSCRIB is not controlled by INCLUDE/EXCLUDE cards. In fact, unless scan 15954 were the only scan on the tapes used in the examples, one would get a display of all data on the tape. As we shall see, for this reason one usually combines INTSCRIB with the programs INTCOPY or INTAVG that we are about to describe.

(3) INTINDEX

Some of the information that can be obtained in cumbersome form with INTLOOK, but which is not obtained with INTSCRIB, can be obtained in compact form with a program called INTINDEX. Figure III-5a was obtained with the following program:

```
//_EXEC_INTINDEX,INTAPE=1548,INNAME=CALDATA
//SYSIN_DD_*
INCLUDE_3C48_15954
```

(results shown in Figure III-5a).

INTINDEX gives, for each scan encountered, the scan number, source name, local sidereal day number, right ascension and declination of reference position at time of observation, RA and DEC of reference position for epoch 1950.0, LST, the hour angle range covered by the scan, observer initials, mode, the amount of clock correction applied to the data, any combination of PACB indicating which rections have been applied to the data, the interferometer spacings rounded off in hundreds of meters, and the number of 30-second records in the scan. In most cases a combination of INTINDEX and INTSCRIB will provide the user with most of the information he needs about the data.

(f) Copying and Averaging Data

(1) INTCOPY.

There are many obvious reasons why one would want to just copy certain portions of data from one tape to another, or tape to disk, etc.

(a)

```
                                                                        INTERFEROMETER INDEX                                          PAGE  1
                                                                                                        HA                  CLOCK                    DATA
SCAN  SOURCE          LSDN   RA (DATE)       DEC (DATE)     RA (1950)       DEC (1950)       LST        RANGE      OBS M  CORR  PACB SPACINGS  RECS
15954 3C48         2448287   01 36 10.170   33 01 30.49   01 34 49.815   32 54 20.41   02 53 07   1.28/ 1.39 RH D   -40 PACB 19-18- 1     13
```

(b)

```
                                                       ---------- DATA FOR CONFIGURATION  1-18-19 ----------
SCAN   M SOURCE        HA  RMS/100  AMP1R2RPHI    AMP1L2LPHI    AMP1R3RPHI    AMP1L3LPHI    AMP2R3RPHI    AMP2L3LPHI NREC TPOWER      LST
15954 SD 3C48        01 20 000000   8800    -0     9150    -1    8870     0    9090     0    9190    -1    9130    -0     7 557655  02 56 26
15954 XD 3C48        01 20 000000   3331     2     3452     2    3256     4    3357     4    3390    -1    3400    -1     6 666656  02 56 26

END
```

(c)

```
NTCORAV DISPLAY

SCAN      SOURCE      LST        HA       UT            S(3.7)     RMS       S(11.1)     RMS      ALPHA       PAGE= 1
15954   3C48        2 56 27     1.34   10/11.290/ 657                        9.0387  0.0651
15954   3C48        2 56 26     1.34   10/11.290/ 657      3.3648  0.0326                         -0.90
```

(d)

SCAN= 15954 SOURCE=3C48

SBAND CORR	BASELINE 1-2 REAL	IMAG	AMP	PHASE	BASELINE 1-3 REAL	IMAG	AMP	PHASE	BASELINE 2-3 REAL	IMAG	AMP	PHASE
RR	8600.00	-70.00	8600.27	-0.46	8870.00	50.00	8870.14	0.32	9190.00	-120.00	9190.78	-0.75
LL	9150.00	-50.00	9150.44	-0.56	9090.00	60.00	9090.20	0.38	9130.00	-60.00	9130.20	-0.38
RL/LL	-0.77	1.01	1.27	127.56	-0.74	1.80	1.94	112.29	-1.17	-1.74	2.10	-124.00
LR/LL	-1.32	-1.67	2.13	-128.21	-1.03	-1.09	1.50	-133.33	-0.88	1.52	1.75	120.01
RL/RR	-0.80	1.05	1.32	127.45	-0.76	1.84	1.99	112.34	-1.15	-1.73	2.08	-123.63
LR/RR	-1.37	-1.74	2.21	-128.32	-1.05	-1.12	1.54	-133.27	-0.88	1.50	1.74	120.38

PERCENT POL= 1.787   AMPLITUDE RMS= 0.079   POSITION ANGLE= 61.908

XBAND CORR	BASELINE 1-2 REAL	IMAG	AMP	PHASE	BASELINE 1-3 REAL	IMAG	AMP	PHASE	BASELINE 2-3 REAL	IMAG	AMP	PHASE
RR	3330.00	100.00	3331.50	1.72	3250.00	210.00	3256.78	3.70	3390.00	-70.00	3390.72	-1.18
LL	3450.00	130.00	3452.45	2.16	3350.00	220.00	3357.22	3.76	3400.00	-50.00	3400.37	-0.84
RL/LL	-3.72	-3.45	5.08	-137.16	-2.77	-4.06	4.91	-124.39	-3.08	5.63	6.42	118.72
LR/LL	-3.94	3.80	5.48	136.08	-5.33	1.10	5.44	168.41	-5.53	-3.06	6.67	-152.73
RL/RR	-3.83	-3.61	5.26	-136.75	-2.86	-4.16	5.07	-124.33	-3.13	5.63	6.44	119.06
LR/RR	-4.12	3.91	5.66	136.52	-5.50	1.12	5.61	168.47	-5.92	-3.10	6.69	-152.39

PERCENT POL= 5.485   AMPLITUDE RMS= 0.148   POSITION ANGLE= -69.817

THIS RUN IS OVER. GOODNIGHT ALL.

Fig. III-5. (a) INTINDEX display for scan 15954; (b) INTSCRIB display of scan 15954 after it has been scan averaged by INTAVG with PARM='ARITH'; (c) INTCORAV display after it has been scan averaged by INTAVG with PARM='ARITH'; (d) INTPOLAV display of scan 15954 after it has been scan averaged by INTAVG.

This is done with a program called INTCOPY which uses INCLUDE/EXCLUDE cards. To illustrate its use, all the contents of Figures III-3b, 4, and 5a could be obtained with the following program:

```
//_EXEC_INTCOPY,INTAPE=1548,INNAME=CALDATA
//SYSIN_DD_*
INCLUDE_3C48_15954
//_EXEC_INTSCRIB,PARM='PLOT'
//_EXEC_INTSCRIB,PARM='CPFU,SUM,PLOT,RANGE=2000'
//_EXEC_INTINDEX
//SYSIN_DD_*
INCLUDE
```

(results shown in Figures III-3b, 4, and 5a).

In the above program we used INTCOPY to select the data we wanted, then its (default) output provided the (default) input to three programs in a row.

(2) INTAVG

(i) Program Description

Frequently one wishes to average together a number of 30-second records in order to improve the signal-to-noise (or for some other reason). This is accomplished by INTAVG under control of a number of PARM options and the usual INCLUDE/EXCLUDE cards. The most useful PARM options are:

PARM OPTION	DEFAULT	USAGE
'ARITH'	vector average	amplitudes averaged arithmetically
'LENGTH=...'	entire scan	specifies time length for average (in minutes)
'NOSCAN'	no more than a single scan averaged together	data in adjacent scans with same source name are averaged together

As an example, the following program will average together all the 3C48 data in scan 15954 and the result is then displayed using INTSCRIB:

```
//_EXEC_INTAVG,INTAPE=1548,INNAME=CALDATA
//SYSIN_DD_*
INCLUDE_3C48_15954
//_EXEC_INTSCRIB
```

(results shown in Figure III-5b)

(ii) Arithmetic vs Vectorial Averaging

The user should understand the ways in which data are averaged. Remember that the data, for each correlator, stored on tape are recorded as the real ($\mathcal{R}$) and imaginary ($\mathcal{I}$) parts of V. If N records are to be averaged together vectorially:

$$\overline{\mathcal{R}} = \sum_{i=1}^{N} \mathcal{R}_i / N$$

$$\overline{\mathcal{I}} = \sum_{i=1}^{N} \mathcal{I}_i / N$$

and the displayed "average" amplitude and phase are

$$\mathrm{AMP} = (\overline{\mathcal{R}}^2 + \overline{\mathcal{I}}^2)^{1/2}$$

and

$$\mathrm{PHI} = \tan^{-1} (\overline{\mathcal{I}}/\overline{\mathcal{R}}).$$

For arithmetic averaging of amplitudes (PARM = 'ARITH'):

$$\mathrm{AMP} = \sum_{i=1}^{N} (\mathcal{R}_i^2 + \mathcal{I}_i^2)^{1/2}/N \ ,$$

with PHI still being obtained as above.

To illustrate the difference between arithmetic and vectorial averaging of amplitudes, let us consider an example of a point source with flux density S observed at the reference position. Let σ_i be the rms noise for the i-th 30-second record. Under these circumstances

$$\mathcal{R}_i \cong S + \sigma_i$$

$$\mathcal{I}_i \cong \sigma_i$$

$$A_i \cong \sqrt{\mathcal{R}_i^{\,2} + \mathcal{I}_i^{\,2}} \cong S \left[1 + \frac{2\sigma_i}{S} + \frac{2\sigma_i^2}{S^2}\right]^{1/2}$$

so that: if $S >> \sigma_i$, then $A_i = S + \sigma_i$; but if $S << \sigma_i$, then $A_i \cong 2^{1/2}\ \sigma_i$.

Now with vectorial averaging of N records to obtain an average amplitude,

$$\bar{A} = \left\{\left[\sum_{i=1}^{N} \mathcal{R}_i/N\right]^2 + \left[\sum_{i=1}^{N} \mathcal{I}_i/N\right]^2\right\}^{1/2}$$

$$\cong S + \bar{\sigma}/N^{1/2}$$

where

$$\bar{\sigma} = \sum_{i=1}^{N} \sigma_i/N.$$

However, with arithmetic averaging,

$$\bar{A}_{arith} = \sum_{i=1}^{N} A_i \cong S + \bar{\sigma} \text{ if } S >> \bar{\sigma}$$

and

$$\cong 2^{1/2}\ \bar{\sigma} \text{ if } S << \bar{\sigma} .$$

Obviously, in the vectorial average case, averaging N records gives a mean amplitude noise of $\bar{\sigma}/N^{1/2}$, whereas for the arithmetic average in most cases the mean amplitude noise is $\bar{\sigma}$.

It might seem as if arithmetic averaging should never be used, but this is not true. Whenever the phases (real, not just noise) vary significantly over the range considered for averaging, the above considerations do not apply and arithmetic averaging is preferable since only amplitude noise is introduced and not phase "noise". In practice, one prefers arithmetic averaging when one knows a single strong point source is all that is being observed. Whenever a point source with S of the order of, or less than, $\bar{\sigma}$ is involved, only vector averaging should be used. It is obvious, but perhaps should be mentioned, that averaged amplitudes will have a very complicated meaning whenever there is more than a single point source in the field.

(3) INTCORAV

It is obvious that, in addition to the averaging done for each correlator by INTAVG, it would be useful to use the data on all correlators to calculate fluxes whenever point sources (like 3C48) are involved. This is invoked by calling upon INTCORAV after INTAVG has obtained the averages for each correlator, e.g.,

```
//_EXEC_INTAVG,INTAPE=1548,INNAME=CALDATA,PARM='ARITH'
//SYSIN_DD_*
INCLUDE
//_EXEC_INTCORAV
```

(result shown in Figure III-5c).

In addition to calculating the flux densities in flux units, INTCORAV will: (i) calculate the Universal time for the time of observation; (ii) calculate crude rms' based upon the scatter between different correlators; and (iii) calculate the empirical spectral index.

$$\text{ALPHA} = \log (S_{8085}/S_{2695})/\log (8085/2695).$$

Note that the UT is given by MONTH/DAY OF MONTH AND FRACTION OF DAY/ HOURS AND MINUTES OF DAY. We see from Figure III-5c that scan 15954 was taken October 11, at 0657 UT. The philosophy with which one uses INTCORAV is obviously to use the INCLUDE/EXCLUDE card specification of INTAVG to control what point sources are to be used to determine averaged fluxes. INTCORAV will read only temporary disk data sets named '&&OUTNAME', which is the default output name for both INTAVG and INTCOPY.

(4) INTPOLAV

Once all LL,RR,LR, and RL correlators have been cleaned, corrected and calibrated, one often wishes to examine the average polarization parameters for each scan. This is accomplished using a program called INTPOLAV. INTPOLAV obtains averaged records written on disk by INTAVG and then does the following: First V_{LR}/V_{LL}, V_{RL}/V_{LL}, V_{LR}/V_{RR}, and V_{RL}/V_{RR} are calculated for each baseline. The resulting twelve values for the percentage of linear polarization (m) and position angle (χ) are then averaged to obtain mean values. In addition, a crude rms estimate is obtained by subtracting the minimum of the 12 calculated percentage polarizations from the maximum, and dividing by 12.

As an example, the following job was used to obtain the INTPOLAV output for scan 15954 of 3C48:

```
//_EXEC_INTAVG,INTAPE=3087,INNAME=CALDATA
//SYSIN_DD_*
INCLUDE_3C48_15954
//_EXEC_INTPOLAV
```

(result shown in Figure III-5d).

Obviously INTPOLAV is to be used with the same philosophy as INTCORAV--using the INCLUDE/EXCLUDE capabilities of INTAVG to pick out what data is to be averaged. In general, all that is required for use of either INTCORAV or INTPOLAV is that the data be available on disk with the name &&OUTNAME (see Appendix 4).

4. Programs for Cleaning, Correcting and Calibrating Data

(a) INTEDIT

(1) Use of INTEDIT.

The all-purpose program for cleaning, correcting, and calibrating data, with the observer deciding upon and controlling the details, is called INTEDIT. In the normal course of events the user will rely upon INTEDIT mainly to solve problems that cannot be handled by the more automatic programs that we will soon discuss. However, in all cases the automatic programs (INTCLEAN, INTCORR, INTCAL) just carry out groups of tasks performed by INTEDIT; therefore we need to discuss its features first.

INTEDIT allows the user to modify, delete, correct, calibrate, etc., data by reading it from tape or disk, performing the desired changes, and writing the resulting data on another tape or disk data set. One decides what to put into INTEDIT by making appropriate use of INTSCRIB (and occasionally INTLOOK), INTAVG, INTBCAL and the diagnostic features of INTCLEAN.

The user instructs INTEDIT concerning what is to be done by means of what are called edit cards. Each edit card is composed of two parts called the verb field and the adverb field. The verb field contains specification of a function to be performed (the verb) and the attributes of the data to be processed; the usage of the verb field is very similar to the usage of INCLUDE/EXCLUDE cards. The adverb field gives specific information in terms of numbers, names, etc., that are needed to accomplish the desired editing. Verb and adverb fields are separated by a semicolon. The verb field must precede the adverb field and a verb name must be present. As with the INCLUDE/EXCLUDE cards, it is optional whether the verb field will limit the scope of the data to be processed. The verb field may specify scan range, LST range, telescopes, correlators, frequencies, telescope pairs, and source names. The symbols for these are the same as for INCLUDE/EXCLUDE cards, except: we can use BL12, BL13, and BL23 to indicate baseline pairs, and LST is indicated by spaced hours, minutes, and seconds enclosed in parentheses, e.g., (10_24_57). The verb fields may be in any order, but the beginning scan number or (LST) must precede the terminating scan number (or LST). If no scan range is specified, all scans will be processed. If no LST range is given, all times are processed. If only one scan number or LST is given, this value is used for both beginning and terminating the processing. If no telescope numbers, correlators, frequencies, telescope pairs, or source names are specified, all are assumed.

In both verb and adverb fields any parameter with a format of (hours, minutes, seconds) or (degrees, arcminutes, arcseconds) must be enclosed in parentheses with a blank between each part.* Any source name with imbedded blanks or which is completely numeric in content must be enclosed in single quotes. Adverb parameters can be separated by blanks or commas.

INTEDIT is used in almost the same way as the other programs we have discussed. For example,

```
//_EXEC_INTEDIT,INTAPE=1601,INNAME=RAWDATA,
//_OUTTAPE=1603,OUTNAME=CALDATA,OUTDISP=NEW
//INTERP.SYSIN_DD_*
   (edit cards)
```

When the program executes it does so in four steps: (i) interpreting, which reads the edit cards and passes one 64 byte record per card to the next step; (ii) sorting, whereby the records to be processed are sorted and arranged by scan number and priority level; (iii) listing, where a list of the sorted records is produced; and (iv) editing, where the actual editing is carried out.

---

* No extra spaces are allowed within the parentheses.

(2) Verbs Available in INTEDIT.

Let us now list the names of the verbs and their usage in connection with the verb and adverb fields.

The first two verbs control what data is to be transferred from the INUNIT to the OUTUNIT:

TRANSFER (verb parameters); no adverb required, all data specified are transferred to the OUTUNIT.

e.g., TRANSFER_1500_1575; will cause scans 1500 through 1575 to be transferred.

STOP (final scan number); no adverb required, editing terminates after the specified scan or before processing scans with numbers greater than the specified scan. Editing will resume anew only if further edit cards follow.

e.g., STOP_1575; will stop the processing when scans greater than 1575 are encountered.

Next are the series of verbs whereby data can be flagged* as bad (or unflagged);

DELETE (verb parameter); no adverb required, used to specify which data records are to be flagged.

e.g., DELETE_(12_17_13)(12_55_43)_17890_SBAND; will cause all SBAND data in scan 17890 to be flagged if the LST is between $12^h17^m13^s$ and $12^h55^m43^s$.

AUTOEDIT (verb parms.);TYPERECORD_WORDNUMBERORBITNUMBER (<) > (=) VALUE.

Flagging is performed if data in a specified word number or bit number do not satisfy a specified test (<,>, or =) (see "Users Guide" for information about record types and word or bit numbers).

ERASE (verb parameters); TYPERECORD. The specified record type is not transferred to the OUTUNIT. If the adverb is omitted, the entire

---

* A data record is flagged by changing its weight from 1 to -1; whenever programs encounter flagged records they bypass and ignore them.

scan is erased. This is much more drastic than flagging because one cannot easily restore the data if desired later on.

RESTORE (verb parameters); no adverb required, the data records which have been flagged are unflagged or restored to original condition.

e.g., RESTORE_1789_SBAND;

Next are four verbs that are used for automatic corrections which must be applied only once to the data.

PHASE (verb parameters); no adverb required, both phases (mainly) and amplitudes (very slightly) are adjusted for effects discussed earlier, using parameters from A/D records and headers.

e.g., PHASE;

all data is processed by this once.

AMPCOR (verb parameter); k_s _ k_x. The correction to outside the atmosphere is applied (affecting only amplitudes). Default values of k_s and k_x are 0.07 for SBAND and 0.19 for XBAND.

e.g., AMPCOR;

usually the default values are satisfactory.

CLOCK (verb parameters); (error)^F_S. The clock error, in seconds of time, is removed from the phase data, where F indicates it is fast (positive clock error), S that it is slow (negative clock error).

e.g., CLOCK_1795_1870;0.015S.

BASELINE (verb parameters); (B_x)_(B_y)_(B_z)_(k). Phases are modified based upon difference between old and new baselines.

e.g., BASELINE_1798_1900_SBAND_BL12;-6812.271 -21440.015 9115.563 0.0.

Note that the BAND must always be specified, and the pair involved (BL12, BL13, or BL23).

Finally there is the set of verbs used to make various changes in the data.

REPLACE (verb parameters); TYPERECORD_WORDNUMBERORBITNUMBER_ REPLACEMENT VALUE. The correct contents of a particular bit number or word are replaced by a replacement value. The replacement value may be preceded by O (octal), H (hexadecimal), or enclosed in single quotes.

e.g., replace 1570;2_16_0.

POSITION (verb parameters); (RA)_(DEC). Phases are adjusted such that an old reference position is replaced by a new reference position.

e.g., POSITION_SCOX-1; (16_18_23.249)(-15_34_37.84).

HEADCORR (scan number for previous good scan);RA=(H_M_S)
+_DEC=(D_M_S)_LST=(H_M_S)_SCAN=..._MODE=..._SOURCE=...

Used to correct information in headers. The first header following the scan specified in the verb field is updated by the adverb parameters. The other header information is copied from the specified scan. Continuation cards, for this verb only, must contain a + in column 1.

e.g., HEADCORR_670;MODE=D_SOURCE=SCOX-1_LST=(14_13_45) means that scan 671 will have its header information changed as specified by the adverbs, with the other information being copied from scan 670.

MULTIPLY (verb parameters); (number or set of six numbers). The visibility functions are multiplied by the given number, or, if all six correlators (1R2R, 1L2L, 1R3R, 1L3L, 2R3R, 2L3L) are to be multiplied by numbers, all six can be specified. Used for manual gain calibration, where the numbers are the g_s discussed earlier.

e.g., MULTIPLY_1000_1070_SBAND_1R2R; 1.35

or MULTIPLY _1000_1070_SBAND: 1.35_1.23_0.91_1.1_0.98_1.7.

PHICENT (verb parameters); (number or set of six numbers). The phases are decreased by the specified amount, usually to accomplish phase centering.

e.g., PHICENT_1000_1070_SBAND_1R2R;-107

or PHICENT_1000_1070_SBAND:-107_17_98_-37_75_-100

(3) Tape Manipulation.

In all of the data processing one soon adopts the habit of thinking of the data processing in terms of trying to create certain data tapes. Each of these data tapes correspond to one of the stages defined earlier in this chapter while discussing the theory of data processing.

It is very difficult to process interferometric data without using at least three tapes, and frequently even more are used. For the rest of this chapter we will discuss straightforward methods of processing involving three magnetic tapes. As an example, we will illustrate the steps in the processing with a segment of about eleven hours of data taken on September 30, 1972.

We assume that the data exists in raw form ($V''=A'' \exp i\phi''$) on a tape that we will call RAWTAPE and that good amplitude and phase calibrator observations are interspersed throughout the data. We can use either INTEDIT or a combination of INTCLEAN and INTCORR to perform the cleaning and correcting needed to produce data ($V'=A' \exp i\phi'$) on a tape we will call CORRTAPE. Finally, complex system gain calibration with either INTEDIT, or INTCAL, for LL and RR correlators, and programs called INTPCAL and INTPCOR for LR and RL correlators, are used to produce data ($V=A \exp i\Phi$) on what we will call a CALTAPE. This sequence of happenings has been schematically represented in Figure III-1.

(4) Cleaning Data with INTEDIT.

The cleaning process, which we have not defined clearly as yet, involves deletion of all bad data and, wherever possible, replacement of bad data with good data. By deletions we usually mean flagging of data records or entire scans; by replacement of bad data with good we mean the rectification of mistakes made when headers or A/D records were written. Unfortunately, bad data records cannot be replaced.

The first step in cleaning data is to examine both the data itself and the data diagnostics generated by the DDP116 during the process of recording the data. The usual method of examining the data is to obtain INTINDEX output for each of the scans and an INTSCRIB display of all the 30-second data records. The data diagnostics are obtained from use of INTCLEAN.

We will illustrate the methods of data processing by giving the programs and resultant output used in processing a set of data consisting primarily of point sources. The scan range involved is 14969 to 15028. To obtain the INTINDEX (see Figure III-6), INTSCRIB (see Figure III-7, with parts a through n referring to successive pages of computer output) and INTCLEAN (see Figures III-8 and 9) displays for this scan range, one can use the following programs:

```
//_EXEC_INTCOPY,INTAPE=3085,INNAME=RAWTAPE
//SYSIN_DD_*
INCLUDE_14969_15028
//_EXEC_INTINDEX
//SYSIN_DD_*
INCLUDE
//_EXEC_INTSCRIB
//_EXEC_INTCLEAN
```

(results shown in Figures III-6, 7, 8, and 9)

Examination of the INTINDEX display (Figure III-6) informs us concerning what data on what sources are contained in the scan range of interest. First signs of bad header information can also appear in terms of nonsensical results for certain scans, particularly nonsensical baseline information.

Next one examines the INTSCRIB display of the 30-second data records (Figure III-7), with the INTCLEAN display of data diagnostics (Figures III-8 and 9) on one hand and the observing logs on the other. Problems noticed by the operators during the observing will be noted in the logs and the appropriate data records can be submitted to close scrutiny. Most of the time the data diagnostics generated by INTCLEAN are of greatest use in detecting bad data. For the moment we will concentrate on only the diagnostic display provided by INTCLEAN, ignoring the messages concerning deletions performed by INTCLEAN; these deletions are part of the "automatic" processing to be discussed later.

The diagnostic summary shown in Figure III-9 gives a listing of the various errors, with a severity proportional to the indicated number of asterisks. We will not discuss each type of message in detail because the user will find that only experience, guided by what the user hopes to achieve, allow proper interpretation of these messages.

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SCAN	SOURCE	LSDN	RA (DATE)	DEC (DATE)	RA (1950)	DEC (1950)	LST	HA RANGE	OBS	M	CLOCK CORR	PACB	SPACINGS	DATA RECS
14969	P0056-17	2448275	00 57 47.885	-17 09 11.16	00 56 38.010	-17 16 48.32	22 02 19	-2.92/-2.80	EF	D	0		19-18- 1	15
14970	3C48	2448275	01 36 10.042	33 01 28.48	01 34 49.835	32 54 20.65	22 12 57	-3.39/-3.27	EF	D	0		19-18- 1	14
14971	D0224+67	2448275	02 26 37.777	67 13 48.75	02 24 41.177	67 07 40.10	22 22 11	-4.07/-3.95	EF	D	0		19-18- 1	14
14972	NRA091	2448275	02 03 23.638	15 06 35.77	02 02 07.434	14 59 50.61	22 33 05	-3.51/-3.39	EF	D	0		19-18- 1	14
14973	3C119	2448275	04 30 44.731	41 35 04.41	04 29 07.929	41 32 08.67	22 42 19	-5.81/-5.69	EF	D	0		19-18- 1	15
14974	P2149-28	2448275	21 50 31.718	-28 36 07.90	21 49 10.581	-28 42 36.69	22 55 20	1.08/ 1.08	EF	D	0		19-18- 1	0
14974	P2149-28	2448275	21 50 31.718	-28 36 07.90	21 49 10.581	-28 42 36.69	22 55 37	1.08/ 1.15	EF	D	0		19-18- 1	8
14975	OV080	2448275	19 48 47.539	08 03 14.03	19 47 40.126	07 59 36.93	23 02 21	3.23/ 3.35	EF	D	0		19-18- 1	15
14976	BLLAC	2448275	22 01 37.572	42 09 01.59	22 00 39.356	42 02 08.83	23 12 09	1.18/ 1.30	EF	D	0		19-18- 1	14
14977	3C454.3	2448275	22 52 38.921	16 00 24.38	22 51 29.515	15 52 53.82	23 21 47	0.49/ 0.62	EF	D	0		19-18- 1	15
14978	P0114-21	2448275	01 15 34.390	-21 00 25.77	01 14 25.942	-21 07 53.54	23 32 17	-1.72/-1.60	EF	D	0		19-18- 1	15
14979	P0056-17	2448275	00 57 47.885	-17 09 11.16	00 56 38.010	-17 16 48.32	23 41 00	-1.28/-1.13	EF	D	0		19-18- 1	18
14980	3C48	2448275	01 36 10.042	33 01 28.48	01 34 49.835	32 54 20.65	23 52 59	-1.72/-1.62	EF	D	0		19-18- 1	12
14981	P2149-28	2448276	21 50 31.718	-28 36 07.90	21 49 10.582	-28 42 36.61	00 02 31	2.20/ 2.32	EF	D	0		19-18- 1	15
14982	CYGX-3	2448276	20 31 28.143	40 52 08.98	20 30 37.627	40 47 12.38	00 13 55	3.71/ 3.80	EF	D	0		19-18- 1	11
14983	P0114-21	2448276	01 15 34.390	-21 00 25.77	01 14 25.924	-21 07 53.48	00 23 51	-0.86/-0.76	EF	D	0		19-18- 1	12
14984	3C48	2448276	01 36 10.042	33 01 28.48	01 34 49.812	32 54 20.40	00 33 11	-1.05/-0.94	EF	D	0		19-18- 1	13
14985	D0224+67	2448276	02 26 37.777	67 13 48.75	02 24 41.126	67 07 39.75	00 42 08	-1.74/-1.62	EF	D	0		19-18- 1	15
14986	3C147	2448276	05 40 31.109	49 50 18.94	05 38 43.491	49 49 42.76	00 52 47	-4.80/-4.80	EF	D	0		19-18- 1	0
14986	3C147	2448276	05 40 31.109	49 50 18.94	05 38 43.491	49 49 42.76	00 53 12	-4.79/-4.68	EF	D	0		19-18- 1	12
14987	3C119	2448276	04 30 44.731	41 35 04.41	04 29 07.884	41 32 08.53	01 01 33	-3.49/-3.35	EF	D	0		19-18- 1	17
14988	CTA21	2448276	03 17 27.755	16 22 49.36	03 16 09.127	16 17 40.17	01 11 41	-2.10/-1.97	EF	D	0		19-18- 1	16
14989	P0114-21	2448276	01 15 34.390	-21 00 25.77	01 14 25.924	-21 07 53.48	01 22 16	0.11/ 0.23	EF	D	0		19-18- 1	15
14990	3C454.3	2448276	22 52 38.921	16 00 24.38	22 51 29.512	15 52 53.66	01 32 20	2.66/ 2.78	EF	D	0		19-18- 1	14
14991	3C418	2448276	20 37 49.519	51 13 43.58	20 37 07.415	51 08 36.01	01 42 15	5.07/ 5.20	EF	D	0		19-18- 1	14
14992	P0106+01	2448276	01 07 16.785	01 26 32.82	01 06 04.474	01 19 00.98	01 53 37	0.77/ 0.77	EF	D	0		19-18- 1	0
14992	P0106+01	2448276	01 07 16.785	01 26 32.82	01 06 04.474	01 19 00.98	01 54 01	0.78/ 0.88	EF	D	0		19-18- 1	12
14993	NRA0140	2448276	03 34 49.774	32 13 14.25	03 33 22.388	32 08 36.70	02 02 11	-1.54/-1.42	EF	D	0		19-18- 1	15
14994	P0735+17	2448276	07 36 33.678	17 46 07.57	07 35 14.117	17 49 09.51	02 13 26	-5.39/-5.28	EF	D	0		19-18- 1	12
14995	3C120	2448276	04 31 45.720	05 18 04.13	04 30 31.605	05 14 59.19	02 22 39	-2.15/-2.04	EF	D	0		19-18- 1	13
14996	3C446	2448276	22 24 24.103	-05 05 09.78	22 23 11.013	-05 12 17.30	02 35 05	4.18/ 4.26	EF	D	0		19-18- 1	9
14997	3C454.3	2448276	22 52 38.921	16 00 24.38	22 51 29.512	15 52 53.66	02 41 36	3.82/ 3.94	EF	D	0		19-18- 1	15
14998	3C48	2448276	01 36 10.042	33 01 28.48	01 34 49.812	32 54 20.40	02 52 43	1.28/ 1.28	EF	D	0		19-18- 1	0
14998	3C48	2448276	01 36 10.042	33 01 28.48	01 34 49.812	32 54 20.40	02 53 03	1.28/ 1.39	EF	D	0		19-18- 1	14
14999	D0224+67	2448276	02 26 37.777	67 13 48.75	02 24 41.126	67 07 39.75	03 02 06	0.59/ 0.71	EF	D	0		19-18- 1	14
15000	3C147	2448276	05 40 31.109	49 50 18.94	05 38 43.491	49 49 42.76	03 12 45	-2.46/-2.35	EF	D	0		19-18- 1	14
15001	D0742+10	2448276	07 44 03.960	10 15 19.82	07 42 48.445	10 18 33.01	03 22 23	-4.36/-4.24	EF	D	0		19-18- 1	14
15002	P0607-15	2448276	06 08 28.360	-15 42 03.28	06 07 26.026	-15 42 04.09	03 31 42	-2.61/-2.48	EF	D	0		19-18- 1	16
15003	P0056-17	2448276	00 57 47.885	-17 09 11.16	00 56 37.994	-17 16 48.29	03 44 18	2.78/ 2.86	EF	D	0		19-18- 1	11
15004	3C454.3	2448276	22 52 38.921	16 00 24.38	22 51 29.512	15 52 53.66	03 52 10	4.99/ 5.11	EF	D	0		19-18- 1	15
15005	NRA091	2448276	02 03 23.638	15 06 35.77	02 02 07.410	14 59 50.47	04 02 38	1.99/ 2.10	EF	D	0		19-18- 1	14
15006	3C119	2448276	04 30 44.731	41 35 04.41	04 29 07.884	41 32 08.53	04 12 12	-0.31/-0.31	EF	D	0		19-18- 1	0
15006	3C119	2448276	04 30 44.731	41 35 04.41	04 29 07.884	41 32 08.53	04 12 37	-0.30/-0.19	EF	D	0		19-18- 1	14
15007	P0106+01	2448276	01 07 16.785	01 26 32.82	01 06 04.474	01 19 00.98	04 23 01	3.26/ 3.38	EF	D	0		19-18- 1	14
15008	P0438-43	2448276	04 39 27.471	-43 35 55.41	04 38 43.259	-43 38 56.27	04 32 56	-0.11/ 0.01	EF	D	0		19-18- 1	14
15009	P0614-34	2448276	06 15 38.321	-34 55 18.10	06 14 48.827	-34 55 08.79	04 41 37	-1.57/-1.44	EF	D	0		19-18- 1	16
15010	3C138	2448276	05 19 36.798	16 36 56.18	05 18 16.507	16 35 27.29	04 53 07	-0.44/-0.34	EF	D	0		19-18- 1	13
15011	3C48	2448276	01 36 10.042	33 01 28.48	01 34 49.812	32 54 20.40	05 03 14	3.45/ 3.56	EF	D	0		19-18- 1	13
15012	D0224+67	2448276	02 26 37.777	67 13 48.75	02 24 41.126	67 07 39.75	05 12 10	2.76/ 2.88	EF	D	0		19-18- 1	15
15013	3C147	2448276	05 40 31.109	49 50 18.94	05 38 43.491	49 49 42.76	05 22 44	-0.30/-0.18	EF	D	0		19-18- 1	14
15014	DA267	2448276	09 25 20.963	39 09 24.54	09 23 55.285	39 15 24.31	05 33 10	-3.87/-3.76	EF	D	0		19-18- 1	13
15015	P1116+12	2448276	11 17 31.738	12 43 40.19	11 16 20.730	12 51 06.82	05 41 51	-5.59/-5.46	EF	D	0		19-18- 1	15
15016	P1055+01	2448276	10 57 05.231	01 42 49.49	10 55 55.250	01 50 05.01	05 51 14	-5.10/-4.96	EF	D	0		19-18- 1	17
15017	P0859-14	2448276	09 00 59.525	-14 08 51.59	08 59 54.959	-14 03 38.49	06 01 55	-2.98/-2.85	EF	D	0		19-18- 1	16
15018	P0614-34	2448276	06 15 38.321	-34 55 18.10	06 14 48.827	-34 55 08.79	06 12 25	-0.05/ 0.07	EF	D	0		19-18- 1	14

INTERFEROMETER INDEX PAGE 2

SCAN	SOURCE	LSDN	RA (DATE)	DEC (DATE)	RA (1950)	DEC (1950)	LST	HA RANGE	OBS	M	CLOCK CORR	PACB	SPACINGS	DATA RECS
15019	D0742+10	2448276	07 44 03.960	10 15 19.82	07 42 48.445	10 18 33.01	06 22 47	-1.35/-1.24	EF	D	0		19-18- 1	14
15020	P1116+12	2448276	11 17 31.738	12 43 40.19	11 16 20.730	12 51 06.82	06 33 02	-4.74/-4.63	EF	D	0		19-18- 1	13
15021	3C138	2448276	05 19 36.798	16 36 56.18	05 18 16.507	16 35 27.29	06 44 47	1.42/ 1.50	EF	D	0		19-18- 1	10
15022	3C147	2448276	05 40 31.165	49 50 19.02	05 38 43.548	49 49 42.84	07 49 06	2.14/ 2.68	EF	D	0		19-18- 1	64
15023	1216+48	2448276	12 17 45.541	48 39 01.12	12 16 38.905	48 46 37.68	08 27 33	-3.84/-3.70	EF	M	0		19-18- 1	17
15024	1242+41	2448276	12 43 30.839	40 57 08.77	12 42 26.403	41 04 36.72	08 37 00	-4.11/-3.99	EF	M	0		19-18- 1	14
15025	1244+49	2448276	12 45 52.330	49 09 15.05	12 44 50.102	49 16 42.69	08 45 01	-4.01/-3.90	EF	M	0		19-18- 1	14
15026	1315+34	2448276	13 16 20.627	34 34 27.15	13 15 17.997	34 41 36.71	08 53 08	-4.39/-4.25	EF	M	0		19-18- 1	17
15027	1317+52	2448276	13 18 37.494	51 56 49.91	13 17 41.495	52 03 58.67	09 03 27	-4.25/-4.15	EF	M	0		19-18- 1	13
15028	3C286	2448276	13 29 52.309	30 38 58.49	13 28 49.664	30 45 58.01	09 11 30	-4.31/-4.17	EF	M	0		19-18- 1	17

Fig. III-6. INTINDEX display for raw data form of scans 14969 through scans 15028.

---------- DATA FOR CONFIGURATION 1-18-19 ----------

(a)

SCAN	M	SOURCE	HA	RMS/100	AMP1R2RPHI	AMP1L2LPHI	AMP1R3RPHI	AMP1L3LPHI	AMP2R3RPHI	AMP2L3LPHI	NREC	TPOWER	LST
14969	SD	P0056-17	-02 55	000000	973 -9	992 -99	934 -96	1030 30	915 -96	905 44	1	665665	22 02 37
14969	XD	P0056-17	-02 54	000000	101 -79	152 -113	90 6	145 -16	152 169	126 72	1	666666	22 03 07
14969	SD	P0056-17	-02 54	000000	896 7	1004 -85	806 -79	900 49	941 -94	856 47	1	665665	22 03 37
14969	XD	P0056-17	-02 53	000000	60 -9	155 -105	41 -76	60 9	148 160	165 65	1	666666	22 04 07
14969	SD	P0056-17	-02 53	000000	886 16	1006 -77	820 -81	920 53	960 -91	942 53	1	665665	22 04 37
14969	XD	P0056-17	-02 52	000000	31 72	67 -27	89 -63	80 83	143 168	70 82	1	666666	22 05 07
14969	SD	P0056-17	-02 52	000000	816 7	1030 -72	858 -75	974 54	751 -94	938 51	1	665665	22 05 37
14969	XD	P0056-17	-02 51	000000	111 -63	72 -106	130 -58	53 22	145 164	107 68	1	666666	22 06 07
14969	SD	P0056-17	-02 51	000000	807 -8	1010 -89	862 -95	932 35	954 -95	955 48	1	665665	22 06 37
14969	XD	P0056-17	-02 50	000000	110 -95	114 -128	111 -63	111 -27	164 166	161 68	1	666666	22 07 07
14969	SD	P0056-17	-02 50	000000	899 -8	1022 -99	825 -101	966 28	1093 -95	905 46	1	665665	22 07 37
14969	XD	P0056-17	-02 49	000000	161 -68	123 -76	20 -90	160 -4	114 142	92 41	1	666666	22 08 07
14969	SD	P0056-17	-02 49	000000	910 -2	989 -82	850 -88	838 51	1000 -92	870 47	1	665665	22 08 37
14969	XD	P0056-17	-02 48	000000	113 45	80 -90	31 72	40 180	176 137	104 73	1	666666	22 09 07
14969	SD	P0056-17	-02 48	000000	871 48	997 -46	868 -57	871 87	901 -93	892 49	1	665655	22 09 37
14970	SD	3C48	-03 22	111101	13010 -18	13194 -107	11176 -114	12636 18	11289 -84	10902 56	1	655665	22 13 15
14970	XD	3C48	-03 22	000000	2696 -159	2548 150	2422 -142	3143 -114	2549 166	2661 85	1	666666	22 13 45
14970	SD	3C48	-03 21	100000	14137 -21	13586 -109	11636 -117	12901 15	11295 -85	11182 55	1	655665	22 14 15
14970	XD	3C48	-03 21	000000	2952 -159	2688 152	2660 -142	3202 -117	2525 165	2593 87	1	666666	22 14 45
14970	SD	3C48	-03 20	100000	13401 -21	13585 -109	11444 -115	12951 17	11258 -85	11166 54	1	655665	22 15 15
14970	XD	3C48	-03 20	000000	2839 -170	2606 138	2410 -153	3234 -126	2520 166	2725 86	1	666666	22 15 45
14970	SD	3C48	-03 19	000000	13887 -27	13640 -115	11612 -121	12826 11	11393 -85	11357 55	1	655665	22 16 15
14970	XD	3C48	-03 19	000000	2942 177	2661 129	2583 -170	3261 -141	2686 168	2710 91	1	666666	22 16 45
14970	SD	3C48	-03 18	000000	13064 -26	13632 -113	12278 -120	13129 12	11312 -84	11056 55	1	655665	22 17 15
14970	XD	3C48	-03 18	000000	2875 -160	2655 150	2530 -144	3117 -116	2589 164	2808 86	1	666666	22 17 45
14970	SD	3C48	-03 17	101100	12709 -26	13535 -114	11748 -122	12871 12	10914 -85	11109 54	1	655665	22 18 15
14970	XD	3C48	-03 17	000000	2745 -170	2694 141	2594 -155	3234 -127	2653 166	2660 88	1	666666	22 18 45
14970	SD	3C48	-03 16	100000	13069 -22	13607 -109	12186 -117	12977 16	10705 -84	10987 54	1	655665	22 19 15
14970	XD	3C48	-03 16	000000	2729 -169	2747 142	2589 -153	3173 -124	2597 166	2675 86	1	666666	22 19 45
14971	SD	D0224+67	-04 04	0000	1511 -26	1691 -109	1452 -121	1455 8	0	0	1	655665	22 22 30
14971	SD	D0224+67	-04 03	000000	1494 -16	1793 -109	1483 -120	1462 14	1523 -82	1396 58	1	655665	22 23 00
14971	XD	D0224+67	-04 03	000000	1566 -142	1582 168	1452 -142	1793 -112	1370 178	1486 95	1	666666	22 23 30
14971	SD	D0224+67	-04 02	0000	1596 -10	1604 -94	1494 -104	1475 27	0	0	1	555665	22 24 00
14971	SD	D0224+67	-04 02	000000	1531 -12	1747 -100	1422 -112	1465 21	1493 -82	1398 58	1	555665	22 24 30
14971	XD	D0224+67	-04 01	000000	1668 -135	1530 180	1400 -136	1732 -105	1447 174	1494 98	1	666666	22 25 00
14971	SD	D0224+67	-04 01	0000	1671 -13	1681 -99	1513 -111	1509 21	0	0	1	555665	22 25 30
14971	SD	D0224+67	-04 00	000000	1388 -18	1736 -103	1548 -114	1549 17	1520 -83	1493 59	1	555665	22 26 00
14971	XD	D0224+67	-04 00	000000	1585 -159	1607 151	1286 -158	1797 -129	1365 175	1363 98	1	666666	22 26 30
14971	SD	D0224+67	-03 59	0000	1584 -25	1680 -113	1486 -125	1613 7	0	0	1	555665	22 27 00
14971	SD	D0224+67	-03 59	000000	1496 -13	1651 -101	1401 -114	1603 17	1492 -83	1324 59	1	555665	22 27 30
14971	XD	D0224+67	-03 58	000000	1548 -127	1622 -177	1369 -119	1700 -90	1336 171	1368 96	1	666666	22 28 00
14971	SD	D0224+67	-03 58	0000	1544 -14	1736 -103	1408 -110	1416 18	0	0	1	555665	22 28 30
14971	XD	D0224+67	-03 57	000000	1709 -140	1656 175	1399 -129	1790 -101	1393 176	1502 93	1	666666	22 29 30
14972	SD	NRAO91	-03 29	000000	5313 -12	5713 -99	5239 -105	5475 28	4722 -86	4564 52	1	655665	22 33 23
14972	XD	NRAO91	-03 29	000000	2360 -120	2284 -169	2139 -101	2697 -71	2204 161	2142 84	1	666666	22 33 53
14972	SD	NRAO91	-03 28	000000	5183 -10	5795 -98	5065 -103	5578 29	4686 -87	4694 51	1	655665	22 34 23
14972	XD	NRAO91	-03 28	000000	2167 -121	2310 -169	2130 -100	2588 -75	2151 160	2155 83	1	666666	22 34 53
14972	SD	NRAO91	-03 27	000000	5202 -14	5860 -102	5214 -106	5643 27	4540 -89	4714 52	1	655665	22 35 23
14972	XD	NRAO91	-03 27	000000	2155 -141	2241 169	2097 -122	2496 -94	2185 158	2183 82	1	666666	22 35 53
14972	SD	NRAO91	-03 26	000000	5154 -14	5884 -102	5189 -109	5620 24	4647 -87	4668 52	1	655665	22 36 23
14972	XD	NRAO91	-03 26	000000	2115 -153	2210 155	2060 -129	2504 -101	2183 155	2214 75	1	666666	22 36 53
14972	SD	NRAO91	-03 25	000000	5645 -22	5915 -110	4946 -116	5369 16	4884 -87	4668 52	1	655665	22 37 23
14972	XD	NRAO91	-03 25	000000	2239 -165	2139 145	2027 -141	2507 -113	2052 154	2236 76	1	666666	22 37 53
14972	SD	NRAO91	-03 24	000000	5547 -28	5914 -115	5095 -118	5339 13	4841 -88	4691 52	1	655665	22 38 23
14972	XD	NRAO91	-03 24	000000	2143 177	2096 132	2036 -160	2454 -133	1953 159	2138 81	1	666676	22 38 53
14972	SD	NRAO91	-03 23	000000	5393 -26	5824 -114	5022 -117	5236 15	4783 -88	4687 50	1	655665	22 39 23
14972	XD	NRAO91	-03 23	000000	2120 180	2000 131	1939 -157	2383 -129	1950 157	2089 78	1	666676	22 39 53
14973	SD	3C119	-05 48	0000	7357 -10	7582 -97	6322 -106	7003 26	0	0	1	666666	22 42 37

(b)

SCAN	M	SOURCE	HA	RMS/100	AMP1R2RPHI	AMP1L2LPHI	AMP1R3RPHI	AMP1L3LPHI	AMP2R3RPHI	AMP2L3LPHI	NREC	TPOWER	LST
14973	SD	3C119	-05 47	0000	7920 -6	7861 -93	6799 -101	7382 32	0	0	1	666666	22 43 07
14973	SD	3C119	-05 47	000000	7660 0	7712 -87	6773 -97	7379 36	6127 -85	6241 55	1	666666	22 43 37
14973	XD	3C119	-05 46	000000	2013 -77	1836 -127	1536 -67	1812 -37	1553 168	1510 91	1	666666	22 44 07
14973	SD	3C119	-05 46	0000	7734 6	7747 -82	6940 -91	7498 42	0	0	1	656666	22 44 37
14973	SD	3C119	-05 45	0000	7795 -2	7820 -90	7082 -98	7593 34	0	0	1	656665	22 45 07
14973	SD	3C119	-05 45	000000	7773 -3	7724 -92	6947 -101	7426 32	6386 -85	6318 55	1	655665	22 45 37
14973	XD	3C119	-05 44	000000	1936 -106	1842 -152	1740 -90	2070 -65	1680 169	1810 91	1	666666	22 46 07
14973	SD	3C119	-05 44	0000	8077 -15	7916 -102	6934 -109	7456 24	0	0	1	656665	22 46 37
14973	SD	3C119	-05 43	0000	8161 -20	7958 -107	6821 -115	7423 17	0	0	1	655665	22 47 07
14973	SD	3C119	-05 43	000000	8634 -19	7967 -107	7219 -115	7567 18	6226 -86	6532 54	1	655665	22 47 37
14973	XD	3C119	-05 42	000000	2118 -156	1889 156	1735 -141	2150 -112	1656 165	1787 82	1	666666	22 48 07
14973	SD	3C119	-05 42	0000	8717 -26	8028 -113	7433 -122	7685 11	0	0	1	655665	22 48 37
14973	SD	3C119	-05 41	000000	8723 -24	8109 -112	7491 -121	7661 12	6349 -84	6432 56	1	656665	22 49 07
14973	XD	3C119	-05 41	000000	2178 -150	1827 161	1880 -135	2071 -107	1718 160	1909 84	1	666666	22 49 37
14974	SD	P2149-28	01 05	000000	2564 4	2640 -81	2337 -81	2456 53	2160 -96	2142 46	1	665665	22 55 55
14974	XD	P2149-28	01 05	000000	723 -131	563 -174	555 -104	762 -73	684 151	673 72	1	665666	22 56 25
14974	SD	P2149-28	01 06	000000	2611 -5	2641 -92	2429 -95	2417 39	2140 -91	2234 50	1	665665	22 56 55
14974	XD	P2149-28	01 06	000000	669 -76	550 -127	532 -40	645 -16	644 156	635 71	1	666666	22 57 25
14974	SD	P2149-28	01 07	000000	2641 13	2714 -76	2394 -79	2466 55	2231 -92	2117 48	1	665665	22 57 55
14974	XD	P2149-28	01 07	000000	575 -73	552 -125	528 -37	641 -4	590 152	658 73	1	666666	22 58 25
14974	SD	P2149-28	01 08	000000	2615 18	2669 -73	2311 -77	2488 58	2140 -89	2134 49	1	665665	22 58 55
14974	XD	P2149-28	01 08	000000	626 -25	579 -75	628 14	648 34	675 155	690 80	1	666666	22 59 25
14975	SD	OV080	03 13	0000	1959 -23	1974 -107	1665 -111	1760 21	0	0	1	655665	23 02 40
14975	SD	OV080	03 14	000000	2116 -20	2001 -109	1736 -107	1840 23	1580 -92	1457 47	1	655665	23 03 10
14975	XD	OV080	03 14	000000	883 -158	818 155	742 -133	839 -112	804 159	740 91	1	665666	23 03 40
14975	SD	OV080	03 15	0000	1963 -23	1939 -110	1727 -110	1809 23	0	0	1	655665	23 04 10
14975	SD	OV080	03 15	000000	1985 -27	1959 -115	1836 -113	1859 18	1575 -95	1444 48	1	655665	23 04 40
14975	XD	OV080	03 16	000000	876 169	819 120	729 -171	892 -143	686 161	743 85	1	665666	23 05 10
14975	SD	OV080	03 16	0000	1806 -32	1917 -120	1847 -125	1762 9	0	0	1	655665	23 05 40
14975	SD	OV080	03 17	000000	1908 -35	1926 -122	1696 -121	1802 11	1600 -92	1479 47	1	655665	23 06 10
14975	XD	OV080	03 17	000000	933 170	792 115	760 -178	1008 -150	742 166	741 86	1	665666	23 06 40
14975	SD	OV080	03 18	0000	1963 -34	1844 -123	1811 -125	1833 11	0	0	1	655665	23 07 10
14975	SD	OV080	03 18	000000	1927 -33	1912 -122	1689 -123	1835 4	1641 -92	1437 48	1	655665	23 07 40
14975	XD	OV080	03 19	000000	973 158	824 113	682 -175	846 -145	639 160	751 76	1	665666	23 08 10
14975	SD	OV080	03 19	0000	1970 -37	1839 -125	1704 -128	1704 4	0	0	1	655665	23 08 40
14975	SD	OV080	03 20	000000	1930 -37	1915 -121	1766 -128	1840 6	1660 -90	1536 48	1	655665	23 09 10
14975	XD	OV080	03 20	000000	920 -171	829 139	769 -155	1043 -122	733 163	680 93	1	665666	23 09 40
14976	SD	BLLAC	01 10	000000	9918 -21	8955 -109	7795 -116	8333 17	7394 -86	7219 55	1	666665	23 12 27
14976	XD	BLLAC	01 11	000000	6928 -153	6112 157	5742 -143	6754 -114	5163 168	5891 89	1	665666	23 12 57
14976	SD	BLLAC	01 11	000000	10019 -19	9178 -107	7862 -116	8327 17	7337 -86	7137 54	1	666665	23 13 27
14976	XD	BLLAC	01 12	000000	6755 -165	5892 145	5688 -151	6760 -122	5182 164	5859 87	1	665666	23 13 57
14976	SD	BLLAC	01 12	000000	9576 -28	8880 -114	7793 -123	8310 11	7478 -86	7187 54	1	666666	23 14 27
14976	XD	BLLAC	01 13	000000	6573 -178	5780 133	5544 -166	6594 -137	5217 165	5704 88	1	666666	23 14 57
14976	SD	BLLAC	01 13	000000	9561 -42	9006 -129	7828 -136	8414 -3	7541 -87	7261 52	1	665665	23 15 27
14976	SD	BLLAC	01 14	000000	9617 -43	8965 -130	7639 -137	8298 -4	7404 -86	7086 53	1	666665	23 16 27
14976	XD	BLLAC	01 15	000000	6590 148	5814 99	5582 163	6613 -169	5158 166	5706 87	1	666666	23 16 57
14976	SD	BLLAC	01 15	000000	9935 -46	9075 -133	7897 -141	8376 -8	7384 -86	7220 53	1	666665	23 17 27
14976	XD	BLLAC	01 16	000000	6596 159	5694 111	5297 171	6514 -161	5224 167	5860 90	1	665666	23 17 57
14976	SD	BLLAC	01 16	000000	9504 -37	8986 -124	7979 -131	8347 2	7572 -87	7242 53	1	665665	23 18 27
14976	XD	BLLAC	01 17	000000	6477 156	5705 108	5323 170	6542 -161	4989 165	5809 87	1	665666	23 18 57
14976	SD	BLLAC	01 17	000000	9994 -33	9038 -120	8008 -128	8552 6	7503 -87	7164 53	1	665665	23 19 27
14977	SD	3C454.3	00 29	011110	14272 -48	15100 -136	12598 -142	14082 -10	12584 -88	12467 51	1	665665	23 22 05
14977	XD	3C454.3	00 29	111100	10559 168	9810 119	8303 -171	10796 -143	9216 158	10143 79	1	665666	23 22 35
14977	SD	3C454.3	00 30	100100	14852 -46	15626 -133	13455 -140	14590 -8	13230 -87	12722 53	1	665665	23 23 05
14977	SD	3C454.3	00 31	110100	14664 -37	15448 -125	13573 -130	14597 3	12990 -88	12668 51	1	655665	23 24 05
14977	XD	3C454.3	00 31	110100	10429 -165	9889 145	8837 -151	10883 -122	9799 164	10184 87	1	665666	23 24 35
14977	SD	3C454.3	00 32	111100	15010 -33	15317 -120	13275 -126	14213 7	12941 -88	12381 52	1	655665	23 25 05
14977	XD	3C454.3	00 32	000000	10334 -164	9893 148	9205 -145	11037 -117	9668 162	10032 83	1	666666	23 25 35
14977	SD	3C454.3	00 33	100100	14303 -30	15394 -117	13654 -123	14722 9	13115 -87	12615 52	1	655665	23 26 05
14977	XD	3C454.3	00 33	110100	10470 -165	9863 145	8569 -145	10940 -117	9258 159	10000 81	1	666666	23 26 35

Figs. III-7a-n. INTSCRIB display of 30 second raw data records for scans 14969 through 15028.

(c)

SCAN	M	SOURCE	HA	RMS/100	AMP1R2RPHI		AMP1L2LPHI		AMP1R3RPHI		AMP1L3LPHI		AMP2R3RPHI		AMP2L3LPHI		NREC	TPOWER	LST
14977	SD	3C454.3	00 34	110100	15225	-32	15317	-120	12902	-125	14344	7	12862	-87	12492	52	1	655665	23 27 05
14977	XD	3C454.3	00 34	110100	10578	-172	9573	139	8918	-150	10848	-123	9110	158	9675	79	1	666666	23 27 35
14977	SD	3C454.3	00 35	100100	15908	-33	15322	-120	13427	-126	14430	6	12960	-87	12494	53	1	656665	23 28 05
14977	XD	3C454.3	00 35	000000	10519	-168	9389	142	8235	-150	10255	-123	8291	162	9043	83	1	666666	23 28 35
14977	SD	3C454.3	00 36	100100	15453	-30	15290	-117	13325	-123	14419	10	12949	-87	12554	53	1	655665	23 29 05
14977	XD	3C454.3	00 36	111100	9634	176	8918	126	8357	-166	10046	-139	8943	161	9219	82	1	676666	23 29 35
14978	SD	P0114-21	-01 42	000000	3162	17	3103	-70	2701	-73	2888	58	2653	-93	2602	49	1	655665	23 32 35
14978	XD	P0114-21	-01 42	000000	575	-98	550	-153	458	-70	587	-43	488	145	490	73	1	676676	23 33 05
14978	SD	P0114-21	-01 41	000000	3230	16	3193	-72	2693	-74	2945	57	2611	-92	2570	50	1	655665	23 33 35
14978	XD	P0114-21	-01 41	000000	563	-115	438	-153	419	-78	537	-45	496	140	451	65	1	676777	23 34 05
14978	SD	P0114-21	-01 40	000000	3004	11	3141	-77	2622	-79	2998	57	2460	-91	2545	51	1	655665	23 34 35
14978	XD	P0114-21	-01 40	000000	407	-79	478	-116	411	-41	493	-21	441	147	386	73	1	776777	23 35 05
14978	SD	P0114-21	-01 39	000000	2878	20	3070	-67	2648	-69	2804	64	2563	-93	2554	47	1	665665	23 35 35
14978	XD	P0114-21	-01 39	000000	461	-95	388	-134	458	-54	483	-24	402	145	490	73	1	776777	23 36 05
14978	SD	P0114-21	-01 38	000000	2703	21	3071	-70	2665	-69	2894	65	2570	-91	2435	48	1	665665	23 36 35
14978	XD	P0114-21	-01 38	000000	525	-69	450	-127	390	-40	421	-5	452	145	438	55	1	776777	23 37 05
14978	SD	P0114-21	-01 37	000000	2834	17	3080	-72	2740	-74	2856	61	2640	-91	2539	47	1	665665	23 37 35
14978	XD	P0114-21	-01 37	000000	509	-74	474	-132	412	-51	500	-16	453	139	443	67	1	776777	23 38 05
14978	SD	P0114-21	-01 36	000000	2969	11	3067	-79	2678	-77	2817	56	2600	-91	2553	46	1	665665	23 38 35
14978	XD	P0114-21	-01 36	000000	480	-149	382	174	470	-94	458	-70	496	146	366	64	1	776777	23 39 05
14978	SD	P0114-21	-01 35	000000	2975	-18	3080	-103	2639	-103	2884	31	2624	-93	2538	45	1	665665	23 39 35
14979	SD	P0056-17	-01 16	000000	1001	-3	1003	-95	826	-97	796	39	1110	-98	926	47	1	655665	23 41 18
14979	XD	P0056-17	-01 15	000000	133	-103	141	-135	76	-67	125	-29	143	168	76	67	1	776676	23 41 48
14979	SD	P0056-17	-01 15	000000	1060	-1	882	-95	852	-95	924	39	984	-95	933	43	1	655665	23 42 18
14979	XD	P0056-17	-01 14	000000	90	-84	130	-157	72	-34	94	-18	76	-157	31	18	1	776776	23 42 48
14979	SD	P0056-17	-01 14	000000	1050	1	990	-88	910	-92	894	40	971	-93	906	49	1	655665	23 43 18
14979	XD	P0056-17	-01 13	000000	134	-48	158	-125	155	-75	160	0	169	135	120	48	1	776777	23 43 48
14979	SD	P0056-17	-01 13	000000	1022	-4	983	-85	842	-95	905	45	1036	-97	905	46	1	655665	23 44 18
14979	XD	P0056-17	-01 12	000000	72	-106	94	-148	127	-45	86	-54	152	169	188	58	1	776676	23 44 48
14979	SD	P0056-17	-01 12	000000	937	-11	1002	-102	823	-100	785	31	1063	-95	884	46	1	655665	23 45 18
14979	XD	P0056-17	-01 11	000000	117	-70	117	-160	120	-85	183	-61	72	146	125	61	1	776777	23 45 48
14979	SD	P0056-17	-01 11	000000	997	-16	955	-100	851	-103	895	29	1031	-93	891	48	1	655665	23 46 18
14979	XD	P0056-17	-01 10	000000	78	-50	70	-172	92	-41	130	-86	60	171	122	55	1	776777	23 46 48
14979	SD	P0056-17	-01 10	000000	958	-18	911	-111	920	-109	927	24	972	-94	982	45	1	655665	23 47 18
14979	XD	P0056-17	-01 09	000000	171	-83	191	-137	90	-96	107	-22	70	135	78	40	1	776777	23 47 48
14979	SD	P0056-17	-01 09	000000	974	-17	992	-109	898	-111	813	26	998	-97	947	46	1	665665	23 48 18
14979	XD	P0056-17	-01 08	000000	136	-126	134	-138	111	-80	63	18	167	163	158	55	1	776777	23 48 48
14979	SD	P0056-17	-01 08	000000	1048	-30	967	-113	850	-114	908	17	981	-93	969	43	1	655665	23 49 18
14979	XD	P0056-17	-01 07	000000	138	-120	128	-141	111	-100	92	-77	128	129	111	80	1	776777	23 49 48
14980	SD	3C48	-01 42	111111	12346	-31	13211	-120	11130	-127	12341	5	10688	-84	10510	54	1	666666	23 53 18
14980	XD	3C48	-01 42	000000	2604	169	2483	120	2373	-177	2974	-150	2379	166	2581	88	1	676666	23 53 48
14980	SD	3C48	-01 41	000000	12763	-32	13280	-120	10918	-127	12362	5	10943	-86	10746	53	1	666666	23 54 18
14980	XD	3C48	-01 41	000000	2736	167	2473	117	2340	179	3057	-151	2578	167	2640	89	1	666666	23 54 48
14980	SD	3C48	-01 40	000000	12641	-31	13328	-120	11282	-128	12429	5	11018	-83	10714	56	1	666666	23 55 18
14980	XD	3C48	-01 40	000000	2736	-172	2554	140	2459	-159	2984	-134	2451	171	2541	92	1	666676	23 55 48
14980	SD	3C48	-01 39	000000	12842	-18	13365	-105	11618	-113	12560	19	11063	-84	10825	56	1	666666	23 56 18
14980	XD	3C48	-01 39	000000	2479	-171	2468	140	2367	-156	2873	-129	2510	167	2580	89	1	676666	23 56 48
14980	SD	3C48	-01 38	000000	12029	-31	13245	-119	11384	-128	12371	5	10575	-84	10699	55	1	666666	23 57 18
14980	XD	3C48	-01 38	000000	2501	164	2388	115	2441	-178	2889	-152	2425	166	2450	89	1	676676	23 57 48
14980	SD	3C48	-01 37	000000	11948	-34	13244	-122	11399	-130	12417	2	10584	-84	10825	56	1	666666	23 58 18
14980	XD	3C48	-01 37	000000	2602	-177	2610	133	2327	-162	2970	-136	2450	167	2581	88	1	676666	23 58 48
14981	SD	P2149-28	02 12	000000	2350	-1	2412	-88	2242	-93	2321	43	2041	-88	1869	51	1	666666	00 02 50
14981	XD	P2149-28	02 12	000000	482	-96	510	-145	474	-72	594	-48	451	155	440	69	1	776777	00 03 20
14981	SD	P2149-28	02 13	0000	2519	-16	2547	-102	2289	-104	2431	29		0		0	1	666666	00 03 50
14981	SD	P2149-28	02 13	000000	2442	-25	2566	-112	2279	-114	2324	19	2060	-92	1987	47	1	666666	00 04 20
14981	XD	P2149-28	02 14	000000	598	159	520	113	515	-162	521	-148	617	151	493	69	1	776676	00 04 50
14981	SD	P2149-28	02 14	0000	2267	-23	2436	-112	2294	-116	2317	18		0		0	1	666666	00 05 20
14981	SD	P2149-28	02 15	000000	2399	-24	2540	-112	2206	-114	2337	17	2010	-91	1984	49	1	666666	00 05 50
14981	XD	P2149-28	02 15	000000	620	-159	447	156	516	-144	549	-100	497	158	488	79	1	776676	00 06 20
14981	SD	P2149-28	02 16	0000	2362	-18	2454	-108	2299	-109	2341	24		0		0	1	666666	00 06 50

(d)

SCAN	M	SOURCE	HA	RMS/100	AMP1R2RPHI		AMP1L2LPHI		AMP1R3RPHI		AMP1L3LPHI		AMP2R3RPHI		AMP2L3LPHI		NREC	TPOWER	LST
14981	SD	P2149-28	02 16	000000	2255	-29	2514	-113	2173	-116	2335	15	2100	-90	2004	48	1	666666	00 07 20
14981	XD	P2149-28	02 17	000000	660	178	523	135	502	-145	635	-116	538	158	608	81	1	776666	00 07 50
14981	SD	P2149-28	02 17	0000	2232	-16	2463	-102	2207	-108	2316	26		0		0	1	666666	00 08 20
14981	SD	P2149-28	02 18	000000	2280	0	2510	-89	2171	-92	2352	41	2090	-89	1970	49	1	666666	00 08 50
14981	XD	P2149-28	02 18	000000	671	-94	518	-146	508	-80	608	-44	518	155	541	74	1	676676	00 09 20
14981	SD	P2149-28	02 19	0000	2459	-10	2544	-96	2209	-99	2346	32		0		0	1	666666	00 09 50
14982	SD	CYGX-3	03 42	0000	5851	-22	5784	-109	5160	-121	5464	14		0		0	1	655665	00 14 13
14982	SD	CYGX-3	03 43	0000	5760	-23	5856	-109	4920	-119	5267	14		0		0	1	655665	00 14 43
14982	SD	CYGX-3	03 43	000000	5428	-17	5789	-104	5192	-116	5380	17	4667	-85	4516	54	1	655665	00 15 13
14982	XD	CYGX-3	03 44	000000	2042	-127	1842	-177	1783	-122	2142	-96	1665	175	1736	98	1	665666	00 15 43
14982	SD	CYGX-3	03 44	0000	5572	-12	5804	-99	5064	-110	5230	24		0		0	1	655665	00 16 13
14982	SD	CYGX-3	03 45	0000	5828	-18	5739	-105	5169	-116	5379	18		0		0	1	655665	00 16 43
14982	SD	CYGX-3	03 45	000000	5971	-22	5765	-109	5064	-120	5257	12	4773	-84	4494	54	1	655665	00 17 13
14982	XD	CYGX-3	03 46	000000	2042	-139	1861	171	1711	-135	2066	-107	1618	174	1701	97	1	666666	00 17 43
14982	SD	CYGX-3	03 46	0000	5901	-25	5643	-113	5212	-123	5481	11		0		0	1	655665	00 18 13
14982	SD	CYGX-3	03 47	000000	5607	-17	5726	-106	5183	-116	5288	17	4809	-85	4470	54	1	655665	00 19 13
14982	XD	CYGX-3	03 48	000000	2010	-156	1758	155	1749	-149	2100	-122	1612	170	1749	96	1	665666	00 19 43
14983	SD	P0114-21	-00 51	000000	3304	-26	3084	-111	2728	-113	2907	20	2621	-92	2515	49	1	555665	00 24 10
14983	XD	P0114-21	-00 50	000000	571	-147	565	167	496	-109	691	-86	513	147	662	61	1	665666	00 24 40
14983	SD	P0114-21	-00 50	000000	3222	-42	3047	-130	2914	-127	3029	6	2745	-96	2560	40	1	555665	00 25 10
14983	XD	P0114-21	-00 49	000000	581	151	539	101	516	-165	554	-141	509	135	593	57	1	665666	00 25 40
14983	SD	P0114-21	-00 49	000000	3403	-47	3160	-135	2991	-134	3000	1	2784	-98	2609	45	1	555665	00 26 10
14983	XD	P0114-21	-00 48	000000	629	147	529	101	530	179	639	-155	537	151	586	67	1	665666	00 26 40
14983	SD	P0114-21	-00 48	000000	3577	-45	3217	-131	2972	-129	3010	1	2725	-94	2701	46	1	555665	00 27 10
14983	XD	P0114-21	-00 47	000000	650	178	601	136	540	-141	672	-113	511	149	586	65	1	665666	00 27 40
14983	SD	P0114-21	-00 47	000000	3214	-34	3108	-117	2865	-112	2928	22	2727	-99	2600	41	1	555665	00 28 11
14983	XD	P0114-21	-00 46	000000	617	-140	570	178	547	-99	657	-70	604	146	588	69	1	665666	00 28 41
14983	SD	P0114-21	-00 46	000000	3339	-18	3270	-106	2827	-107	3003	24	2680	-91	2529	49	1	555665	00 29 11
14983	XD	P0114-21	-00 45	000000	680	-126	600	177	522	-107	657	-81	593	147	506	68	1	665666	00 29 41
14984	SD	3C48	-01 02	111100	13256	-26	13139	-113	10471	-121	11343	11	10311	-86	10084	54	1	656665	00 33 30
14984	XD	3C48	-01 02	000000	3303	177	2850	128	2557	-169	3067	-140	2460	164	2734	87	1	665666	00 34 00
14984	SD	3C48	-01 01	000000	13408	-28	13323	-116	11033	-123	11609	9	10806	-85	10324	54	1	656665	00 34 30
14984	XD	3C48	-01 01	000000	3074	177	2836	128	2449	-166	2994	-138	2502	164	2684	84	1	665666	00 35 00
14984	SD	3C48	-01 00	000000	13073	-30	13341	-117	10913	-124	11843	9	10806	-86	10434	54	1	656665	00 35 30
14984	XD	3C48	-01 00	000000	2952	171	2795	124	2255	-173	3001	-148	2471	165	2684	87	1	666666	00 36 00
14984	SD	3C48	-00 59	000000	12854	-30	13352	-118	10767	-124	11820	8	10931	-84	10492	56	1	656665	00 36 30
14984	XD	3C48	-00 59	000000	3078	-155	2795	153	2332	-142	3045	-116	2432	167	2811	88	1	666666	00 37 00
14984	SD	3C48	-00 58	000000	12695	-23	13318	-111	10925	-117	11965	16	10852	-86	10471	54	1	656665	00 37 30
14984	XD	3C48	-00 58	000000	3035	176	2770	128	2268	-167	2951	-140	2449	165	2681	88	1	665666	00 38 00
14984	SD	3C48	-00 57	100100	13041	-40	13214	-127	10663	-133	11610	-0	10699	-85	10078	53	1	666665	00 38 30
14984	XD	3C48	-00 57	000000	3051	147	2806	99	2465	164	3069	-170	2452	166	2762	88	1	666666	00 39 00
14984	SD	3C48	-00 56	000000	13307	-45	13306	-132	10925	-137	11620	-5	10816	-86	10216	53	1	656665	00 39 30
14985	SD	D0224+67	-01 44	0000	1920	-22	1719	-111	1381	-124	1706	5		0		0	1	555665	00 42 26
14985	SD	D0224+67	-01 43	000000	1848	-14	1737	-100	1436	-114	1556	17	1405	-81	1420	60	1	555665	00 42 56
14985	XD	D0224+67	-01 43	000000	1832	-111	1652	-159	1612	-100	2008	-71	1314	169	1585	95	1	665666	00 43 26
14985	SD	D0224+67	-01 42	0000	1790	-19	1799	-107	1503	-119	1663	17		0		0	1	555665	00 43 56
14985	SD	D0224+67	-01 42	000000	1891	-39	1722	-123	1421	-134	1620	-1	1423	-86	1420	56	1	555665	00 44 26
14985	XD	D0224+67	-01 41	000000	1886	157	1543	109	1471	163	1980	-168	1293	176	1636	98	1	665666	00 44 56
14985	SD	D0224+67	-01 41	0000	1863	-33	1824	-121	1571	-132	1620	0		0		0	1	555665	00 45 26
14985	SD	D0224+67	-01 40	000000	1880	-24	1734	-111	1531	-123	1728	8	1445	-79	1413	59	1	555665	00 45 56
14985	XD	D0224+67	-01 40	000000	1785	176	1661	130	1450	180	1908	-150	1250	173	1616	95	1	665666	00 46 26
14985	SD	D0224+67	-01 39	0000	1771	-25	1756	-113	1445	-125	1557	11		0		0	1	555665	00 46 56
14985	SD	D0224+67	-01 39	000000	1812	-29	1799	-112	1453	-124	1681	7	1386	-81	1414	57	1	555665	00 47 26
14985	XD	D0224+67	-01 38	000000	1896	-172	1679	139	1565	-170	2006	-139	1356	174	1514	98	1	665666	00 47 56
14985	SD	D0224+67	-01 38	0000	1820	-32	1762	-118	1636	-129	1711	2		0		0	1	555665	00 48 26
14985	SD	D0224+67	-01 37	000000	1755	-33	1783	-122	1535	-133	1670	-1	1498	-84	1423	55	1	555665	00 48 56
14985	XD	D0224+67	-01 37	000000	1780	158	1666	113	1533	165	1943	-168	1494	176	1578	96	1	665666	00 49 26
14986	SD	3C147	-04 46	1111	20423	-25	18703	-113	18441	-123	19108	10		0		0	1	555665	00 53 31
14986	SD	3C147	-04 46	111111	20417	-31	18763	-118	18506	-128	19133	5	15855	-84	15249	57	1	655665	00 54 01
14986	XD	3C147	-04 45	000000	4839	-147	4188	165	4112	-142	4999	-114	3915	177	4385	98	1	665666	00 54 31

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SCAN	M	SOURCE	HA	RMS/100	AMP1R2RPHI	AMP1L2LPHI	AMP1R3RPHI	AMP1L3LPHI	AMP2R3RPHI	AMP2L3LPHI	NREC	TPOWER	LST
14986	SD	3C147	-04 45	1001	20677 -8	18917 -96	17584 -106	18770 27	0	0	1	655665	00 55 01
14986	XD	3C147	-04 44	000000	4922 -132	4310 -179	4346 -123	5222 -94	3889 172	4393 94	1	665666	00 56 01
14986	SD	3C147	-04 43	1111	20283 -20	18828 -108	17675 -118	18913 15	0	0	1	555665	00 56 31
14986	SD	3C147	-04 43	110111	20244 -23	18725 -110	18148 -121	18966 12	15633 -83	15428 57	1	555665	00 57 01
14986	XD	3C147	-04 42	000000	4931 -147	4174 165	4398 -138	5161 -108	4039 173	4205 95	1	665666	00 57 31
14986	SD	3C147	-04 42	1111	20405 -20	18997 -108	18387 -117	18933 15	0	0	1	655665	00 58 01
14986	SD	3C147	-04 41	101111	20617 -27	18980 -114	17568 -123	18548 10	15596 -84	15319 56	1	655665	00 58 31
14986	XD	3C147	-04 41	000000	4882 -173	4229 139	4338 -164	5027 -135	3889 171	4405 93	1	665666	00 59 01
14986	SD	3C147	-04 40	1101	20907 -31	19310 -119	18190 -127	18833 6	0	0	1	655665	00 59 31
14987	SD	3C119	-03 28	000000	8114 -49	8132 -136	6912 -144	7789 -11	6519 -86	6516 53	1	555665	01 01 51
14987	XD	3C119	-03 28	000000	2174 129	2065 79	1864 139	2462 167	1894 169	2100 91	1	665666	01 02 21
14987	SD	3C119	-03 27	000000	8175 -42	8212 -129	7021 -138	7691 -5	6611 -84	6547 55	1	555665	01 02 51
14987	XD	3C119	-03 27	000000	2199 150	2000 102	1999 163	2463 -168	1940 167	2081 88	1	665666	01 03 21
14987	SD	3C119	-03 26	000000	7977 -35	8132 -122	6929 -130	7783 2	6767 -85	6611 54	1	555665	01 03 51
14987	XD	3C119	-03 26	000000	2164 150	1989 103	1855 166	2435 -167	1911 165	1952 87	1	665666	01 04 21
14987	SD	3C119	-03 25	000000	8541 -45	8285 -133	7148 -141	7828 -9	6785 -85	6704 55	1	555665	01 04 51
14987	XD	3C119	-03 25	000000	2211 141	2050 96	2003 155	2503 -177	1938 170	2100 89	1	665666	01 05 21
14987	SD	3C119	-03 24	000000	8242 -36	8254 -124	7023 -132	7610 1	6818 -85	6620 55	1	555665	01 05 51
14987	XD	3C119	-03 24	000000	2163 150	1996 104	1952 167	2598 -169	1967 167	2092 87	1	665666	01 06 21
14987	SD	3C119	-03 23	000000	8111 -40	8236 -127	7086 -134	7746 -2	6845 -86	6622 54	1	555665	01 06 51
14987	XD	3C119	-03 23	000000	2148 144	1989 98	1965 159	2440 -175	1961 170	1970 89	1	665666	01 07 21
14987	SD	3C119	-03 22	000000	8310 -42	8244 -130	6923 -138	7786 -6	6658 -86	6600 54	1	555665	01 07 51
14987	XD	3C119	-03 22	000000	2250 144	2003 93	1855 159	2463 -174	1891 167	2110 89	1	665666	01 08 21
14987	SD	3C119	-03 21	000000	8408 -44	8253 -131	6909 -139	7753 -6	6757 -87	6678 53	1	555665	01 08 51
14987	XD	3C119	-03 21	000000	2100 136	2033 87	1958 147	2470 173	1945 168	2010 88	1	665666	01 09 21
14987	SD	3C119	-03 20	000000	8469 -42	8285 -130	7254 -139	7801 -6	6721 -84	6587 54	1	555665	01 09 51
14988	SD	CTA21	-02 05	000000	7060 -43	7432 -131	6471 -136	7103 -3	6242 -88	6114 52	1	655665	01 12 00
14988	XD	CTA21	-02 04	000000	1543 138	1542 87	1243 163	1663 -169	1480 158	1581 81	1	665666	01 12 30
14988	SD	CTA21	-02 04	000000	7322 -42	7648 -129	6356 -135	7104 -2	6126 -87	6188 52	1	655665	01 13 00
14988	XD	CTA21	-02 03	000000	1546 161	1503 114	1440 -180	1742 -148	1492 161	1541 83	1	665666	01 13 30
14988	SD	CTA21	-02 03	000000	7117 -33	7577 -122	6447 -126	7101 6	6232 -88	6063 52	1	655665	01 14 00
14988	XD	CTA21	-02 02	000000	1489 153	1482 102	1340 180	1763 -156	1478 159	1552 77	1	665666	01 14 30
14988	SD	CTA21	-02 02	000000	7409 -36	7621 -124	6778 -129	7200 3	6295 -88	6180 52	1	655665	01 15 00
14988	XD	CTA21	-02 01	000000	1542 143	1579 96	1410 168	1690 -166	1537 157	1547 77	1	665666	01 15 30
14988	SD	CTA21	-02 01	000000	6747 -38	7614 -125	6690 -131	7151 1	6094 -88	6191 52	1	655665	01 16 00
14988	XD	CTA21	-02 00	000000	1490 140	1470 88	1357 163	1739 -168	1516 155	1519 81	1	665666	01 16 30
14988	SD	CTA21	-02 00	000000	6911 -43	7709 -131	6597 -135	7119 -3	6193 -88	6189 51	1	655665	01 17 00
14988	XD	CTA21	-01 59	000000	1509 131	1497 81	1400 155	1721 -178	1486 156	1472 76	1	665666	01 17 30
14988	SD	CTA21	-01 59	000000	6662 -44	7536 -131	6371 -136	7116 -4	6002 -88	6097 51	1	655665	01 18 00
14988	XD	CTA21	-01 58	000000	1545 120	1474 67	1394 143	1802 173	1339 157	1513 75	1	665666	01 18 30
14988	SD	CTA21	-01 58	000000	6578 -53	7558 -139	6711 -144	7095 -12	5962 -88	6041 51	1	655665	01 19 00
14988	XD	CTA21	-01 57	000000	1442 135	1487 81	1381 154	1700 179	1423 160	1543 80	1	665666	01 19 30
14989	SD	P0114-21	00 07	000000	3306 -3	3270 -91	2873 -93	3072 40	2751 -92	2674 47	1	655665	01 22 35
14989	XD	P0114-21	00 07	000000	665 -147	623 174	615 -122	630 -88	560 158	628 76	1	665666	01 23 05
14989	SD	P0114-21	00 08	000000	3278 -4	3296 -94	2885 -93	3009 39	2795 -94	2610 47	1	655665	01 23 35
14989	XD	P0114-21	00 08	000000	608 -132	621 -176	545 -98	732 -76	640 157	621 64	1	665666	01 24 05
14989	SD	P0114-21	00 09	000000	3379 -12	3205 -100	2928 -100	3054 31	2811 -92	2596 50	1	655665	01 24 35
14989	XD	P0114-21	00 09	000000	602 -132	700 -178	512 -111	676 -82	607 147	617 65	1	665666	01 25 05
14989	SD	P0114-21	00 10	000000	3310 -6	3261 -95	2805 -96	3002 37	2741 -92	2649 48	1	655665	01 25 35
14989	XD	P0114-21	00 10	000000	629 -137	643 174	600 -108	657 -77	547 149	564 60	1	665666	01 26 05
14989	SD	P0114-21	00 11	000000	3415 -19	3330 -107	2752 -106	2967 24	2732 -92	2603 47	1	665665	01 26 35
14989	XD	P0114-21	00 11	000000	564 -157	623 158	532 -118	625 -97	566 144	595 65	1	665666	01 27 05
14989	SD	P0114-21	00 12	000000	3285 -40	3287 -129	2894 -128	3066 4	2771 -92	2578 48	1	655665	01 27 35
14989	XD	P0114-21	00 12	000000	554 146	620 92	522 175	616 -163	614 158	563 73	1	665666	01 28 05
14989	SD	P0114-21	00 13	000000	3328 -31	3281 -119	2942 -123	3089 9	2841 -88	2572 52	1	655665	01 28 35
14989	XD	P0114-21	00 13	000000	651 -139	595 172	547 -111	651 -86	608 153	650 76	1	665666	01 29 05
14989	SD	P0114-21	00 14	000000	3194 -18	3303 -104	2836 -108	2929 26	2780 -90	2628 49	1	655665	01 29 35
14990	SD	3C454.3	02 40	1111	14686 -34	15766 -121	13867 -129	15033 4	0	0	1	655665	01 32 38
14990	SD	3C454.3	02 40	000111	13979 -29	16032 -117	14391 -125	15481 7	12213 -85	12540 54	1	655665	01 33 08
14990	XD	3C454.3	02 41	111100	11390 180	11184 132	10531 -167	13117 -138	10395 165	11031 87	1	665666	01 33 38

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SCAN	M	SOURCE	HA	RMS/100	AMP1R2RPHI	AMP1L2LPHI	AMP1R3RPHI	AMP1L3LPHI	AMP2R3RPHI	AMP2L3LPHI	NREC	TPOWER	LST
14990	SD	3C454.3	02 41	1001	14727 -34	16179 -122	13334 -130	15179 2	0	0	1	655665	01 34 08
14990	SD	3C454.3	02 42	000001	14844 -41	16219 -128	13783 -136	15253 -3	12687 -85	12793 55	1	655665	01 34 38
14990	SD	3C454.3	02 43	1000	13968 -43	16040 -131	13164 -139	15023 -7	0	0	1	655665	01 35 38
14990	SD	3C454.3	02 43	000101	12798 -40	15987 -128	14226 -138	15262 -5	12635 -84	12765 55	1	655665	01 36 08
14990	XD	3C454.3	02 44	000000	11055 152	11433 103	10662 163	13071 -169	10350 168	10840 90	1	665666	01 36 38
14990	SD	3C454.3	02 44	1101	13767 -32	16066 -120	13841 -129	15139 4	0	0	1	655665	01 37 08
14990	SD	3C454.3	02 45	000001	13015 -22	15984 -110	13656 -121	15111 12	12542 -83	12836 56	1	655665	01 37 38
14990	XD	3C454.3	02 45	100100	11189 -141	11469 170	10234 -134	13010 -106	10406 173	11038 93	1	665666	01 38 08
14990	SD	3C454.3	02 46	0000	13122 -15	16057 -102	14052 -113	15394 20	0	0	1	655665	01 38 38
14990	SD	3C454.3	02 46	110000	13586 -17	16133 -105	13946 -116	15349 17	12488 -82	12814 57	1	655665	01 39 08
14990	XD	3C454.3	02 47	000100	10719 -135	11314 176	10386 -131	13229 -103	10384 174	10983 96	1	665666	01 39 38
14991	SD	3C418	05 04	0000	6070 -14	6020 -100	5532 -113	5897 22	0	0	1	655665	01 42 33
14991	SD	3C418	05 05	0000	5591 -22	5995 -108	5609 -118	5748 14	0	0	1	655665	01 43 03
14991	SD	3C418	05 05	0000	5759 -29	6106 -115	5306 -126	5858 7	0	0	1	655665	01 43 33
14991	SD	3C418	05 06	0000	6013 -33	6231 -120	5528 -129	5835 4	0	0	1	655665	01 44 03
14991	SD	3C418	05 06	0000	5458 -31	5981 -118	5527 -128	5881 6	0	0	1	655665	01 44 33
14991	SD	3C418	05 07	0000	5765 -28	6157 -114	5298 -125	5774 8	0	0	1	655665	01 45 03
14991	SD	3C418	05 07	0000	5864 -22	6130 -111	5582 -122	5875 11	0	0	1	655665	01 45 33
14991	SD	3C418	05 08	0000	6128 -18	6189 -106	5429 -116	5716 16	0	0	1	655665	01 46 03
14991	SD	3C418	05 08	0000	5752 -18	6060 -106	5295 -116	5700 17	0	0	1	655665	01 46 33
14991	XD	3C418	05 09	0000	2996 -172	2777 140	2580 -162	3140 -134	0	0	1	665666	01 47 33
14991	XD	3C418	05 10	0000	2851 -159	2723 153	2419 -154	3130 -126	0	0	1	665666	01 48 03
14991	XD	3C418	05 10	0000	2621 -161	2514 150	2446 -153	2912 -123	0	0	1	665666	01 48 33
14991	XD	3C418	05 11	000000	2934 -177	2708 135	2634 -170	3095 -140	2651 175	2681 97	1	665666	01 49 03
14991	SD	3C418	05 11	0000	6010 -35	6090 -123	5479 -132	5693 2	0	0	1	655665	01 49 33
14992	SD	P0106+01	00 47	000000	3619 -20	3755 -105	3352 -114	3485 18	3395 -87	3120 54	1	655665	01 54 20
14992	XD	P0106+01	00 47	000000	3477 -138	3288 174	3186 -121	3902 -95	3063 164	3372 85	1	665666	01 54 50
14992	SD	P0106+01	00 48	000000	4004 -25	3838 -112	3502 -118	3640 16	3397 -86	3203 52	1	655665	01 55 20
14992	XD	P0106+01	00 48	000000	3852 -157	3414 156	3340 -139	3843 -113	3220 166	3526 86	1	665666	01 55 50
14992	SD	P0106+01	00 49	000000	4092 -26	3905 -111	3511 -120	3587 13	3425 -87	3166 53	1	655665	01 56 20
14992	XD	P0106+01	00 49	000000	3579 -166	3274 144	3057 -149	3910 -121	2904 163	3487 84	1	665666	01 56 50
14992	SD	P0106+01	00 50	000000	4127 -27	3901 -113	3445 -121	3588 11	3229 -86	3218 54	1	655665	01 57 20
14992	XD	P0106+01	00 50	000000	3818 -144	3477 169	3208 -128	3885 -101	3086 164	3525 87	1	665666	01 57 50
14992	SD	P0106+01	00 51	000000	4053 -22	3956 -109	3539 -115	3680 16	3346 -86	3128 52	1	655665	01 58 20
14992	XD	P0106+01	00 51	000000	3737 -167	3240 145	3078 -150	3783 -120	2892 164	3392 85	1	665666	01 58 50
14992	SD	P0106+01	00 52	000000	4018 -30	3948 -116	3458 -124	3551 9	3282 -88	3270 53	1	655665	01 59 20
14992	XD	P0106+01	00 52	000000	3825 -152	3479 161	3361 -133	3975 -106	3424 162	3687 84	1	665666	01 59 50
14993	SD	NRAO140	-01 32	000000	3826 -46	4167 -133	3706 -140	3907 -8	3400 -85	3372 56	1	666665	02 02 30
14993	XD	NRAO140	-01 31	000000	1816 142	1747 95	1558 157	2001 -178	1663 169	1702 93	1	666666	02 03 00
14993	SD	NRAO140	-01 31	000000	3849 -41	4156 -127	3712 -134	3981 -1	3411 -85	3259 56	1	656665	02 03 30
14993	XD	NRAO140	-01 30	000000	1905 145	1774 97	1624 158	1988 -172	1720 169	1762 87	1	666666	02 04 00
14993	SD	NRAO140	-01 30	000000	3575 -42	4249 -128	3755 -136	3982 -4	3302 -85	3385 55	1	656665	02 04 30
14993	XD	NRAO140	-01 29	000000	1744 143	1792 93	1527 160	2017 -175	1681 167	1850 88	1	665666	02 05 00
14993	SD	NRAO140	-01 29	000000	3649 -50	4208 -136	3632 -143	3859 -11	3511 -85	3402 54	1	666665	02 05 30
14993	XD	NRAO140	-01 28	000000	1713 118	1781 70	1480 131	1870 159	1606 168	1652 87	1	666666	02 06 00
14993	SD	NRAO140	-01 28	000000	4165 -44	4231 -130	3592 -139	3876 -7	3504 -85	3228 55	1	656665	02 06 30
14993	XD	NRAO140	-01 27	000000	1933 147	1782 97	1465 159	1923 -173	1651 169	1775 95	1	665666	02 07 00
14993	SD	NRAO140	-01 27	000000	4045 -38	4229 -126	3627 -135	3713 -2	3502 -85	3306 54	1	656665	02 07 30
14993	XD	NRAO140	-01 26	000000	1887 152	1851 102	1477 165	1907 -163	1708 170	1730 89	1	665666	02 08 00
14993	SD	NRAO140	-01 26	000000	4152 -35	4227 -123	3509 -131	3901 1	3417 -86	3353 55	1	656665	02 08 30
14993	XD	NRAO140	-01 25	000000	1969 165	1879 115	1512 177	1994 -154	1571 167	1700 91	1	665666	02 09 00
14993	SD	NRAO140	-01 25	000000	4024 -39	4252 -127	3382 -133	3730 -1	3405 -85	3286 56	1	655665	02 09 30
14994	SD	P0735+17	-05 22	0000	2434 10	2471 -75	2175 -81	2364 52	0	0	1	656665	02 13 45
14994	SD	P0735+17	-05 22	000000	2572 16	2501 -72	2352 -80	2350 52	2071 -88	1980 55	1	656665	02 14 15
14994	XD	P0735+17	-05 21	000000	1344 -23	1258 -72	1017 -7	1251 22	1082 164	1236 84	1	666666	02 14 45
14994	SD	P0735+17	-05 21	0000	2428 16	2527 -73	2308 -76	2424 56	0	0	1	666665	02 15 15
14994	SD	P0735+17	-05 20	000000	2588 11	2619 -77	2211 -82	2484 52	2111 -88	2082 54	1	666665	02 15 45
14994	XD	P0735+17	-05 20	000000	1412 -55	1215 -102	1060 -38	1245 -6	1032 158	1208 83	1	666666	02 16 15
14994	SD	P0735+17	-05 19	0000	2684 12	2549 -76	2281 -82	2389 51	0	0	1	666665	02 16 45
14994	SD	P0735+17	-05 19	000000	2479 18	2505 -70	2206 -74	2414 59	2130 -89	2038 52	1	666665	02 17 15

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SCAN	M	SOURCE	HA	RMS/100	AMP1R2RPHI		AMP1L2LPHI		AMP1R3RPHI		AMP1L3LPHI		AMP2R3RPHI		AMP2L3LPHI		NREC	TPOWER	LST
14994	SD	P0735+17	-05 18	0000	2701	2	2630	-85	2180	-91	2295	41		0		0	1	666665	02 18 15
14994	SD	P0735+17	-05 17	000000	2807	-4	2640	-90	2390	-95	2460	38	2063	-87	2080	50	1	666665	02 18 45
14994	XD	P0735+17	-05 17	000000	1514	-55	1241	-105	1243	-39	1384	-8	1135	162	1254	85	1	666666	02 19 15
14994	SD	P0735+17	-05 16	0000	2773	19	2622	-69	2534	-76	2384	54		0		0	1	656665	02 19 45
14995	SD	3C120	-02 08	000000	8139	-27	9773	-116	8802	-119	9267	14	7997	-86	8248	53	1	655665	02 22 58
14995	XD	3C120	-02 08	111100	10226	178	10404	129	9778	-155	12066	-127	10988	153	11515	75	1	665666	02 23 28
14995	SD	3C120	-02 07	000000	8955	-28	9929	-116	8478	-118	9032	14	8698	-87	8299	51	1	655665	02 23 58
14995	XD	3C120	-02 07	111100	11122	168	10614	119	9636	-166	12025	-139	10499	156	11445	76	1	665666	02 24 28
14995	SD	3C120	-02 06	000000	9649	-32	10023	-119	8768	-122	9148	10	8684	-88	8227	51	1	655665	02 24 58
14995	XD	3C120	-02 06	111100	11623	-179	10771	132	9877	-157	12143	-129	10692	159	11528	81	1	665666	02 25 28
14995	SD	3C120	-02 05	000000	9543	-26	9861	-114	8573	-119	9087	14	8690	-87	8383	51	1	655665	02 25 58
14995	XD	3C120	-02 05	111100	11123	173	10781	123	9571	-163	12254	-135	10778	157	11864	78	1	665666	02 26 28
14995	SD	3C120	-02 04	000000	9576	-33	9854	-120	8308	-125	9090	8	8678	-87	8247	51	1	655665	02 26 58
14995	XD	3C120	-02 04	000100	10810	179	10734	130	9716	-156	12230	-128	10850	156	11570	78	1	666666	02 27 28
14995	XD	3C120	-02 03	111101	10712	179	10401	129	9368	-155	11930	-127	10462	155	11447	76	1	665666	02 28 28
14995	SD	3C120	-02 02	000000	8504	-42	9831	-130	8657	-132	8980	-0	8680	-89	8528	50	1	655665	02 28 58
14995	XD	3C120	-02 02	110100	11293	152	10601	104	9614	178	11949	-154	10695	155	11411	76	1	665666	02 29 28
14996	SD	3C446	04 10	0000	6781	22	6991	-65	6246	-75	6592	60		0		0	1	666666	02 35 23
14996	SD	3C446	04 11	0000	6623	22	6968	-66	6487	-74	6868	59		0		0	1	666666	02 35 53
14996	SD	3C446	04 12	000000	6493	-5	7096	-92	6436	-102	6865	31	5765	-83	5627	56	1	666666	02 36 53
14996	XD	3C446	04 12	0000	3156	-114	3013	-162	2917	-103	3296	-75		0		0	1	666676	02 37 23
14996	XD	3C446	04 13	000000	2999	-110	2969	-159	2949	-104	3233	-75	2682	173	2669	95	1	666666	02 37 53
14996	SD	3C446	04 13	0000	6460	8	7052	-80	6223	-92	6772	42		0		0	1	666666	02 38 23
14996	SD	3C446	04 14	0000	6567	9	7070	-78	6230	-90	6887	45		0		0	1	666666	02 38 53
14996	SD	3C446	04 14	0000	6598	10	7133	-75	6192	-86	6876	47		0		0	1	666666	02 39 23
14996	SD	3C446	04 15	0000	6570	1	7012	-85	6339	-96	6943	38		0		0	1	666666	02 39 53
14997	SD	3C454.3	03 49	1111	14787	-10	15179	-98	13768	-108	14580	24		0		0	1	655665	02 41 55
14997	SD	3C454.3	03 49	1000	15603	-13	15807	-100	13915	-110	14850	23		0		0	1	655665	02 42 25
14997	SD	3C454.3	03 50	000001	15480	-21	15786	-109	13990	-117	14699	15	13043	-85	12479	54	1	655665	02 42 55
14997	XD	3C454.3	03 50	111100	11730	-165	11061	146	10199	-155	12122	-126	10001	168	10314	88	1	666666	02 43 25
14997	SD	3C454.3	03 51	1101	14973	-27	15708	-115	13737	-125	14746	8		0		0	1	655665	02 43 55
14997	SD	3C454.3	03 51	0001	14746	-22	15676	-109	13766	-120	14718	13		0		0	1	655665	02 44 25
14997	SD	3C454.3	03 52	000100	15747	-17	15873	-105	14025	-116	14681	17	13235	-83	12586	57	1	655665	02 44 55
14997	XD	3C454.3	03 52	000000	12135	-139	11372	172	10588	-134	12405	-104	10060	173	10778	92	1	666666	02 45 25
14997	SD	3C454.3	03 53	1100	15307	-19	15771	-107	14209	-116	14855	17		0		0	1	655665	02 45 55
14997	SD	3C454.3	03 53	0011	15220	-18	15772	-105	14170	-115	14819	18		0		0	1	655665	02 46 25
14997	SD	3C454.3	03 54	100100	15055	-15	15630	-103	14151	-113	14812	20	13292	-84	12694	56	1	655665	02 46 55
14997	XD	3C454.3	03 54	110100	11289	-150	10740	161	10456	-145	12102	-116	10478	173	10757	95	1	666666	02 47 25
14997	SD	3C454.3	03 55	1100	14937	-27	15629	-114	14225	-124	14730	9		0		0	1	655665	02 47 55
14997	SD	3C454.3	03 55	1001	15082	-32	15635	-119	13753	-128	14323	5		0		0	1	655665	02 48 25
14997	SD	3C454.3	03 56	100100	16354	-31	15738	-118	13971	-128	14591	5	12997	-84	12515	55	1	656665	02 48 55
14998	SD	3C48	01 17	110100	12174	-37	12998	-125	11236	-135	12385	-2	10882	-83	10659	56	1	666665	02 53 21
14998	XD	3C48	01 17	000000	2849	135	2688	86	2440	144	3128	171	2667	172	2825	93	1	665666	02 53 51
14998	SD	3C48	01 18	000000	12532	-37	13524	-124	11607	-133	12570	-0	11069	-85	10815	55	1	666665	02 54 21
14998	XD	3C48	01 18	000000	3039	146	2714	96	2523	159	3213	-173	2607	170	2820	91	1	665666	02 54 51
14998	SD	3C48	01 19	100000	12233	-45	13382	-133	10942	-141	12535	-8	10958	-85	10722	55	1	656665	02 55 21
14998	XD	3C48	01 19	000000	2756	123	2720	73	2510	135	3152	164	2739	169	2790	89	1	665666	02 55 51
14998	SD	3C48	01 20	100000	12698	-56	13302	-143	11238	-151	12558	-18	10893	-85	10799	55	1	656665	02 56 21
14998	XD	3C48	01 20	000000	3019	141	2770	91	2529	149	3182	178	2591	171	2876	94	1	665666	02 56 51
14998	SD	3C48	01 21	000000	12325	-44	13259	-132	11083	-141	12521	-8	10890	-83	10601	56	1	656665	02 57 21
14998	XD	3C48	01 21	000000	2935	163	2817	113	2561	175	3187	-159	2709	170	2750	91	1	665666	02 57 51
14998	SD	3C48	01 22	100000	12862	-46	13305	-133	11478	-141	12531	-8	11153	-83	10643	55	1	656665	02 58 21
14998	XD	3C48	01 22	000000	2845	157	2712	106	2644	167	3295	-164	2697	170	2781	92	1	665666	02 58 51
14998	SD	3C48	01 23	000000	12660	-53	13351	-141	11545	-149	12571	-16	10970	-85	10643	55	1	656665	02 59 21
14998	XD	3C48	01 23	000000	2915	154	2760	103	2568	163	3140	-170	2622	171	2833	93	1	665666	02 59 51
14999	SD	D0224+67	00 35	0000	1584	-25	1693	-113	1492	-124	1480	12		0		0	1	655665	03 02 25
14999	SD	D0224+67	00 36	000000	1547	-28	1675	-113	1528	-122	1483	8	1517	-84	1392	56	1	655665	03 02 55
14999	XD	D0224+67	00 36	000000	1672	-177	1612	134	1512	-170	1785	-139	1416	174	1498	96	1	665666	03 03 25
14999	SD	D0224+67	00 37	0000	1473	-32	1703	-117	1478	-125	1532	3		0		0	1	655665	03 03 55
14999	SD	D0224+67	00 37	000000	1597	-29	1735	-115	1413	-130	1427	9	1529	-84	1370	56	1	655665	03 04 25

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SCAN	M	SOURCE	HA	RMS/100	AMP1R2RPHI		AMP1L2LPHI		AMP1R3RPHI		AMP1L3LPHI		AMP2R3RPHI		AMP2L3LPHI		NREC	TPOWER	LST
14999	XD	D0224+67	00 38	000000	1863	-168	1714	147	1548	-158	1939	-129	1318	173	1495	95	1	665666	03 04 55
14999	SD	D0224+67	00 38	0000	1869	-27	1724	-114	1426	-126	1578	6		0		0	1	655665	03 05 25
14999	SD	D0224+67	00 39	000000	1756	-23	1774	-109	1411	-124	1465	11	1436	-84	1322	53	1	655665	03 05 55
14999	XD	D0224+67	00 39	000000	1836	-167	1642	143	1369	-162	1779	-131	1254	171	1415	95	1	665666	03 06 25
14999	SD	D0224+67	00 40	0000	1595	-32	1642	-119	1543	-132	1562	3		0		0	1	655665	03 06 55
14999	SD	D0224+67	00 40	000000	1693	-30	1703	-116	1429	-129	1486	5	1463	-86	1320	56	1	655665	03 07 25
14999	XD	D0224+67	00 41	000000	1802	-162	1703	153	1494	-158	1806	-129	1292	176	1466	95	1	665666	03 07 55
14999	SD	D0224+67	00 41	0000	1772	-24	1739	-109	1411	-120	1478	16		0		0	1	655665	03 08 25
14999	XD	D0224+67	00 42	000000	1760	-179	1542	137	1500	-168	1892	-139	1316	174	1512	93	1	665666	03 09 25
15000	SD	3C147	-02 27	111111	20068	-44	19168	-132	16540	-141	17547	-8	15674	-83	15022	57	1	656665	03 13 03
15000	XD	3C147	-02 26	000000	4889	152	4462	103	4224	161	5277	-172	3871	171	4286	93	1	665666	03 13 33
15000	SD	3C147	-02 26	111111	20312	-32	19116	-119	17160	-128	18198	4	15628	-84	15254	56	1	656665	03 14 03
15000	XD	3C147	-02 25	000000	4776	171	4332	122	4077	-177	5097	-149	3910	168	4490	91	1	665666	03 14 33
15000	SD	3C147	-02 25	111101	20488	-30	19153	-118	17002	-126	18158	6	15779	-84	15384	57	1	656665	03 15 03
15000	XD	3C147	-02 24	000000	4890	170	4387	123	4170	-179	5134	-151	3753	171	4259	94	1	665666	03 15 33
15000	SD	3C147	-02 24	111111	20309	-34	19265	-122	16846	-130	17961	2	15571	-83	15060	56	1	656665	03 16 03
15000	XD	3C147	-02 23	000000	4890	-179	4330	133	4021	-171	5138	-143	3705	171	4422	94	1	665666	03 16 33
15000	SD	3C147	-02 23	111111	20468	-34	19189	-121	16568	-129	17716	3	15585	-84	15277	55	1	656665	03 17 03
15000	XD	3C147	-02 22	000000	4852	173	4328	125	4456	-177	5199	-149	4052	173	4367	93	1	665666	03 17 33
15000	SD	3C147	-02 22	111111	20305	-31	19091	-118	16988	-126	17829	6	15699	-85	15291	55	1	656665	03 18 03
15000	XD	3C147	-02 21	000000	4773	166	4217	117	4410	179	5169	-153	3877	168	4250	90	1	665666	03 18 33
15000	SD	3C147	-02 21	111111	20085	-36	19058	-123	17436	-133	18151	-1	15771	-83	15418	56	1	656665	03 19 03
15000	XD	3C147	-02 20	000000	4742	167	4233	119	4311	176	5183	-157	3926	171	4367	93	1	665666	03 19 33
15001	SD	D0742+10	-04 21	000000	5994	9	5585	-79	4979	-85	5177	48	4528	-87	4608	53	1	655665	03 22 42
15001	XD	D0742+10	-04 20	000000	2564	-82	2229	-130	2185	-60	2481	-30	2200	155	2545	79	1	665666	03 23 12
15001	SD	D0742+10	-04 20	000000	5951	4	5616	-84	5281	-88	5431	44	4572	-88	4613	51	1	655665	03 23 42
15001	XD	D0742+10	-04 19	000000	2714	-93	2202	-143	2126	-68	2610	-40	2176	158	2457	79	1	665666	03 24 12
15001	SD	D0742+10	-04 19	000000	5705	-3	5472	-92	5118	-96	5302	36	4683	-88	4514	52	1	655665	03 24 42
15001	XD	D0742+10	-04 18	000000	2761	-83	2236	-130	2406	-65	2770	-37	2238	166	2334	86	1	665666	03 25 12
15001	XD	D0742+10	-04 17	000000	2705	-55	2336	-103	2332	-36	2663	-6	2110	163	2382	84	1	665666	03 26 12
15001	SD	D0742+10	-04 17	000000	6324	8	5632	-80	5506	-84	5569	49	4700	-89	4588	50	1	655665	03 26 42
15001	XD	D0742+10	-04 16	000000	2586	-79	2152	-126	2352	-56	2575	-26	2224	156	2406	78	1	665666	03 27 12
15001	SD	D0742+10	-04 16	000000	6250	5	5558	-82	5340	-89	5381	44	4637	-87	4648	52	1	655665	03 27 42
15001	XD	D0742+10	-04 15	000000	2618	-69	2299	-115	2354	-45	2638	-20	2263	159	2360	81	1	665666	03 28 12
15001	SD	D0742+10	-04 15	000000	6283	9	5646	-78	5416	-82	5396	50	4641	-89	4650	51	1	655665	03 28 42
15001	XD	D0742+10	-04 14	000000	2624	-79	2262	-127	2380	-55	2620	-26	2157	158	2403	80	1	665666	03 29 12
15001	SD	D0742+10	-04 14	211100	4847	30	4384	-56	3763	-56	3723	76	4697	-96	4808	46	1	655665	03 29 43
15002	SD	P0607-15	-02 36	000000	1933	7	2148	-83	1760	-81	1810	50	1770	-92	1560	50	1	655665	03 32 00
15002	XD	P0607-15	-02 35	000000	2007	-95	1975	-145	1735	-62	2052	-34	1886	150	2016	67	1	665666	03 32 30
15002	SD	P0607-15	-02 35	000000	2183	10	2163	-79	1878	-78	1886	57	1831	-93	1641	46	1	655665	03 33 00
15002	XD	P0607-15	-02 34	000000	2151	-92	2071	-140	1725	-57	2116	-29	1871	149	2008	71	1	665666	03 33 30
15002	SD	P0607-15	-02 34	000000	2125	-4	2180	-91	1950	-91	1889	43	1811	-93	1633	45	1	655665	03 34 00
15002	XD	P0607-15	-02 33	000000	2030	-128	2013	-177	1733	-94	1996	-66	1848	149	1967	70	1	665666	03 34 30
15002	SD	P0607-15	-02 33	000000	2211	2	2202	-84	1822	-93	1880	45	1700	-91	1631	49	1	655665	03 35 00
15002	XD	P0607-15	-02 32	000000	2053	-42	2030	-90	1809	-15	2163	14	1830	156	1994	78	1	665666	03 35 30
15002	SD	P0607-15	-02 32	000000	1995	18	2110	-70	1877	-69	1972	64	1882	-93	1641	46	1	655665	03 36 00
15002	XD	P0607-15	-02 31	000000	1921	-74	1884	-126	1535	-39	1888	-12	1908	145	1987	66	1	666666	03 36 30
15002	SD	P0607-15	-02 31	000000	2046	-7	2213	-93	1880	-91	1851	40	1811	-93	1662	46	1	655665	03 37 00
15002	XD	P0607-15	-02 30	000000	1961	-102	1925	-151	1514	-71	1982	-42	1878	152	2028	74	1	665666	03 37 30
15002	SD	P0607-15	-02 30	000000	2086	-24	2182	-109	1907	-107	2033	22	1778	-95	1669	47	1	655665	03 38 00
15002	XD	P0607-15	-02 29	000000	2094	-123	2029	-172	1730	-91	2116	-61	1865	149	2023	72	1	666666	03 38 30
15002	SD	P0607-15	-02 29	000000	2120	-28	2147	-115	1839	-114	1878	19	1796	-95	1595	49	1	655665	03 39 00
15002	XD	P0607-15	-02 28	000000	2010	-89	1902	-134	1700	-62	1994	-32	1920	158	1981	77	1	666666	03 39 30
15003	SD	P0056-17	02 46	0000	1050	-8	1010	-89	990	-106	1020	33		0		0	1	655665	03 44 37
15003	SD	P0056-17	02 47	000000	914	-10	1078	-101	1025	-100	832	33	931	-86	878	53	1	653665	03 45 07
15003	XD	P0056-17	02 47	000000	151	-98	156	-140	143	-102	148	-48	200	-174	136	73	1	666666	03 45 37
15003	SD	P0056-17	02 48	0000	368	33	436	-74	292	-82	308	54		0		0	1	655665	03 46 08
15003	SD	P0056-17	02 48	000000	1104	12	1024	-80	920	-90	822	41	970	-89	844	54	1	656665	03 46 38
15003	XD	P0056-17	02 49	000000	190	-93	201	-117	156	-63	134	-27	152	-169	186	74	1	666666	03 47 08
15003	SD	P0056-17	02 49	0000	935	6	991	-87	942	-94	898	45		0		0	1	656665	03 47 38

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SCAN	M	SOURCE	HA	RMS/100	AMP1R2RPHI		AMP1L2LPHI		AMP1R3RPHI		AMP1L3LPHI		AMP2R3RPHI		AMP2L3LPHI		NREC	TPOWER	LST
15003	SD	P0056-17	02 50	000000	942	4	1051	-87	870	-93	950	41	950	-90	890	52	1	656665	03 48 08
15003	XD	P0056-17	02 50	000000	82	-104	134	-117	106	-49	191	-47	160	176	104	73	1	666666	03 48 38
15003	SD	P0056-17	02 51	0000	911	3	984	-77	930	-91	877	42		0		0	1	656665	03 49 08
15003	SD	P0056-17	02 51	000000	910	-1	980	-88	987	-97	890	38	970	-90	813	44	1	656665	03 49 38
15004	SD	3C454.3	04 59	1000	14840	-10	15038	-97	13761	-110	14325	25		0		0	1	666666	03 52 28
15004	SD	3C454.3	05 00	1000	15732	-10	14827	-98	13246	-108	14048	25		0		0	1	666666	03 52 58
15004	SD	3C454.3	05 00	0000	14829	-11	14822	-98	13653	-110	14307	24		0		0	1	666666	03 53 28
15004	SD	3C454.3	05 01	0000	15602	-7	15180	-94	13671	-106	14252	27		0		0	1	666666	03 53 58
15004	SD	3C454.3	05 01	1111	15430	-14	14864	-101	13757	-110	14162	24		0		0	1	666666	03 54 28
15004	SD	3C454.3	05 02	1100	15095	-23	14763	-110	13293	-122	14156	12		0		0	1	666666	03 54 58
15004	SD	3C454.3	05 02	0001	15814	-5	14814	-93	13425	-108	14190	26		0		0	1	666666	03 55 28
15004	SD	3C454.3	05 03	0000	15657	4	15036	-83	13819	-96	14346	38		0		0	1	666666	03 55 58
15004	SD	3C454.3	05 03	100000	14944	-1	14901	-89	13526	-99	14181	34	12872	-83	11784	58	1	666666	03 56 28
15004	XD	3C454.3	05 04	1000	10913	-116	9789	-164	9488	-110	10829	-81		0		0	1	666666	03 56 58
15004	XD	3C454.3	05 04	2212	9959	-94	9005	-142	8521	-93	9878	-63		0		0	1	666666	03 57 28
15004	XD	3C454.3	05 05	322200	9220	-111	8274	-160	8100	-99	9496	-69	9177	167	9778	99	1	666666	03 57 58
15004	SD	3C454.3	05 05	1101	15635	-20	14699	-108	13550	-120	13940	14		0		0	1	666666	03 58 28
15004	SD	3C454.3	05 06	1011	15502	-11	14735	-100	13456	-110	13785	23		0		0	1	666666	03 58 58
15004	SD	3C454.3	05 06	1000	15452	-6	14868	-93	13357	-105	13751	29		0		0	1	666666	03 59 28
15005	SD	NRA091	01 59	000000	5800	-40	5726	-127	4935	-135	5366	-3	4727	-85	4388	56	1	655665	04 02 57
15005	XD	NRA091	02 00	000000	2522	148	2237	99	2122	162	2586	-170	2253	165	2410	89	1	666666	04 03 27
15005	SD	NRA091	02 00	000000	5763	-45	5821	-131	5032	-141	5441	-8	4699	-85	4470	54	1	655665	04 03 57
15005	XD	NRA091	02 01	000000	2553	164	2353	118	2248	175	2680	-157	2211	172	2376	94	1	666666	04 04 27
15005	SD	NRA091	02 01	000000	5428	-32	5704	-119	4884	-127	5415	6	4628	-84	4520	54	1	655665	04 04 57
15005	XD	NRA091	02 02	000000	2484	158	2371	108	2028	172	2631	-160	2320	168	2320	90	1	666666	04 05 27
15005	SD	NRA091	02 02	000000	5567	-32	5893	-119	4788	-126	5448	6	4798	-85	4652	54	1	655665	04 05 57
15005	XD	NRA091	02 03	000000	2374	177	2278	128	2003	-173	2743	-147	2297	173	2384	96	1	666666	04 06 27
15005	SD	NRA091	02 03	000000	5587	-29	5873	-118	4834	-126	5460	6	4793	-84	4696	55	1	655665	04 06 57
15005	XD	NRA091	02 04	000000	2332	174	2242	126	1984	-171	2582	-143	2318	168	2401	88	1	666666	04 07 27
15005	SD	NRA091	02 04	000000	5538	-38	5904	-124	4872	-134	5470	-1	4649	-85	4618	55	1	655665	04 07 57
15005	XD	NRA091	02 05	000000	2418	157	2366	106	2024	168	2636	-164	2120	170	2282	93	1	666666	04 08 27
15005	SD	NRA091	02 05	000000	5375	-36	5930	-123	4861	-130	5467	3	4813	-84	4607	55	1	655665	04 08 57
15005	XD	NRA091	02 06	000000	2482	164	2303	115	2032	177	2563	-155	2183	170	2371	92	1	666666	04 09 27
15006	SD	3C119	-00 17	000000	7808	-37	7885	-123	6802	-132	7370	0	6470	-84	6280	55	1	666665	04 12 56
15006	XD	3C119	-00 17	000000	2100	157	1894	107	1747	170	2169	-163	1579	171	1841	92	1	666666	04 13 26
15006	SD	3C119	-00 16	000000	7716	-36	7804	-123	6545	-133	7560	-1	6300	-83	6301	57	1	666665	04 13 56
15006	XD	3C119	-00 16	000000	2163	171	1838	118	1697	175	2085	-158	1454	176	1645	95	1	666666	04 14 26
15006	SD	3C119	-00 15	000000	7617	-39	7788	-126	6569	-135	7417	-3	6360	-84	6257	54	1	666665	04 14 56
15006	XD	3C119	-00 15	000000	2081	156	1809	105	1606	161	2098	-166	1402	170	1673	94	1	666666	04 15 26
15006	SD	3C119	-00 14	000000	8066	-43	7822	-131	6519	-140	7321	-7	6235	-84	6160	56	1	666665	04 15 56
15006	XD	3C119	-00 14	000000	2013	149	1825	101	1625	156	2086	-176	1506	175	1657	96	1	666666	04 16 26
15006	SD	3C119	-00 13	000000	8346	-34	7752	-121	6378	-130	7211	1	5957	-84	5982	56	1	666665	04 16 56
15006	XD	3C119	-00 13	000000	2092	170	1844	119	1630	-179	2165	-152	1435	172	1671	92	1	666666	04 17 26
15006	SD	3C119	-00 12	000000	8287	-29	7822	-116	6579	-126	7307	8	6203	-84	6119	55	1	666665	04 17 56
15006	XD	3C119	-00 12	000000	2030	160	1786	109	1627	174	2063	-158	1466	169	1650	88	1	666666	04 18 26
15006	SD	3C119	-00 11	000000	8147	-30	7772	-117	6474	-127	7219	6	6112	-83	6068	57	1	666665	04 18 56
15006	XD	3C119	-00 11	000000	2032	177	1892	129	1751	-177	2076	-149	1552	177	1652	99	1	666666	04 19 26
15007	SD	P0106+01	03 16	0000	3445	-17	3772	-105	3383	-113	3515	21		0		0	1	655665	04 23 20
15007	SD	P0106+01	03 16	000000	3434	-19	3714	-105	3390	-116	3523	17	3145	-84	3145	55	1	655665	04 23 50
15007	XD	P0106+01	03 17	000000	3655	-139	3248	172	3185	-130	3684	-104	3126	172	3401	92	1	666666	04 24 20
15007	SD	P0106+01	03 17	0000	3995	-25	3905	-112	3514	-123	3626	11		0		0	1	655665	04 24 50
15007	SD	P0106+01	03 18	000000	4009	-29	3881	-116	3490	-126	3644	8	3271	-85	3131	55	1	655665	04 25 20
15007	XD	P0106+01	03 18	000000	3617	-159	3176	152	3064	-150	3606	-123	3089	171	3333	93	1	666666	04 25 50
15007	SD	P0106+01	03 19	0000	3886	-19	3763	-106	3409	-115	3500	18		0		0	1	655665	04 26 20
15007	SD	P0106+01	03 19	000000	3878	-15	3769	-102	3466	-109	3578	24	3154	-85	3110	53	1	655665	04 26 50
15007	XD	P0106+01	03 20	000000	3549	-135	3206	176	3100	-124	3585	-95	3043	167	3300	89	1	666666	04 27 20
15007	SD	P0106+01	03 20	0000	3980	-24	3766	-111	3406	-120	3600	13		0		0	1	655665	04 27 50
15007	SD	P0106+01	03 21	000000	3850	-27	3721	-112	3394	-123	3603	10	3170	-85	3091	55	1	655665	04 28 20
15007	XD	P0106+01	03 21	000000	3572	-172	3164	138	2998	-163	3579	-133	3091	168	3250	91	1	666666	04 28 50
15007	SD	P0106+01	03 22	0000	3844	-36	3727	-123	3428	-131	3550	1		0		0	1	655665	04 29 20

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SCAN	M	SOURCE	HA	RMS/100	AMP1R2RPHI		AMP1L2LPHI		AMP1R3RPHI		AMP1L3LPHI		AMP2R3RPHI		AMP2L3LPHI		NREC	TPOWER	LST
15007	SD	P0106+01	03 22	000000	3864	-30	3837	-117	3380	-127	3521	6	3149	-86	3096	54	1	655665	04 29 50
15008	SD	P0438-43	-00 06	000000	6783	32	6717	-56	6054	-57	6296	76	5855	-94	5587	46	1	666776	04 33 15
15008	XD	P0438-43	-00 05	100000	716	54	700	0	858	75	1057	103	1692	169	1671	87	1	776777	04 33 45
15008	SD	P0438-43	-00 05	000000	7357	95	6750	8	6324	2	6597	136	5921	-89	5236	51	1	666776	04 34 15
15008	XD	P0438-43	-00 04	000000	1624	140	1420	91	1330	180	1490	-152	1476	142	1531	60	1	777777	04 34 45
15008	SD	P0438-43	-00 04	000000	7271	55	6845	-33	6293	-36	6360	97	5760	-91	5408	49	1	666776	04 35 15
15008	XD	P0438-43	-00 03	000000	1672	152	1545	102	1333	176	1415	-157	1328	162	1395	81	1	787787	04 35 45
15008	SD	P0438-43	-00 03	100000	7120	100	6640	12	6013	10	6324	142	5740	-90	5323	50	1	666776	04 36 15
15008	XD	P0438-43	-00 02	000000	1686	-26	1461	-78	1338	-14	1509	16	1392	168	1550	89	1	787887	04 36 45
15008	SD	P0438-43	-00 02	111100	6882	110	6590	22	5905	21	6243	154	5692	-92	5433	47	1	666776	04 37 15
15008	XD	P0438-43	-00 01	000000	1796	-161	1592	152	1619	-134	1866	-106	1512	160	1484	78	1	787787	04 37 45
15008	SD	P0438-43	-00 01	000000	7112	92	6765	4	6242	2	6541	134	5740	-90	5470	49	1	666776	04 38 15
15008	XD	P0438-43	-00 00	000000	1606	102	1432	52	1328	145	1571	167	1423	145	1428	66	1	787787	04 38 45
15008	SD	P0438-43	-00 00	000000	6982	55	6853	-33	6188	-33	6426	101	5812	-92	5333	47	1	666776	04 39 15
15008	XD	P0438-43	00 00	000000	1655	57	1503	4	1455	95	1547	124	1392	145	1445	65	1	887887	04 39 45
15009	SD	P0614-34	-01 33	000000	2816	15	2532	-75	2223	-79	2274	54	2118	-85	1962	53	1	666666	04 41 55
15009	XD	P0614-34	-01 33	000000	622	-37	519	-79	382	6	488	31	432	146	516	68	1	776777	04 42 25
15009	SD	P0614-34	-01 32	000000	2724	25	2491	-63	2273	-66	2337	68	2190	-90	2028	49	1	666666	04 42 55
15009	XD	P0614-34	-01 32	000000	490	2	392	-52	432	40	425	81	506	150	525	69	1	776777	04 43 25
15009	SD	P0614-34	-01 31	000000	2755	10	2620	-78	2156	-75	2304	57	2044	-94	2093	45	1	666666	04 43 55
15009	XD	P0614-34	-01 31	000000	674	-35	508	-80	480	2	593	33	444	144	490	57	1	776777	04 44 25
15009	SD	P0614-34	-01 30	000000	2751	17	2644	-70	2295	-74	2342	59	2200	-91	2088	52	1	666666	04 44 55
15009	XD	P0614-34	-01 30	000000	596	31	537	-24	382	49	592	85	513	147	452	72	1	776777	04 45 25
15009	SD	P0614-34	-01 29	000000	2738	37	2361	-49	2320	-46	2328	83	2273	-96	2023	43	1	666666	04 45 55
15009	XD	P0614-34	-01 29	000000	610	2	563	-25	481	43	620	75	504	146	481	69	1	776777	04 46 25
15009	SD	P0614-34	-01 28	000000	2655	21	2592	-66	2120	-62	2324	71	2239	-95	2101	43	1	666666	04 46 55
15009	XD	P0614-34	-01 28	000000	533	-6	553	-49	483	18	472	54	501	157	518	71	1	776777	04 47 25
15009	SD	P0614-34	-01 27	000000	2700	51	2522	-37	2267	-41	2320	91	2155	-86	2011	51	1	666666	04 47 55
15009	XD	P0614-34	-01 27	000000	632	129	490	78	536	153	661	-176	585	160	480	73	1	776776	04 48 25
15009	SD	P0614-34	-01 26	000000	2708	58	2471	-32	2161	-32	2342	104	2220	-89	2000	49	1	666666	04 48 55
15009	XD	P0614-34	-01 26	000000	647	9	473	-46	406	38	550	71	544	144	560	79	1	776777	04 49 25
15010	SD	3C138	-00 26	000000	8678	-39	8399	-126	7229	-130	7864	2	6723	-86	6748	55	1	666665	04 53 26
15010	XD	3C138	-00 25	000000	2319	145	1983	97	1971	163	2404	-169	1960	162	2067	85	1	666666	04 53 56
15010	SD	3C138	-00 25	000000	8306	-33	8274	-121	7324	-127	7904	5	6746	-84	6587	56	1	666665	04 54 26
15010	XD	3C138	-00 24	000000	2161	169	1991	121	1900	-178	2276	-154	1792	171	2070	89	1	676776	04 54 56
15010	SD	3C138	-00 24	000000	8426	-34	8387	-122	7094	-129	7562	3	6838	-85	6664	55	1	666665	04 55 26
15010	XD	3C138	-00 23	000000	1963	141	1832	93	1752	163	2077	-168	1764	161	1843	83	1	776777	04 55 56
15010	SD	3C138	-00 23	000000	8222	-39	8185	-126	7038	-133	7360	-1	6753	-83	6476	56	1	666666	04 56 26
15010	XD	3C138	-00 22	000000	2102	152	1775	104	1701	171	2134	-162	1926	165	1998	85	1	776776	04 56 56
15010	SD	3C138	-00 22	000000	8261	-39	8253	-126	7258	-133	7680	-0	6802	-84	6540	57	1	666665	04 57 26
15010	XD	3C138	-00 21	000000	2111	164	1891	116	1771	178	2147	-155	1816	169	2003	93	1	776776	04 57 56
15010	SD	3C138	-00 21	000000	8403	-39	8282	-126	6931	-132	7480	-1	6677	-85	6576	55	1	666665	04 58 26
15010	XD	3C138	-00 20	000000	2139	145	1936	97	1752	160	2112	-172	1867	167	1942	87	1	776777	04 58 56
15010	SD	3C138	-00 20	000000	8304	-37	8329	-124	6856	-132	7470	1	6858	-84	6598	56	1	666665	04 59 26
15011	SD	3C48	03 27	1011	13385	-30	13465	-117	11453	-129	12438	4		0		0	1	655665	05 03 32
15011	SD	3C48	03 27	100000	12938	-27	13335	-115	12032	-127	12683	5	10715	-82	10377	57	1	665665	05 04 02
15011	XD	3C48	03 28	000000	2761	178	2472	129	2254	-176	2747	-148	2246	173	2335	94	1	776676	05 04 32
15011	SD	3C48	03 28	1000	12953	-39	13281	-126	11664	-136	12478	-4		0		0	1	655665	05 05 02
15011	SD	3C48	03 29	000000	13247	-42	13412	-129	12102	-140	12572	-7	10833	-83	10597	56	1	655665	05 05 32
15011	XD	3C48	03 29	000000	3042	164	2701	116	2492	169	2966	-163	2584	177	2754	98	1	676666	05 06 02
15011	SD	3C48	03 30	0000	12790	-41	13266	-128	12283	-139	12715	-6		0		0	1	655665	05 06 32
15011	SD	3C48	03 30	000000	14456	-44	13559	-131	11963	-142	12612	-9	11077	-83	10451	57	1	655665	05 07 02
15011	XD	3C48	03 31	000000	3174	164	2752	114	2721	167	3156	-162	2347	175	2611	95	1	666666	05 07 32
15011	SD	3C48	03 31	0000	14772	-34	13607	-121	11998	-133	12560	0		0		0	1	655665	05 08 02
15011	SD	3C48	03 32	1000	14556	-30	13744	-117	12355	-129	12629	4		0		0	1	655665	05 08 32
15011	SD	3C48	03 32	100000	14590	-26	13698	-113	12016	-125	12544	9	10807	-83	10403	57	1	655665	05 09 02
15011	XD	3C48	03 33	000000	2983	-157	2701	155	2647	-154	3040	-125	2523	177	2765	99	1	666666	05 09 32
15012	SD	D0224+67	02 45	0000	1566	-20	1550	-111	1467	-115	1581	15		0		0	1	555665	05 12 28
15012	SD	D0224+67	02 46	0000	1543	-20	1672	-108	1427	-119	1512	12		0		0	1	555665	05 12 58
15012	SD	D0224+67	02 46	0000	1635	-17	1555	-108	1450	-119	1535	12		0		0	1	555665	05 13 28

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SCAN	M	SOURCE	HA	RMS/100	AMP1R2RPHI		AMP1L2LPHI		AMP1R3RPHI		AMP1L3LPHI		AMP2R3RPHI		AMP2L3LPHI		NREC	TPOWER	LST
15012	SD	D0224+67	02 47	000000	1499	-17	1695	-107	1462	-116	1550	16	1486	-85	1450	55	1	655665	05 13 58
15012	XD	D0224+67	02 47	000000	1484	-147	1436	164	1406	-146	1871	-114	1336	174	1358	96	1	666666	05 14 28
15012	SD	D0224+67	02 48	0000	1499	-17	1566	-104	1471	-116	1548	16		0		0	1	655665	05 14 58
15012	SD	D0224+67	02 48	0000	1478	-16	1634	-105	1378	-114	1508	19		0		0	1	655665	05 15 28
15012	SD	D0224+67	02 49	0000	1480	-22	1571	-109	1474	-121	1602	12		0		0	1	655665	05 15 58
15012	SD	D0224+67	02 49	000000	1498	-25	1674	-114	1536	-120	1524	10	1497	-84	1412	55	1	555665	05 16 28
15012	XD	D0224+67	02 50	000000	1736	-167	1577	141	1559	-161	1937	-134	1395	175	1376	95	1	665666	05 16 58
15012	SD	D0224+67	02 50	0000	1556	-28	1605	-116	1486	-125	1510	10		0		0	1	555665	05 17 28
15012	SD	D0224+67	02 51	0000	1668	-25	1691	-114	1444	-121	1504	12		0		0	1	555665	05 17 58
15012	SD	D0224+67	02 51	0000	1650	-26	1593	-112	1486	-123	1591	15		0		0	1	555665	05 18 28
15012	SD	D0224+67	02 52	000000	1727	-20	1710	-112	1444	-121	1576	11	1515	-85	1386	57	1	555665	05 18 58
15012	XD	D0224+67	02 52	000000	1781	-156	1587	158	1469	-150	1884	-121	1343	176	1514	94	1	665666	05 19 28
15013	SD	3C147	-00 17	111111	18407	-21	18913	-109	16282	-118	17301	13	15190	-84	14680	56	1	666665	05 23 02
15013	XD	3C147	-00 16	000000	4501	171	4242	122	3503	178	4619	-153	3659	173	3887	94	1	666666	05 23 32
15013	SD	3C147	-00 16	110111	19381	-24	19074	-112	15866	-123	17229	9	15029	-83	14347	57	1	666665	05 24 02
15013	XD	3C147	-00 15	000000	4679	-172	4300	140	3723	-165	4549	-137	3571	172	3887	95	1	666666	05 24 32
15013	SD	3C147	-00 15	111101	18590	-37	19054	-125	16412	-134	17488	-2	15383	-84	14888	56	1	666665	05 25 02
15013	XD	3C147	-00 14	000000	4455	167	4155	118	3785	172	4522	-159	3583	175	3825	95	1	666666	05 25 32
15013	SD	3C147	-00 14	100111	18797	-23	18904	-111	15791	-121	16948	12	14791	-84	14388	56	1	666665	05 26 02
15013	XD	3C147	-00 13	000000	4583	-170	4175	140	3581	-164	4578	-137	3302	175	3726	95	1	666666	05 26 32
15013	SD	3C147	-00 13	110101	19187	-20	19000	-108	16740	-117	17405	15	15146	-84	14712	55	1	666665	05 27 02
15013	XD	3C147	-00 12	000000	4367	163	4041	114	3784	171	4509	-161	3459	171	3777	94	1	666666	05 27 32
15013	SD	3C147	-00 12	110111	18899	-33	18880	-120	15979	-129	16604	4	14712	-85	14306	54	1	666665	05 28 02
15013	XD	3C147	-00 11	000000	4498	143	4136	93	3476	148	4247	177	3264	173	3645	95	1	666666	05 28 32
15013	SD	3C147	-00 11	111101	19352	-37	18990	-125	16718	-134	17094	-1	15028	-85	14561	55	1	666665	05 29 02
15013	XD	3C147	-00 10	000000	4424	164	4132	114	3784	167	4393	-165	3427	176	3613	97	1	666666	05 29 32
15014	SD	DA267	-03 51	000000	7585	-29	6855	-116	6637	-124	6743	10	5699	-84	5755	55	1	555665	05 33 30
15014	XD	DA267	-03 51	000000	10612	179	9065	130	9794	-172	11150	-143	8655	173	9312	94	1	666666	05 34 00
15014	SD	DA267	-03 50	000000	7644	-36	6870	-123	6775	-131	6871	1	5894	-86	5733	55	1	555665	05 34 30
15014	XD	DA267	-03 50	000000	10849	168	9363	119	9712	179	11198	-153	8573	171	9747	93	1	666666	05 35 00
15014	SD	DA267	-03 49	000000	7835	-27	7041	-114	6680	-122	6744	11	5819	-84	5809	55	1	555665	05 35 30
15014	XD	DA267	-03 49	000000	10632	-158	9494	154	9892	-151	11295	-123	8795	177	9600	99	1	665666	05 36 00
15014	SD	DA267	-03 48	000000	6715	-33	7160	-120	6414	-125	6842	7	6059	-87	6022	53	1	555665	05 36 30
15014	XD	DA267	-03 48	110000	9923	156	9463	107	9620	170	11514	-162	9264	170	9543	92	1	665666	05 37 00
15014	SD	DA267	-03 47	000000	6873	-35	7154	-123	6481	-131	6925	2	5982	-85	5799	56	1	555665	05 37 30
15014	XD	DA267	-03 47	110100	10007	170	9562	121	8975	-177	11515	-148	9056	169	9591	91	1	665666	05 38 00
15014	SD	DA267	-03 46	000000	7004	-30	7245	-116	6468	-124	6977	9	5937	-84	5807	55.	1	555665	05 38 30
15014	XD	DA267	-03 46	111100	9899	157	9395	108	8735	175	11180	-156	8825	165	9684	87	1	665666	05 39 00
15014	SD	DA267	-03 45	000000	6906	-42	7224	-128	6310	-137	6928	-4	5994	-86	5954	55	1	655665	05 39 30
15015	SD	P1116+12	-05 35	0000	2422	93	2280	2	1957	-8	2256	127		0		0	1	666666	05 42 10
15015	SD	P1116+12	-05 34	000000	2382	82	2392	-6	2103	-15	2283	119	1994	-86	1991	55	1	666666	05 42 40
15015	XD	P1116+12	-05 34	000000	999	166	905	121	822	175	968	-149	838	172	870	91	1	676776	05 43 10
15015	SD	P1116+12	-05 33	0000	2500	92	2381	2	2253	-3	2385	132		0		0	1	666666	05 43 40
15015	SD	P1116+12	-05 33	000000	2506	83	2414	-6	2157	-12	2246	121	2051	-87	1938	50	1	666666	05 44 10
15015	XD	P1116+12	-05 32	000000	886	114	868	61	704	125	814	152	886	169	820	91	1	776676	05 44 40
15015	SD	P1116+12	-05 31	000000	2483	58	2481	-30	2145	-42	2253	93	2050	-84	1974	57	1	666666	05 45 40
15015	XD	P1116+12	-05 31	000000	1104	171	984	119	852	175	1015	-152	873	175	896	97	1	666776	05 46 10
15015	SD	P1116+12	-05 30	0000	2291	96	2322	10	2034	-4	2223	132		0		0	1	666666	05 46 40
15015	SD	P1116+12	-05 30	000000	2489	103	2318	15	2056	4	2375	135	1970	-82	1994	58	1	666666	05 47 10
15015	XD	P1116+12	-05 29	000000	941	-137	896	173	896	-125	949	-102	863	175	943	95	1	776676	05 47 40
15015	SD	P1116+12	-05 29	0000	2338	105	2382	15	1960	1	2250	137		0		0	1	666666	05 48 10
15015	SD	P1116+12	-05 28	000000	2322	102	2301	14	1949	6	2264	142	1991	-84	2044	58	1	666666	05 48 40
15015	XD	P1116+12	-05 28	000000	1123	151	912	103	800	167	1028	-164	941	168	914	96	1	666666	05 49 10
15015	SD	P1116+12	-05 27	0000	2488	83	2328	-5	2027	-14	2296	119		0		0	1	666666	05 49 40
15016	SD	P1055+01	-05 05	0000	4338	66	3758	-22	3614	-28	3716	105		0		0	1	666666	05 51 33
15016	SD	P1055+01	-05 05	000000	4409	73	3851	-16	3680	-23	3786	110	3338	-86	3302	53	1	666666	05 52 03
15016	XD	P1055+01	-05 04	000000	2495	139	2160	91	2059	149	2493	177	2114	171	2175	94	1	666666	05 52 33
15016	SD	P1055+01	-05 04	0000	4373	83	3797	-4	3750	-10	3722	122		0		0	1	666666	05 53 03
15016	SD	P1055+01	-05 03	000000	4363	79	3870	-8	3630	-14	3841	117	3383	-87	3360	53	1	666666	05 53 33
15016	XD	P1055+01	-05 03	000000	2163	96	1757	49	1804	120	2050	148	1946	159	2168	81	1	666666	05 54 03

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SCAN	M	SOURCE	HA	RMS/100	AMP1R2RPHI		AMP1L2LPHI		AMP1R3RPHI		AMP1L3LPHI		AMP2R3RPHI		AMP2L3LPHI		NREC	TPOWER	LST
15016	SD	P1055+01	-05 02	0000	4285	57	3898	-30	3618	-37	3824	95		0		0	1	666666	05 54 33
15016	SD	P1055+01	-05 02	000000	4372	92	3917	4	3736	-3	3846	132	3355	-87	3294	54	1	666666	05 55 03
15016	XD	P1055+01	-05 01	100100	1772	99	1423	48	1220	127	1399	153	2012	153	2093	77	1	666666	05 55 33
15016	SD	P1055+01	-05 01	0000	4398	34	3896	-53	3613	-58	3696	76		0		0	1	666666	05 56 03
15016	SD	P1055+01	-05 00	000000	4603	24	3915	-65	3780	-69	3913	63	3371	-88	3393	51	1	666666	05 56 33
15016	XD	P1055+01	-05 00	000000	2156	53	1888	5	1933	78	2249	107	1949	159	2120	77	1	666666	05 57 03
15016	SD	P1055+01	-04 59	0000	4395	55	3971	-34	3788	-39	3830	94		0		0	1	666666	05 57 33
15016	SD	P1055+01	-04 59	000000	4405	59	3887	-28	3822	-34	3999	100	3384	-87	3256	52	1	666666	05 58 03
15016	XD	P1055+01	-04 58	000000	2472	98	2095	48	2113	119	2374	146	2046	163	2076	86	1	666666	05 58 33
15016	SD	P1055+01	-04 58	0000	4402	59	3940	-28	3784	-30	3881	102		0		0	1	666666	05 59 03
15016	SD	P1055+01	-04 57	000000	4490	63	3970	-24	3742	-33	3866	100	3472	-88	3224	53	1	666666	05 59 33
15017	SD	P0859-14	-02 58	000000	3615	-3	3800	-89	3332	-92	3603	42	3150	-90	3042	47	1	655665	06 02 13
15017	XD	P0859-14	-02 58	000000	1385	-108	1311	-151	1159	-66	1489	-41	1298	145	1390	63	1	666666	06 02 43
15017	SD	P0859-14	-02 57	000000	3764	-14	3907	-102	3233	-103	3565	31	3181	-92	3267	46	1	655665	06 03 13
15017	XD	P0859-14	-02 57	000000	1402	-113	1359	-158	1302	-79	1434	-50	1368	149	1350	71	1	666666	06 03 43
15017	SD	P0859-14	-02 56	000000	3484	3	3861	-84	3370	-86	3625	48	3241	-92	3221	48	1	655665	06 04 13
15017	XD	P0859-14	-02 56	000000	1303	-113	1263	-169	1061	-87	1301	-59	1295	146	1474	67	1	666666	06 04 43
15017	SD	P0859-14	-02 55	000000	3598	-11	3990	-99	3342	-102	3551	31	3230	-91	3179	48	1	655665	06 05 13
15017	XD	P0859-14	-02 55	000000	1417	-131	1340	-179	1170	-89	1500	-69	1366	142	1490	61	1	666666	06 05 43
15017	SD	P0859-14	-02 54	000000	3530	1	3838	-86	3400	-89	3573	43	3330	-91	3127	47	1	655665	06 06 13
15017	XD	P0859-14	-02 54	000000	1380	-89	1456	-136	1254	-52	1547	-25	1356	146	1417	65	1	666666	06 06 43
15017	SD	P0859-14	-02 53	000000	3592	-12	3909	-100	3551	-101	3647	31	3156	-94	3140	46	1	655665	06 07 13
15017	XD	P0859-14	-02 53	000000	1375	-146	1335	169	1207	-116	1480	-90	1368	153	1404	73	1	666666	06 07 43
15017	SD	P0859-14	-02 52	000000	3616	-9	4006	-98	3332	-100	3661	34	3120	-91	3159	49	1	655665	06 08 13
15017	XD	P0859-14	-02 52	000000	1271	-109	1367	-159	1172	-82	1536	-53	1373	155	1409	76	1	666666	06 08 43
15017	SD	P0859-14	-02 51	000000	3480	10	3934	-79	3434	-79	3652	53	3240	-91	3144	48	1	655665	06 09 13
15017	XD	P0859-14	-02 51	000000	1224	-95	1274	-138	1198	-58	1387	-28	1372	149	1420	73	1	666666	06 09 43
15018	SD	P0614-34	-00 02	000000	2713	17	2618	-71	2286	-71	2492	61	2133	-93	2150	47	1	666666	06 12 43
15018	XD	P0614-34	-00 02	000000	635	-83	601	-136	566	-48	796	-27	635	147	642	69	1	666666	06 13 13
15018	XD	P0614-34	-00 01	000000	615	-47	695	-97	532	-26	661	4	621	152	631	67	1	666666	06 14 13
15018	SD	P0614-34	-00 00	000000	2728	14	2706	-72	2402	-78	2441	55	2342	-88	2069	51	1	666666	06 14 43
15018	XD	P0614-34	-00 00	000000	704	-11	617	-61	550	19	624	40	646	158	628	76	1	666666	06 15 13
15018	SD	P0614-34	00 00	000000	2759	26	2724	-62	2464	-63	2536	68	2340	-91	2180	52	1	666665	06 15 43
15018	XD	P0614-34	00 00	000000	643	-47	596	-99	545	-8	628	14	609	157	660	72	1	666666	06 16 13
15018	SD	P0614-34	00 01	000000	2866	6	2801	-80	2514	-84	2513	48	2313	-87	2041	49	1	666665	06 16 43
15018	XD	P0614-34	00 01	000000	791	-94	640	-141	645	-74	724	-35	586	143	670	73	1	666666	06 17 13
15018	SD	P0614-34	00 02	000000	2955	-6	2760	-95	2384	-94	2430	41	2262	-93	2100	46	1	666665	06 17 43
15018	XD	P0614-34	00 02	000000	799	-99	737	-153	608	-76	785	-48	603	153	718	77	1	666666	06 18 13
15018	SD	P0614-34	00 03	000000	2844	10	2667	-76	2349	-79	2557	57	2301	-92	2139	51	1	666665	06 18 43
15018	XD	P0614-34	00 03	000000	687	-49	680	-92	515	-18	718	16	532	152	671	75	1	666666	06 19 13
15018	SD	P0614-34	00 04	000000	2781	10	2675	-77	2351	-79	2442	54	2310	-91	2102	48	1	666665	06 19 43
15019	SD	D0742+10	-01 20	000000	5413	-39	5636	-126	5010	-130	5362	2	4542	-88	4554	53	1	655665	06 23 05
15019	XD	D0742+10	-01 20	000000	2509	153	2452	105	2161	178	2812	-154	2351	159	2544	81	1	665666	06 23 35
15019	SD	D0742+10	-01 19	000000	5553	-35	5751	-122	4990	-127	5399	6	4693	-88	4561	51	1	655665	06 24 05
15019	XD	D0742+10	-01 19	000000	2691	161	2456	112	2215	-176	2768	-147	2219	159	2461	79	1	665666	06 24 35
15019	SD	D0742+10	-01 18	000000	6022	-35	5837	-121	5228	-127	5367	6	4703	-86	4430	53	1	655665	06 25 05
15019	XD	D0742+10	-01 18	000000	2600	157	2423	107	2110	-180	2738	-152	2196	159	2600	78	1	665666	06 25 35
15019	SD	D0742+10	-01 17	000000	6085	-34	5805	-122	4842	-127	5480	5	4533	-88	4680	53	1	655665	06 26 05
15019	XD	D0742+10	-01 17	000000	2703	158	2447	108	1960	-174	2754	-148	2044	155	2512	76	1	665666	06 26 35
15019	SD	D0742+10	-01 16	000000	6011	-38	5815	-125	5017	-130	5502	2	4746	-87	4618	53	1	655665	06 27 05
15019	XD	D0742+10	-01 16	000000	2576	157	2442	107	2124	176	2774	-155	2310	159	2525	80	1	665666	06 27 35
15019	SD	D0742+10	-01 15	000000	5718	-28	5787	-116	4851	-123	5456	10	4616	-87	4668	52	1	655665	06 28 05
15019	XD	D0742+10	-01 15	000000	2533	169	2384	120	2055	-169	2729	-141	2167	158	2523	81	1	665666	06 28 35
15019	SD	D0742+10	-01 14	000000	5853	-39	5783	-128	4923	-131	5560	0	4633	-88	4704	51	1	655665	06 29 05
15019	XD	D0742+10	-01 14	000000	2797	138	2473	87	2232	159	2766	-174	2132	160	2547	82	1	665666	06 29 35
15020	SD	P1116+12	-04 44	000000	2700	0	2420	-89	2401	-92	2455	40	1990	-88	2064	50	1	655665	06 33 20
15020	XD	P1116+12	-04 43	000000	1299	-97	1133	-139	1023	-75	1159	-46	967	166	962	86	1	665666	06 33 50
15020	SD	P1116+12	-04 43	000000	2872	22	2573	-65	2320	-74	2336	58	2035	-86	2040	53	1	655665	06 34 20
15020	XD	P1116+12	-04 42	000000	1275	-41	1050	-91	993	-21	1096	6	987	164	1003	85	1	665666	06 34 50
15020	SD	P1116+12	-04 42	000000	2747	8	2502	-81	2352	-87	2383	47	2120	-90	2027	49	1	655665	06 35 20

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SCAN	M	SOURCE	HA	RMS/100	AMP1R2R	PHI	AMP1L2L	PHI	AMP1R3R	PHI	AMP1L3L	PHI	AMP2R3R	PHI	AMP2L3L	PHI	NREC	TPOWER	LST
15020	XD	P1116+12	-04 41	000000	1270	-80	1034	-128	1142	-60	1207	-26	950	158	1006	84	1	665666	06 35 50
15020	SD	P1116+12	-04 41	000000	2678	7	2493	-81	2380	-89	2504	43	2129	-85	2033	55	1	655665	06 36 20
15020	XD	P1116+12	-04 40	000000	1220	-53	1046	-109	1056	-33	1222	-4	1013	158	1014	80	1	665666	06 36 50
15020	SD	P1116+12	-04 40	000000	2758	7	2555	-82	2349	-85	2447	47	2071	-88	2034	51	1	655665	06 37 20
15020	XD	P1116+12	-04 39	000000	1149	-69	1002	-115	1152	-45	1299	-19	1002	161	1054	85	1	665666	06 37 50
15020	SD	P1116+12	-04 39	000000	2801	10	2553	-78	2427	-86	2477	48	2071	-88	2112	53	1	655665	06 38 20
15020	SD	P1116+12	-04 38	000000	2813	-9	2454	-96	2441	-99	2371	34	2190	-90	2003	51	1	655665	06 39 20
15020	XD	P1116+12	-04 37	000000	1168	-111	1020	-152	1060	-88	1305	-63	926	162	1031	87	1	666666	06 39 50
15021	SD	3C138	01 25	100000	8593	-41	8504	-128	7035	-135	7541	-1	6785	-84	6249	54	1	665665	06 45 06
15021	XD	3C138	01 26	000000	2422	122	2211	73	2016	140	2514	168	2010	166	2235	86	1	666666	06 45 36
15021	SD	3C138	01 26	000000	8923	-52	8830	-140	7305	-146	7980	-13	6793	-83	6471	55	1	665665	06 46 06
15021	XD	3C138	01 27	000000	2421	124	2136	74	2097	141	2548	170	2071	166	2310	89	1	666666	06 46 36
15021	SD	3C138	01 27	000000	8977	-41	8742	-130	7376	-136	7797	-4	6877	-84	6526	55	1	665665	06 47 06
15021	XD	3C138	01 28	000000	2449	146	1989	95	2003	167	2385	-163	2011	162	2133	84	1	776666	06 47 36
15021	SD	3C138	01 28	000000	9058	-37	8817	-126	7353	-131	7864	2	6879	-85	6593	54	1	665665	06 48 06
15021	XD	3C138	01 29	000000	2271	157	2096	108	1989	175	2344	-155	2064	167	2211	88	1	776666	06 48 36
15021	SD	3C138	01 29	000000	8923	-45	8812	-132	7409	-138	7833	-5	7050	-85	6683	55	1	665665	06 49 06
15021	XD	3C138	01 30	000000	2407	140	2182	93	2080	162	2483	-172	2049	166	2261	84	1	666666	06 49 36
15022	SD	3C147	02 08	1111	19130	-35	18374	-122	16153	-132	17352	1		0		0	1	565665	07 49 25
15022	SD	3C147	02 09	110111	20075	-28	18745	-116	16000	-126	17409	8	15421	-83	14810	56	1	565665	07 49 55
15022	XD	3C147	02 09	000000	4778	174	4235	125	3800	-172	4578	-143	3507	166	3866	87	1	566666	07 50 25
15022	SD	3C147	02 10	1101	20041	-36	18918	-123	16602	-133	17560	0		0		0	1	566665	07 50 55
15022	SD	3C147	02 10	100000	19675	-35	18826	-123	16386	-133	17659	0	15240	-83	15054	56	1	565665	07 51 25
15022	XD	3C147	02 11	000000	4772	153	4186	104	3869	158	4796	-174	3510	172	3884	95	1	566666	07 51 55
15022	SD	3C147	02 11	1101	19669	-35	18826	-122	16145	-133	17250	0		0		0	1	556665	07 52 25
15022	SD	3C147	02 12	101100	19144	-38	18601	-125	15875	-135	17246	-2	14980	-84	15142	55	1	555665	07 52 55
15022	XD	3C147	02 12	000000	4597	154	4218	105	3806	168	4647	-163	3281	166	3684	87	1	566666	07 53 25
15022	SD	3C147	02 13	1111	19648	-36	18821	-123	16947	-132	17874	1		0		0	1	555665	07 53 55
15022	SD	3C147	02 13	111101	19489	-34	18563	-121	16747	-131	17772	2	15186	-84	14974	55	1	556665	07 54 25
15022	SD	3C147	02 14	1011	19539	-32	18858	-120	16827	-128	17631	5		0		0	1	555665	07 55 25
15022	SD	3C147	02 15	100111	19186	-32	18626	-119	16627	-128	17616	5	15427	-86	15164	55	1	556665	07 55 55
15022	XD	3C147	02 15	000000	4639	175	4160	127	4021	-179	4855	-150	3637	172	3842	95	1	566666	07 56 25
15022	SD	3C147	02 16	1011	19548	-25	18995	-113	16696	-123	17836	10		0		0	1	556665	07 56 55
15022	SD	3C147	02 16	111111	19394	-30	18831	-118	16721	-129	17935	4	15350	-83	14957	56	1	556665	07 57 25
15022	XD	3C147	02 17	000000	4917	158	4358	111	4098	170	4987	-160	3689	168	3980	90	1	566666	07 57 55
15022	SD	3C147	02 17	1111	18625	-36	18632	-124	16545	-132	17941	1		0		0	1	555665	07 58 25
15022	SD	3C147	02 18	111111	19390	-34	18922	-122	15880	-131	17504	2	15138	-85	15087	55	1	556665	07 58 55
15022	XD	3C147	02 18	000000	4764	160	4322	110	3713	174	4701	-159	3446	165	4082	88	1	566666	07 59 25
15022	SD	3C147	02 19	1001	19113	-31	18821	-118	16124	-127	17564	6		0		0	1	556665	07 59 55
15022	SD	3C147	02 19	110111	18849	-29	18684	-117	16367	-126	17622	7	15270	-84	15230	56	1	556665	C8 00 25
15022	XD	3C147	02 20	000000	4742	158	4265	109	3931	164	4896	-167	3686	172	4004	96	1	566666	08 00 55
15022	SD	3C147	02 20	0011	18526	-33	18429	-120	16496	-128	17772	4		0		0	1	556665	08 01 25
15022	SD	3C147	02 21	001111	18298	-40	18299	-128	16608	-137	17812	-3	15316	-85	15097	55	1	555665	08 01 55
15022	XD	3C147	02 21	000000	4865	147	4279	98	4093	155	4984	-177	3613	172	3869	94	1	566666	08 02 25
15022	SD	3C147	02 22	1100	19896	-31	18768	-119	15919	-128	17300	6		0		0	1	555665	08 02 55
15022	SD	3C147	02 22	111111	20086	-24	18726	-111	16632	-119	17609	13	15205	-84	14809	56	1	555665	08 03 25
15022	XD	3C147	02 23	000000	4817	-174	4300	137	4128	-167	4813	-138	3691	171	3911	92	1	566666	08 03 55
15022	SD	3C147	02 23	1111	19740	-29	18747	-116	17071	-125	17899	8		0		0	1	556665	08 04 25
15022	SD	3C147	02 24	111111	19653	-30	18657	-118	17181	-128	17906	5	15731	-84	15058	56	1	556665	08 04 55
15022	XD	3C147	02 24	000000	4947	-177	4306	134	4048	-168	4919	-140	3661	171	4031	91	1	566666	08 05 25
15022	SD	3C147	02 25	1100	19616	-27	18652	-114	16848	-125	17712	7		0		0	1	555665	08 05 55
15022	SD	3C147	02 25	111111	19836	-25	18761	-112	17098	-122	17740	11	15384	-83	14916	57	1	556665	08 06 25
15022	XD	3C147	02 26	000000	4886	-174	4332	138	4144	-163	4836	-134	3630	168	4020	91	1	566666	08 06 55
15022	SD	3C147	02 26	1101	19897	-28	18761	-115	17143	-124	17589	9		0		0	1	555665	08 07 25
15022	SD	3C147	02 27	110111	19598	-23	18674	-110	17170	-121	17814	12	15783	-84	15110	55	1	555665	08 07 55
15022	XD	3C147	02 27	000000	4967	-131	4410	-179	4129	-126	4787	-98	3489	176	3991	96	1	566666	08 08 25
15022	SD	3C147	02 28	1111	19789	-13	18789	-100	16991	-109	17600	24		0		0	1	556665	08 08 55
15022	SD	3C147	02 28	111111	19011	-18	18538	-106	17030	-117	17695	16	15650	-84	15276	55	1	555665	08 09 25
15022	XD	3C147	02 29	000000	4930	-180	4491	132	4217	-171	4959	-144	3810	173	4229	94	1	565666	08 09 55
15022	SD	3C147	02 29	1101	19326	-29	18774	-117	16954	-125	17969	8		0		0	1	555665	08 10 25

(n)

SCAN	M	SOURCE	HA	RMS/100	AMP1R2R	PHI	AMP1L2L	PHI	AMP1R3R	PHI	AMP1L3L	PHI	AMP2R3R	PHI	AMP2L3L	PHI	NREC	TPOWER	LST
15022	SD	3C147	02 30	110110	19354	-30	18833	-117	17162	-126	18016	7	15690	-85	14869	54	1	556665	08 10 55
15022	XD	3C147	02 30	000000	4999	177	4525	129	4007	-170	5033	-141	3769	165	4053	87	1	566666	08 11 25
15022	SD	3C147	02 31	1011	19734	-31	18978	-118	16964	-127	17994	6		0		0	1	555665	08 11 55
15022	SD	3C147	02 31	111110	18726	-20	18637	-108	16627	-117	17636	16	15786	-84	14979	55	1	556665	08 12 25
15022	XD	3C147	02 32	000000	4924	-161	4465	152	4233	-155	5178	-127	3797	175	4122	97	1	566666	08 12 55
15022	SD	3C147	02 32	1111	19316	-23	18818	-110	16270	-120	17636	13		0		0	1	556665	08 13 25
15022	SD	3C147	02 33	111110	19622	-28	18925	-115	17014	-125	17877	8	15486	-84	14990	56	1	556665	08 13 55
15022	XD	3C147	02 33	000000	4682	-178	4224	133	4242	-168	5030	-141	3803	170	3971	92	1	566666	08 14 25
15022	SD	3C147	02 34	1111	18739	-29	18595	-117	16800	-126	17675	7		0		0	1	556665	08 14 55
15022	SD	3C147	02 34	111111	18943	-34	18592	-121	16529	-130	17361	2	15618	-84	14900	55	1	555665	08 15 25
15022	XD	3C147	02 35	000000	5134	-154	4592	158	4135	-146	4745	-117	3440	170	4012	92	1	566666	08 15 55
15022	SD	3C147	02 35	1111	20454	-20	18972	-107	16580	-114	17617	18		0		0	1	556665	08 16 25
15022	SD	3C147	02 36	111111	20612	-37	19048	-124	16138	-134	17266	-2	15066	-85	15147	55	1	555665	08 16 55
15022	XD	3C147	02 36	000000	5066	-161	4416	150	4042	-153	4736	-125	3660	173	3967	93	1	566666	08 17 25
15022	SD	3C147	02 37	1111	20046	-20	18688	-107	16882	-114	17863	19		0		0	1	556665	08 17 55
15022	SD	3C147	02 37	111101	20307	-48	18992	-135	17134	-145	18166	-12	15640	-85	15072	54	1	555665	08 18 25
15022	XD	3C147	02 38	101100	4442	-169	4004	142	3864	-165	4556	-137	3488	174	4034	98	1	566666	08 18 55
15022	SD	3C147	02 38	1111	20642	-20	19062	-107	16752	-116	17626	17		0		0	1	556665	08 19 25
15022	SD	3C147	02 39	221101	20614	-37	18883	-125	16957	-134	17727	-2	15593	-85	15332	56	1	556665	08 19 55
15022	XD	3C147	02 39	101100	4509	-155	3999	158	3834	-144	4566	-116	3460	168	3896	93	1	566666	08 20 25
15022	SD	3C147	02 40	1111	20813	-31	19261	-119	16896	-128	17703	4		0		0	1	555665	08 20 55
15022	SD	3C147	02 40	111100	20243	-26	18819	-113	17481	-125	18079	8	15741	-83	15241	58	1	555665	08 21 25
15028	M	3C286	-04 18	010100	4978	118	14682	-137	4406	144	14304	-8	3894	157	11997	50	1	556665	09 11 48
15028	M	3C286	-04 17	000100	4789	137	14387	-129	4395	164	14560	-0	4097	155	11944	51	1	556665	09 12 18
15028	M	3C286	-04 17	000000	4917	147	14450	-126	4460	180	14704	5	4215	151	11891	49	1	556665	09 12 48
15028	M	3C286	-04 16	000000	4974	131	14503	-131	4234	162	14452	-1	3937	151	12228	49	1	556665	09 13 18
15028	M	3C286	-04 16	010100	4932	150	14679	-125	4479	175	14713	3	4039	159	12287	51	1	556665	09 13 48
15028	M	3C286	-04 15	000000	4975	-176	14292	-113	4364	-156	14637	14	4029	161	12021	52	1	556665	09 14 18
15028	M	3C286	-04 15	000100	4941	170	14284	-118	4368	-166	14611	11	4078	156	11986	51	1	556665	09 14 48
15028	M	3C286	-04 14	000100	4866	161	14544	-121	4507	-171	14692	9	4085	155	11867	50	1	556665	09 15 18
15028	M	3C286	-04 14	000000	5051	167	14838	-119	4434	-165	14547	11	4002	153	12246	49	1	555665	09 15 48
15028	M	3C286	-04 13	000000	4999	171	14863	-118	4615	-167	14712	11	4012	160	12173	52	1	556665	09 16 18
15028	M	3C286	-04 13	000000	5020	166	14882	-119	4532	-169	14622	10	4054	156	12121	50	1	556665	09 16 48
15028	M	3C286	-04 12	000100	4968	177	14964	-115	4548	-156	14581	15	4080	155	11975	50	1	556665	09 17 18
15028	M	3C286	-04 12	000000	4864	174	14582	-115	4443	-161	14510	14	4121	157	11778	51	1	556665	09 17 48
15028	M	3C286	-04 11	010100	4711	173	14526	-116	4389	-162	14444	13	4074	157	11491	51	1	556665	09 18 18
15028	M	3C286	-04 11	000100	4903	-176	14590	-112	4145	-154	13869	16	3943	161	12378	53	1	556665	09 18 48
15028	M	3C286	-04 10	010101	4644	177	14592	-114	4170	-158	14203	13	4066	158	12264	52	1	556665	09 19 18
15028	M	3C286	-04 10	010101	4714	177	14689	-115	4270	-160	14252	12	3991	159	12250	52	1	556665	09 19 48

END

INTCLEAN
MESSAGES WITH SEVERITY OF 3 OR MORE WILL CAUSE DELETION OF AFFECTED CORRELATORS
CORRELATOR RMS'S IN EXCESS OF 1000 FOR HIGH GAIN AND 200 FOR MEDIUM OR LOW GAIN WILL BE FLAGGED
SEVERITY 5 PROBLEMS MAY CAUSE OTHER CHECKS TO BE SUPPRESSED
X1 => HEADER BAD: X2, X3 => DATA, A/D RECORD ERASED

SCAN	TIME	SEVERITY	CORR	MESSAGE ** PROGRAM PROCESSED 04/04/1973 **	MSG STATUS	SOURCE RECORD/WORD	RA DEC MD WORD CONTENTS
14969	22 02 18					P0056-17	005747-170911 D
14970	22 12 57					3C48	013610+330128 D
14971	22 22 11					D0224+67	022637+671348 D
14972	22 33 04					NRA091	020323+150635 D
14973	22 42 18					3C119	043044+413504 D
14974	22 55 19					P2149-28	215031-283607 D
14974	22 55 36					P2149-28	215031-283607 D
	22 55 36	*		ABNORMAL RETURN TO NEW SCAN		HDR 19	20
14975	23 02 20					DV080	194847+080314 D
14976	23 12 08					BLLAC	220137+420901 D
14977	23 21 46					3C454.3	225238+160024 D
14978	23 32 16					P0114-21	011534-210025 D
14979	23 41 00					P0056-17	005747-170911 D
14980	23 52 59					3C48	013610+330128 D
14981	00 02 30					P2149-28	215031-283607 D
14982	00 13 54					CYGX-3	203128+405208 D
14983	00 23 50					P0114-21	011534-210025 D
14984	00 33 10					3C48	013610+330128 D
14985	00 42 07					D0224+67	022637+671348 D
14986	00 52 47					3C147	054031+495018 D
14986	00 53 12					3C147	054031+495018 D
	00 53 12	*		ABNORMAL RETURN TO NEW SCAN		HDR 19	10
14987	01 01 32					3C119	043044+413504 D
14988	01 11 40					CTA21	031727+162249 D
14989	01 22 16					P0114-21	011534-210025 D
14990	01 32 20					3C454.3	225238+160024 D
14991	01 42 14					3C418	203749+511343 D
14992	01 53 36					P0106+01	010716+012632 D
14992	01 54 00					P0106+01	010716+012632 D
	01 54 00	*		ABNORMAL RETURN TO NEW SCAN		HDR 19	10
14993	02 02 11					NRA0140	033449+321314 D
14994	02 13 25					P0735+17	073633+174607 D
14995	02 22 39					3C120	043145+051804 D
14996	02 35 04					3C446	222424-050509 D
14997	02 41 36					3C454.3	225238+160024 D
14998	02 52 42					3C48	013610+330128 D
14998	02 53 02					3C48	013610+330128 D
	02 53 02	*		ABNORMAL RETURN TO NEW SCAN		HDR 19	20
14999	03 02 06					D0224+67	022637+671348 D
15000	03 12 44					3C147	054031+495018 D
15001	03 22 23					D0742+10	074403+101519 D
	03 29 43	****	1R2R	RMS EXCEEDS LIMITS		DTA 48	206
15002	03 31 41					P0607-15	060828-154203 D
15003	03 44 18					P0056-17	005747-170911 D
15004	03 52 09					3C454.3	225238+160024 D
	03 57 28	****	1R2R	RMS EXCEEDS LIMITS		DTA 48	283
	03 57 28	****	1L2L	RMS EXCEEDS LIMITS		DTA 52	248
	03 57 28	****	1L3L	RMS EXCEEDS LIMITS		DTA 60	232
	03 57 58	****	1R2R	RMS EXCEEDS LIMITS		DTA 48	327
	03 57 58	****	1L2L	RMS EXCEEDS LIMITS		DTA 52	294
	03 57 58	****	1R3R	RMS EXCEEDS LIMITS		DTA 56	259
	03 57 58	****	1L3L	RMS EXCEEDS LIMITS		DTA 60	285
15005	04 02 38					NRA091	020323+150635 D
	04 03 27	*	85-3	XL RECEIVER FAULT INDICATION		DTA 15	0000000000000001
15006	04 12 11					3C119	043044+413504 D
15006	04 12 37					3C119	043044+413504 D
	04 12 37	*		ABNORMAL RETURN TO NEW SCAN		HDR 19	10
	04 13 26	*	85-3	XL RECEIVER FAULT INDICATION *NOW INACTIVE*		DTA 15	0000000000000000
15007	04 23 00					P0106+01	010716+012632 D
15008	04 32 55					P0438-43	043927-433555 D
	04 35 45	***	85-1	XL TOTAL POWER OUT OF RANGE		DTA 37	-15196
	04 35 45	***	85-3	XR TOTAL POWER OUT OF RANGE		DTA 40	-15064
	04 36 45	*	85-3	XR RECEIVER FAULT INDICATION		DTA 15	0000000000000010
	04 36 45	***	85-2	XL TOTAL POWER OUT OF RANGE		DTA 39	-15176
	04 37 45	*	85-3	XR RECEIVER FAULT INDICATION *NOW INACTIVE*		DTA 15	0000000000000000
	04 37 45	***	85-2	XL TOTAL POWER OUT OF RANGE *NOW INACTIVE*		DTA 39	-14880
	04 39 45	***	85-1	XR TOTAL POWER OUT OF RANGE		DTA 36	-15200
	04 39 45	***	85-2	XL TOTAL POWER OUT OF RANGE		DTA 39	-15068
15009	04 41 36					P0614-34	061538-345518 D
	04 42 25	***	85-1	XR TOTAL POWER OUT OF RANGE *NOW INACTIVE*		DTA 36	-14408
	04 42 25	***	85-1	XL TOTAL POWER OUT OF RANGE *NOW INACTIVE*		DTA 37	-14680
	04 42 25	***	85-2	XL TOTAL POWER OUT OF RANGE *NOW INACTIVE*		DTA 39	-13852
	04 42 25	***	85-3	XR TOTAL POWER OUT OF RANGE *NOW INACTIVE*		DTA 40	-13964
15010	04 53 07					3C138	051936+163656 D
15011	05 03 13					3C48	013610+330128 D
15012	05 12 09					D0224+67	022637+671348 D
15013	05 22 43					3C147	054031+495018 D
15014	05 33 10					DA267	092520+390924 D
15015	05 41 50					P1116+12	111731+124340 D
15016	05 51 14					P1055+01	105705+014249 D
15017	06 01 54					P0859-14	090059-140851 D
15018	06 12 24					P0614-34	061538-345516 D
15019	06 22 46					D0742+10	074403+101519 D
15020	06 33 02					P1116+12	111731+124340 D
15021	06 44 47					3C138	051936+163656 D
15022	07 49 05					3C147	054031+495018 D
	07 49 05	*		ABNORMAL RETURN TO NEW SCAN		HDR 19	2
	08 19 55	****	1R2R	RMS EXCEEDS LIMITS		DTA 48	222
	08 19 55	****	1L2L	RMS EXCEEDS LIMITS		DTA 52	205
15023	08 27 32					1216+48	121745+483901 M
	08 27 32	*		ABNORMAL RETURN TO NEW SCAN		HDR 19	2
15024	08 37 00					1242+41	124330+405708 M
15025	08 45 00					1244+49	124552+490914 M
15026	08 53 08					1315+34	131620+343427 M
15027	09 03 27					1317+52	131837+515649 M
15028	09 11 29					3C286	132952+303858 M
		NORMAL END					

Fig. III-8. First part of INTCLEAN display for processing of scans 14969 through 15028 from the RAWTAPE.

```
DIAGNOSTIC SUMMARY  04/04/1973          DIAGNOSTIC SUMMARY  04/04/1973          DIAGNOSTIC SUMMARY  04/04/1973

              NUMBER OF OCCURENCES                                         DIAGNOSTICS

              TESTS ON FIRST 6 WORDS                                       NO ERRORS =  0

                                                 *****                     ILLEGAL DATA TYPE
                                                 *****                     NEGATIVE SCAN NO
                                                 *****                     WORD 3 ¬= 0
                                                 *****                     DATE ILLEGAL
                                                    **                     TIME NEGATIVE
                                                 *****                     TIME ILLEGAL

              TESTS ON HEADER RECORDS                                      NO HEADERS FLAGGED =  0 OUT OF  65

                                                    **                     NEW SCAN NO. OUT OF SEQUENCE
                                                     *                     BLANK REMOVED IN SOURCENAME "
                                                 *****                     RIGHT ASC. < 0. HDR BAD.
                                                 *****                     2ND POSN WORD < 0. HDR BAD.
                                                 *****                     ILLEGAL MODE.  HDR BAD.
                                  7                  *                     ABNORMAL RETURN TO NEW SCAN
                                                 *****                     BASELINE CHANGE.  HDR BAD

              TESTS ON DATA RECORDS

                AFFECTED CHANNELS
             85-1      85-2      85-3
    NO TEL  R    L    R    L    R    L                                     NO DATA RECORDS DELETED =  0 OUT OF  892

                                                 *****                     HDR & DATA MODE,POLN SELN DISAGREE
                                                   ***           85-       RECEIVER SYSTEM IN MANUAL CONTROL
                                                 *****           85-       IF SELECTION DOES NOT MATCH MODE
                                                 *****           85-       TELESCOPE OR DELAY TRACKING DISABLED
                                                     *           BL        GAINS IN MANUAL CTRL, SETTINGS CHANGED
                                                     *                     FOCUS AND POLN MOTORS IN MANUAL CONTROL
                                                  ****                     MASTER LO SYSTEM LOCK OR LEVEL PROBLEMS
                                                  ****           85-       LO SYSTEM LOCK PROBLEMS
                                                    **                     RCVR IF LEVEL OUT OF RANGE
                                                    **           85-       BOX TEMP OUT OF RANGE
                                7    1               *           85-          RECEIVER FAULT INDICATION
            1    5         2    5                  ***           85-          TOTAL POWER OUT OF RANGE
            5    5    4    3    1    2            ****                     RMS EXCEEDS LIMITS
                                                 *****                     SCAN NUMBER ERROR. RECORD DELETED.
                                                                           AMPLITUDE JUMP OVER 300

              TESTS ON A/D RECORDS                                         NO A/D RECS DELETED =  0 OUT OF  61

                                                 *****                     CABLE PRESSURE EXCEEDS LIMITS
                                                    **                     LO COUNTER OUT BY >1 KHZ,
                                                  ****           85-       LARGE DELAY CENTER CHANGE

          TOTAL OF 1018 RECORDS PROCESSED

NO OPERATOR MESSAGES FOUND
```

Fig. III-9. Second part of INTCLEAN display, the diagnostic summary, for processing of scans 14969 through 15028 from the RAWTAPE.

In Figure III-8 data diagnostics for each scan are listed. For each scan the display always gives: scan number, LST at the time header is written, source name, right ascension and declination of reference position precessed to date of observation, and the mode. Whenever faults are detected by system monitors or the DDP116, details concerning the fault are recorded on tape and appear in the INTCLEAN display. For each fault encountered, the following are printed out (see Figure III-8): LST for the header/or A/D record/or data record involved; the severity code of the fault, ranging from a single asterisk for a minor complaint to five asterisks for a major disaster; description of the fault encountered; the type of information (HDR, A/D, or DTA) and word (in terms of tape format) involved in the fault; and the contents of the word associated with the faulty data. A summary of the possible faults that can be detected, together with a summary of those actually deleted, is given by INTCLEAN as shown in Figure III-9.

Going through the data diagnostics in Figure III-8, we can begin discussing what needs to be done to clean scans 14969 through 15028 using INTEDIT. The first series of complaints concern "abnormal return to new scan". This is of no concern to the observer, but simply means that during execution of an observing scan some sort of computer interrupt caused an extra header to be written on tape before the observing was continued. However, with scan 15001 there is a complaint of "rms exceeds limits" for certain correlators. This is frequently an indicator of bad data because it means the fringe-fitting algorithm encountered difficulty in coming up with a solution consistent with expectations. Guided by the LST time for the complaint we examine the data record at $03^h29^m43^s$ in scan 15001 (Figure III-7h) and see that there are unusual rms indices for this record for all SBAND correlators involving 85-1. Furthermore, some of the amplitudes are also anomalous. Therefore, we clearly must delete the bad data, so we prepare the following DELETE card:

DELETE_15001_SBAND_(03_29_43)_85-1;

and we can then pass on to a number of complaints about scan 15004. Noting excessive rms' in Figure III-7i for XBAND data involving 85-1, together with anomalous amplitudes, we prepare:

DELETE_15004_XBAND_(03_57_28)_(03_57_58)_85-1;

Going on, we note in Figure III-8 complaints of "XL receiver fault" for 85-3. In this case examination of the appropriate data records in Figure III-7 reveal nothing anomalous, so we conclude that the problem did not affect the data seriously, therefore we do nothing (a conservative observer might delete the offending data as a matter of principle).

In scan 15008 we see complaints of another serious fault (three or more asterisks usually means faults serious enough to require deletions): "total power out of range" for a number of XBAND receivers. Indeed, from Figure III-7j, the total power indices show many anomalies. Further, many of the XBAND amplitudes and phases appear anomalous. Several records involving 85-1 require deletions:

DELETE_15008_XBAND_(04_33_45)_(04_34_45)_85-1;

and we will also erase all XBAND data occurring for this scan after $04^h35^m45^s$ (we will ERASE rather than DELETE only to give some variety in the example; ordinarily only DELETE would be used):

ERASE_15008_XBAND_(04_35_45)_(04_39_45);

Continuing on with Figure III-8, we see more complaints of excessive rms in scan 15022; but the amplitudes and phases are consistent with all the other data so we do nothing. Without good reason to believe the amplitudes and phases are acceptable, we would automatically delete these data records also. Coming to the end of Figure III-8 we have finished examining the data diagnostics recorded on tape. As the reader might suspect, the example just discussed contains fewer than average complaints.

Unfortunately the data diagnostics do not detect many serious faults. For this reason the user must spend a considerable amount of time examining the raw data records while searching for anomalies. In cases where dual-mode data predominates the observer may prefer to examine an INTSCRIB display where first one frequency then another is shown; this could be accomplished by using the following program:

```
//_EXEC_INTCOPY,INTAPE=3085,INNAME=RAWTAPE
//SYSIN_DD_*
INCLUDE_SBAND
END_REWIND
INCLUDE_XBAND
//_EXEC_INTSCRIB
```

What anomalies can be detected just by examining an INTSCRIB of the data records? Only experience will help the user very much, but one always does at least the following: (i) scan the RMS indices looking for sudden changes; (ii) scan the TPOWER indices looking for anomalous changes; (iii) look at the calibrator amplitudes and phases to verify that one is getting roughly constant large amplitudes, and phases roughly constant over short periods; and (iv) if you know what to expect, look for anomalous behavior in all other sources. If the delays malfunction, all amplitudes involving a particular telescope will appear noise-like; remember that noise amplitudes of about 70 counts are the most probable, with a possible range from a few counts to somewhat over a hundred. Interference or other anomalies can show up in unusual amplitudes in random records.

The user will quickly become familiar with the odd behavior of data when the fringe period exceeds 30 seconds. The fringe fitting algorithm will not give a solution for amplitude and phase unless a considerable fraction of a fringe period is included. Hence, as we see in Figure III-7 starting at $22^h22^m30^s$ LST, zeroes are recorded until enough samples of a fringe period are collected to make a solution meaningful. This problem is most serious when the spacing is short (like 100 m); but always occurs near hour angles of $+4^h40^m$ (west) when so-called cross-over occurs. At cross-over the fringe period temporarily becomes "infinite" and, depending upon the spacing, many minutes may pass before enough data are collected to fit a fringe.

Part of the cleaning process involves replacement of bad data in A/D records or headers. In practice one assumes that these are correct until something tells us otherwise, since such problems are usually rare or have negligible effect on the data. The most frequent problem occurs when a bit is "dropped" by the DDP116 when a header is written, so the information written may be garbage. Because of their placement in the header, bad baselines appear most often, but mode, LST, source name, and even scan number may occasionally be messed up. These problems are solved by use of HEADCORR or REPLACE features of INTEDIT; they are never solvable just by using the automatic programs soon to be discussed.

Once all DELETE, ERASE, HEADCORR, and REPLACE edit cards have been prepared they could be run with INTEDIT to clean the data tape. In most cases, however, one cleans the data in the same pass of INTEDIT in which one applies the automatic corrections we will now discuss.

(5) Correcting Data with INTEDIT.

Without further delay we can prepare the cards to accomplish the PHASE, AMPCOR, and CLOCK corrections. The data needed for the latter are obtainable either from observing logs or from tables kept at the interferometer control building. For the data we are processing in our example, we prepare:

```
PHASE_14969_15028;
AMPCOR_14969_15028;
CLOCK_14969_14996;0.005S
CLOCK_14997_15028;0.006S
```

Ordinarily one need not have the CLOCK correction accurate to more than a few milli-seconds; however, we have divided it in two for this case to illustrate how a number of data segments may require different CLOCK corrections.

Finally, we borrow a set of accurate baseline constants, usually already determined by NRAO staff, to apply baseline corrections. In case they are not available, we will shortly discuss the program INTBCAL whereby the user may determine his own. The BASELINE cards are of the form:

```
BASELINE_14969_15028_SBAND_BL12;-4785.5938_-15089.9192_6421.5360_0.0
```

but we will not list all of them since the user can examine them shortly in one of the figures.

All of the edit cards used to accomplish cleaning and correcting, when applied to data on RAWTAPE, produce a CORRTAPE where the visibility functions are in the $V'=A' \exp i\phi'$ stage. The following program accomplishes this:

```
//_EXEC_INTEDIT,INTAPE=3085,INNAME=RAWTAPE
//_OUTTAPE=3086,OUTNAME=CORRTAPE,OUTDISP=NEW
//INTERP.SYSIN_DD_*
TRANSFER_14969_15028;
DELETE_15001_SBAND_(03_29_43)_85-1;
DELETE_15004_XBAND_(03_57_28)_(03_57_58)_85-1;
DELETE_15008_XBAND_(04_33_45)_(04_34_45)_85-1;
ERASE_15008_XBAND_(04_35_45)_(04_39_45);
PHASE_14969_15028;
AMPCOR_14969_15028;
CLOCK_14969_14996;0.005S
CLOCK_14997_15028;0.006S
BASELINE_14969_15028_SBAND_BL12; etc.
```

(results shown in Figures III-10-12)

Note that we have added a TRANSFER card. In this case it is redundant, because all data called for particular processing is automatically transferred to the OUTUNIT; however, it is helpful to habitually include a TRANSFER card, because frequently one edits only part of the data that one wishes to remain together on tape.

The output from the above pass with INTEDIT is shown in Figures III-10-12. In Figure III-10 we see the reproduction of each card together with an interpretation, in hexadecimal form, of the instructions on each card. Format and other errors on the edit cards are found by examination of this output. Figure III-11 shows the result after sorting according to priority of each verb. Finally, Figure III-12 shows the output produced as each edit card processes the data, so that one can confirm that everything has been accomplished. At the end a summary of all processing is given.

Of course, the wise user will want to see the data itself to see if it looks correct. In particular, one can use the following program to check on whether deletions and erasures were accomplished correctly:

```
//_EXEC_INTCOPY,INTAPE=3086,INNAME=CORRTAPE
//SYSIN_DD_*
INCLUDE_15001
INCLUDE_15004
INCLUDE_15008
//_EXEC_INTSCRIB
```

(results shown in Figure III-13)

Comparing the results of Figure III-13 with the raw data in Figure III-7 proves that what was intended has been accomplished.

One could obtain an INTSCRIB display of all the data on CORRTAPE, but that would only be to confirm that the calibrators lack only gain calibration and phase centering. Since our next task is to take care of this unfinished business, and doing this forces us to examine the amplitudes and phases of the calibrators, one usually combines examination of the CORRTAPE with determination of g_S and ϕ_S for each correlator.

Before proceeding, let us diagrammatically summarize what is generally done in cleaning and correcting with INTEDIT.

```
VERB     PRI  SOURCE       SCAN1  SCAN2    LST1       LST2   SMASK XMASK

*******************************************************************************************************************

TRANSFER  14969 15028;
TRANSFER   1                  14969  15028   00 00 00   23 59 59  FFFF FFFF

000100013A793AB4000021C0FFFFFFFF00000000000000000000000000000000000000000000000000000000000000004040404040404040404040400000000

*******************************************************************************************************************

DELETE 15001 SBAND (03 29 43) 85-1;
DELETE     7                  15001  15001   03 29 40   03 29 50  F3CC 0000

000200073A993A9904EA04EBF3CC0000000000000000000000000000000000000000000000000000000000000000000004040404040404040404040400000000

*******************************************************************************************************************

DELETE  15004 XBAND (03 57 28) (03 57 58) 85-1;
DELETE     7                  15004  15004   03 57 20   03 58 00  0000 F3CC

000200073A9C3A9C059005940000F3CC00000000000000000000000000000000000000000000000000000000000000004040404040404040404040400000000

*******************************************************************************************************************

DELETE  15008 XBAND (04 33 45) (04 34 45) 85-1;
DELETE     7                  15008  15008   04 33 40   04 34 50  0000 F3CC

000200073AA03AA0066A06710000F3CC00000000000000000000000000000000000000000000000000000000000000004040404040404040404040400000000

*******************************************************************************************************************

ERASE 15008 XBAND (04 35 45) (04 39 45);
ERASE      5                  15008  15008   04 35 40   04 39 50  0000 FFFF

000400053AA03AA00676066F0000FFFFFFFF000000000000000000000000000000000000000000000000000000000004040404040404040404040400000000

*******************************************************************************************************************

PHASE 14969 15028;
PHASE      19                 14969  15028   00 00 00   23 59 59  FFFF FFFF

001100133A793AB4000021C0FFFFFFFF00000000000000000000000000000000000000000000000000000000000000004040404040404040404040400000000

*******************************************************************************************************************

AMPCOR 14969 15028;
AMPCOR     18                 14969  15028   00 00 00   23 59 59  FFFF FFFF
S-BAND DEFAULTING TO   0.070
X-BAND DEFAULTING TO   0.190

001000123A793AB4000021C0FFFFFFFF4011EB854030A3D7000000000000000000000000000000000000000000000004040404040404040404040400000000

*******************************************************************************************************************

CLOCK 14969 14996; 0.005S
CLOCK      12                 14969  14996   00 00 00   23 59 59  FFFF FFFF
CLOCK CORRECTION IS  00 00 00.00500 SECONDS

0008000C3A793A94000021C0FFFFFFFF3861981B0000000000000000000000000000000000000000000000000000000004040404040404040404040400000000

*******************************************************************************************************************

CLOCK 14997 15028; 0.006S
CLOCK      12                 14997  15028   00 00 00   23 59 59  FFFF FFFF
CLOCK CORRECTION IS  00 00 00.00600 SECONDS

0008000C3A953AB4000021C0FFFFFFFF387520870000000000000000000000000000000000000000000000000000000004040404040404040404040400000000

*******************************************************************************************************************

BASELINE 14969 15028 SBAND BL12;-4785.5938 -15086.9192 6421.5360 0.0
BASELINE  11                  14969  15028   00 00 00   23 59 59  C300 0000
BX=        -4785.593800  BY=       -15086.919200  BZ=         6421.536000  BK=          0.0

000B000B3A793AB4000021C0C3000000C41281980346DC50C43AEEB50B0F27844191589374BC6A70000000000000000404040404040404040404040000000000

*******************************************************************************************************************

BASELINE 14969 15028 SBAND BL13;-4533.3667 -14292.7077 6083.5536 0.0
BASELINE  11                  14969  15028   00 00 00   23 59 59  30C0 0000
BX=        -4533.366700  BY=       -14292.707700  BZ=         6083.553600  BK=          0.0

000B000B3A793AB4000021C030C00000C411B55DE00D1B71C437D4B52BD3C3614417C38DB8BAC710000000000000000404040404040404040404040000000000

*******************************************************************************************************************

BASELINE 14969 15028 SBAND BL23;-252.2271 -794.2115 337.9823 0.0
BASELINE  11                  14969  15028   00 00 00   23 59 59  0C30 0000
BX=         -252.227100  BY=         -794.211500  BZ=          337.982300  BK=          0.0

000B000B3A793AB4000021C00C300000C2FC3A2339C0EBEDC331A3624DD2F1A943151FB780346DC50000000000000000404040404040404040404040000000000

*******************************************************************************************************************

BASELINE 14969 15028 XBAND BL12;-14356.7814 -45260.7576 19264.6080 0.0
BASELINE  11                  14969  15028   00 00 00   23 59 59  0000 C300
BX=       -14356.781400  BY=       -45260.757600  BZ=        19264.608000  BK=          0.0

000B000B3A793AB4000021C00000C300C43814C809D49518C4B0CCC1F212D773444B4098A5E353F70000000000000000404040404040404040404040000000000

*******************************************************************************************************************

BASELINE 14969 15028 XBAND BL13;-13600.1001 -42878.1231 18250.6608 0.0
BASELINE  11                  14969  15028   00 00 00   23 59 59  0000 30C0
BX=       -13600.100100  BY=       -42878.123100  BZ=        18250.660800  BK=          0.0

000B000B3A793AB4000021C0000030C0C4352019A0275254C4A77E1F83784A2344474AA92A305532000000000000000404040404040404040404040000000000

*******************************************************************************************************************

BASELINE 14969 15028 XBAND BL23;-756.6813 -2382.6345 1013.9469 0.0
BASELINE  11                  14969  15028   00 00 00   23 59 59  0000 0C30
BX=         -756.681300  BY=        -2382.634500  BZ=         1013.946900  BK=          0.0

000B000B3A793AB4000021C000000C30C32F4AF69AD42C3CC394EA26E978D4FD433F5F26809D4951000000000000000404040404040404040404040000000000

END OF EDIT CARDS
```

Fig. III-10. First part of INTEDIT output display showing the edit cards that have been supplied and their interpretation.

```
EDIT CARD ORDER FOLLOWING SORT/MERGE STEP
(CARDS ARE RE-SORTED INTERNALLY, IN ORDER OF PRIORITY, AS NEEDED)

000100013A793A84000021C0FFFFFFFF00000000000000000000000000000000000000000000000000000000000000000000000040404040404040404040404000000000
TRANSFER  1 14969     0 15028  8640 FFFF FFFF '          ' TRANSFER SCAN RANGE 14969 TO 15028

000B000B3A793A84000021C000000C30C32F4AE69AD42C3CC394EA26E978D4FD433F5F26809D49510000000000000000040404040404040404040404000000000
BASELINE 11 14969     0 15028  8640 0000 0C30 '          ' BASELINES ARE     -756.681   -2382.635    1013.947        0.0

000B000B3A793A84000021C0000030C0C4352019A0275254C4A77E1F83784A2344474AA92A30553200000000000000000040404040404040404040404000000000
BASELINE 11 14969     0 15028  8640 0000 30C0 '          ' BASELINES ARE   -13600.100  -42878.123   18250.661        0.0

000B000B3A793A84000021C00000C300C43814C809D49518C480CCC1F212D77344484098A5E353F70000000000000000040404040404040404040404000000000
BASELINE 11 14969     0 15028  8640 0000 C300 '          ' BASELINES ARE   -14356.781  -45260.758   19264.608        0.0

000B000B3A793A84000021C00C300000C2FC3A2339C0EBEDC331A3624DD2F1A943151FB780346DC50000000000000000040404040404040404040404000000000
BASELINE 11 14969     0 15028  8640 0C30 0000 '          ' BASELINES ARE     -252.227    -794.212     337.982        0.0

000B000B3A793A84000021C030C00000C411B55DE0001871C437D4B528D3C3614417C38D88AC710000000000000000040404040404040404040404000000000
BASELINE 11 14969     0 15028  8640 30C0 0000 '          ' BASELINES ARE    -4533.367  -14292.708    6083.554        0.0

000B000B3A793A84000021C0C3000000C41281980346DC5DC43AEEEB50B0F278441915893748C6A70000000000000000040404040404040404040404000000000
BASELINE 11 14969     0 15028  8640 C300 0000 '          ' BASELINES ARE    -4785.594  -15086.919    6421.536        0.0

0008000C3A793A94000021C0FFFFFFFF38619B1B00000000000000000000000000000000000000000000000000000040404040404040404040404000000000
CLOCK     12 14969    0 14996  8640 FFFF FFFF '          ' CLOCK CORRECTION IS  00 00 00.005

001000123A793A84000021C0FFFFFFFF4011E8854030A3D7000000000000000000000000000000000000000000000040404040404040404040404000000000
AMPCOR    18 14969    0 15028  8640 FFFF FFFF '          ' SBAND-XBAND FACTORS ARE      0.070     0.190

001100133A793A84000021C0FFFFFFFF000000000000000000000000000000000000000000000000000000000000000040404040404040404040404000000000
PHASE     19 14969    0 15028  8640 FFFF FFFF '          '

0008000C3A953A84000021C0FFFFFFFF3B752087000000000000000000000000000000000000000000000000000000040404040404040404040404000000000
CLOCK     12 14997    0 15028  8640 FFFF FFFF '          ' CLOCK CORRECTION IS  00 00 00.006

000200073A993A9904EA04EBF3CC0000000000000000000000000000000000000000000000000000000000000000000040404040404040404040404000000000
DELETE     7 15001  1258 15001  1259 F3CC 0000 '          ' FLAG DATA RECORDS

000200073A9C3A9C059005940000F3CC000000000000000000000000000000000000000000000000000000000000000040404040404040404040404000000000
DELETE     7 15004  1424 15004  1428 0000 F3CC '          ' FLAG DATA RECORDS

000400053AA03AA0067606BF0000FFFFFFFF0000000000000000000000000000000000000000000000000000000000000040404040404040404040404000000000
ERASE      5 15008  1654 15008  1679 0000 FFFF '          ' ERASE SCAN

000200073AA03AA0066A06710000F3CC000000000000000000000000000000000000000000000000000000000000000040404040404040404040404000000000
DELETE     7 15008  1542 15008  1649 0000 F3CC '          ' FLAG DATA RECORDS
```

Fig. III-11. Second part of INTEDIT output where the translated edit cards are sorted and listed.

```
INTERFEROMETER EDITING PROGRAM - NRAO DUAL FREQUENCY INTERFEROMETER (S AND X BANDS) EDITING BEGINS AT 19 36 30 ON 04/04/73


INPUT FILE BEGINS AT HEADER 14969 LST 22 02 19 SIDEREAL DAY NO.  2448275

THE INPUT FILE:

THE DDNAME IS FT10F001
THE DSNAME IS HJELLMNG.RAW
THE UNIT NUMBER IS 134
THE VOLUMN SERIAL NUMBER IS 666666
THE DISPOSITION IS OLD

DCB PARAMETERS:
     RECFM IS VB (VB=>VSB)
     LRECL IS   204
     BLKSIZE IS  2248


EDIT CARD TRANSFER                 14969 15028 NOW ACTIVE AT SCAN 14969  N=  1
EDIT CARD BASELINE                 14969 15028 NOW ACTIVE AT SCAN 14969  N=  2
EDIT CARD BASELINE                 14969 15028 NOW ACTIVE AT SCAN 14969  N=  3
EDIT CARD BASELINE                 14969 15028 NOW ACTIVE AT SCAN 14969  N=  4
EDIT CARD BASELINE                 14969 15028 NOW ACTIVE AT SCAN 14969  N=  5
EDIT CARD BASELINE                 14969 15028 NOW ACTIVE AT SCAN 14969  N=  6
EDIT CARD BASELINE                 14969 15028 NOW ACTIVE AT SCAN 14969  N=  7
EDIT CARD CLOCK                    14969 14996 NOW ACTIVE AT SCAN 14969  N=  8
EDIT CARD AMPCOR                   14969 15028 NOW ACTIVE AT SCAN 14969  N=  9
EDIT CARD PHASE                    14969 15028 NOW ACTIVE AT SCAN 14969  N= 10
BASELINES NOW      -756.681300   -2382.634500     1013.946900        0.0
BASELINES NOW    -13600.100100  -42878.123100    18250.660800        0.0
BASELINES NOW    -14356.781400  -45260.757600    19264.608000        0.0
BASELINES NOW      -252.227100    -794.211500      337.982300        0.0
BASELINES NOW     -4533.366700  -14292.707700     6083.553600        0.0
BASELINES NOW     -4785.593800  -15086.919200     6421.536000        0.0

THE OUTPUT FILE:

THE DDNAME IS FT08F001
THE DSNAME IS SYS73093.T195908.RF000.FIG10#12.CORR
THE UNIT NUMBER IS 136
THE VOLUMN SERIAL NUMBER IS 777777
THE DISPOSITION IS NEW

DCB PARAMETERS:
     RECFM IS VB (VB=>VSB)
     LRECL IS   204
     BLKSIZE IS  2248


CLOCK CORRECTION HAS CHANGED FROM 00 00 00.0000 TO 00 00 00.0050 AT SCAN 14969 LST  22 02 19

EDIT CARD CLOCK                    14997 15028 NOW ACTIVE AT SCAN 14997  N= 11
EDIT CARD  CLOCK    14969 14996  00 00 00  23 59 50 IS RETIRING AT SCAN 14997                  J=  8 N+1= 11

CLOCK CORRECTION HAS CHANGED FROM 00 00 00.0050 TO 00 00 00.0060 AT SCAN 14997 LST  22 02 19

EDIT CARD DELETE                   15001 15001 NOW ACTIVE AT SCAN 15001  N= 11
EDIT CARD  DELETE   15001 15001  03 24 40  03 24 50 IS RETIRING AT SCAN 15002                  J=  2 N+1= 11
EDIT CARD DELETE                   15004 15004 NOW ACTIVE AT SCAN 15004  N= 11
EDIT CARD  DELETE   15004 15004  03 57 20  03 58 00 IS RETIRING AT SCAN 15005                  J=  2 N+1= 11
EDIT CARD ERASE                    15008 15008 NOW ACTIVE AT SCAN 15008  N= 11
EDIT CARD DELETE                   15008 15008 NOW ACTIVE AT SCAN 15008  N= 12

ALL EDIT CARDS READ AT SCAN 15008

EDIT CARD  ERASE    15008 15008  04 35 40  04 39 50 IS RETIRING AT SCAN 15009                  J=  2 N+1= 12
EDIT CARD  DELETE   15008 15008  04 33 40  04 34 50 IS RETIRING AT SCAN 15009                  J=  2 N+1= 11
EDIT CARD  TRANSFER 14969 15C28  00 00 00  23 59 50 IS RETIRING AT SCAN 15954                  J=  1 N+1= 10
EDIT CARD  BASELINE 14969 15028  00 00 00  23 59 50 IS RETIRING AT SCAN 15954                  J=  1 N+1=  9
EDIT CARD  BASELINE 14969 15028  00 00 00  23 59 50 IS RETIRING AT SCAN 15954                  J=  1 N+1=  8
EDIT CARD  BASELINE 14969 15028  00 00 00  23 59 50 IS RETIRING AT SCAN 15954                  J=  1 N+1=  7
EDIT CARD  BASELINE 14969 15028  00 00 00  23 59 50 IS RETIRING AT SCAN 15954                  J=  1 N+1=  6
EDIT CARD  BASELINE 14969 15028  00 00 00  23 59 50 IS RETIRING AT SCAN 15954                  J=  1 N+1=  5
EDIT CARD  BASELINE 14969 15028  00 00 00  23 59 50 IS RETIRING AT SCAN 15954                  J=  1 N+1=  4
EDIT CARD  CLOCK    14997 15028  00 00 00  23 59 50 IS RETIRING AT SCAN 15954                  J=  1 N+1=  3
EDIT CARD  AMPCOR   14969 15028  00 00 00  23 59 50 IS RETIRING AT SCAN 15954                  J=  1 N+1=  2
EDIT CARD  PHASE    14969 15028  00 00 00  23 59 50 IS RETIRING AT SCAN 15954                  J=  1 N+1=  1

EDITING TERMINATED BY END OF INPUT FILE

EDIT SYNOPSIS:

TRANSFER PERFORMED ON      949 RECORDS
DELETE   PERFORMED ON        6 RECORDS
ERASE    PERFORMED ON        9 RECORDS
CLOCK    PERFORMED ON      883 RFCORDS
BASELINE PERFORMED ON       90 RECORDS
AMPCOR   PERFORMED ON      883 RECORDS
PHASE    PERFORMED ON      883 RECORDS

GETHDR WAS CALLED    67 TIMES
GETDTA WAS CALLED   883 TIMES
 GETBL WAS CALLED    65 TIMES

    61 A-D RECORDS WERE PROCESSED

   1033 RECORDS READ FROM INPUT FILE
   1009 RECORDS WRITTEN ON OUTPUT FILE
```

Fig. III-12. The third and last part of the INTEDIT display in which the properties of the input data set and output data set are described and a description of what processing INTEDIT has accomplished is given.

---------- DATA FOR CONFIGURATION 1-18-19 ----------

SCAN	M	SOURCE	HA	RMS/100	AMP1R2RPHI		AMP1L2LPHI		AMP1R3RPHI		AMP1L3LPHI		AMP2R3RPHI		AMP2L3LPHI		NREC	TPOWER	LST
15001	SD	D0742+10	-04 21	000000	6520	-66	6087	-154	5415	-156	5630	-23	4900	-90	4978	49	1	655665	03 22 42
15001	XD	D0742+10	-04 20	000000	3245	55	2811	7	2741	88	3114	119	2638	143	3058	68	1	665666	03 23 12
15001	SD	D0742+10	-04 20	000000	6480	-71	6111	-159	5740	-159	5903	-27	4942	-92	4988	47	1	655665	03 23 42
15001	XD	D0742+10	-04 19	000000	3422	45	2779	-5	2663	82	3283	110	2601	147	2945	67	1	665666	03 24 12
15001	SD	D0742+10	-04 19	000000	6199	-76	5942	-165	5558	-166	5763	-34	5062	-92	4867	49	1	655665	03 24 42
15001	XD	D0742+10	-04 18	000000	3481	57	2816	10	3025	87	3476	115	2679	155	2791	75	1	665666	03 25 12
15001	XD	D0742+10	-04 17	000000	3403	87	2934	39	2915	117	3345	147	2522	152	2840	73	1	665666	03 26 12
15001	SD	D0742+10	-04 17	000000	6874	-64	6109	-153	5974	-153	6039	-20	5078	-93	4944	47	1	655665	03 26 42
15001	XD	D0742+10	-04 16	000000	3247	64	2695	17	2946	99	3210	128	2655	145	2866	67	1	665666	03 27 12
15001	SD	D0742+10	-04 16	000000	6782	-67	6025	-155	5784	-158	5828	-24	5000	-91	4995	49	1	655665	03 27 42
15001	XD	D0742+10	-04 15	000000	3283	76	2880	30	2930	111	3281	136	2688	148	2799	70	1	665666	03 28 12
15001	SD	D0742+10	-04 15	000000	6807	-62	6119	-149	5866	-150	5841	-18	5004	-93	5003	47	1	655665	03 28 42
15001	XD	D0742+10	-04 14	000000	3280	67	2833	19	2962	103	3258	132	2546	147	2851	69	1	665666	03 29 12
15001	SD	D0742+10	-04 14	00		0		0		0		0	5043	-100	5168	42	1	655665	03 29 43
15004	SD	3C454.3	04 59	1000	16497	-65	16727	-153	15296	-162	15922	-27		0		0	1	666666	03 52 28
15004	SD	3C454.3	05 00	1000	17500	-66	16507	-153	14738	-161	15623	-28		0		0	1	666666	03 52 58
15004	SD	3C454.3	05 00	0000	16503	-66	16497	-154	15201	-162	15926	-29		0		0	1	666666	03 53 28
15004	SD	3C454.3	05 01	0000	17389	-63	16911	-150	15230	-158	15877	-26		0		0	1	666666	03 53 58
15004	SD	3C454.3	05 01	1111	17195	-70	16569	-156	15325	-163	15785	-29		0		0	1	666666	03 54 28
15004	SD	3C454.3	05 02	1100	16839	-79	16463	-166	14840	-175	15795	-41		0		0	1	666666	03 54 58
15004	SD	3C454.3	05 02	0001	17653	-61	16536	-149	14983	-161	15836	-27		0		0	1	666666	03 55 28
15004	SD	3C454.3	05 03	0000	17502	-53	16798	-140	15444	-150	16022	-15		0		0	1	666666	03 55 58
15004	SD	3C454.3	05 03	100000	16711	-58	16658	-146	15118	-152	15860	-20	14390	-86	13168	55	1	666666	03 56 28
15004	XD	3C454.3	05 04	1000	14100	74	12646	25	12257	88	13984	117		0		0	1	666666	03 56 58
15004	XD	3C454.3	05 04			0		0		0		0		0		0	1	666666	03 57 28
15004	XD	3C454.3	05 05	00		0		0		0		0	11888	158	12670	90	1	666666	03 57 58
15004	SD	3C454.3	05 05	1101	17534	-77	16477	-165	15204	-174	15638	-41		0		0	1	666666	03 58 28
15004	SD	3C454.3	05 06	1011	17401	-69	16546	-157	15100	-164	15461	-32		0		0	1	666666	03 58 58
15004	SD	3C454.3	05 06	1000	17360	-63	16700	-151	15012	-160	15451	-26		0		0	1	666666	03 59 28
15008	SD	P0438-43	-00 06	000000	9581	-119	9494	153	8541	160	8898	-67	8223	-102	7836	38	1	666776	04 33 15
15008	XD	P0438-43	-00 05	00		0		0		0		0	3353	146	3314	64	1	776777	04 33 45
15008	SD	P0438-43	-00 05	000000	10398	-56	9548	-143	8927	-141	9315	-7	8313	-96	7351	43	1	666776	04 34 15
15008	XD	P0438-43	-00 04	00		0		0		0		0	2928	119	3026	37	1	777777	04 34 45
15008	SD	P0438-43	-00 04	000000	10274	-95	9672	177	8884	-178	8980	-45	8082	-98	7582	41	1	666776	04 35 15

END

Fig. III-13. An INTSCRIB display of the 30 second records for scans 15001, 15004, and 15008, after they have been selected from the CORRTAPE by INTCOPY, to allow examination of the scans where deletions or erasures should have been performed, so that it can be confirmed that the desired results were obtained.

RAWTAPE $V''=A''e^{i\phi''}$ →

OBTAIN: $V' = G'' \cdot V''$

WHERE $G'' = g_D g_P g_A \exp [i(\Delta\phi_P + \Delta\phi_C + \Delta\phi_B)]$

USING FOLLOWING VERBS OF INTEDIT:

TRANSFER, PHASE, AMPCOR, CLOCK } ALWAYS

DELETE, ERASE, AUTOEDIT, HEADCORR, POSITION } IF NEEDED

BASELINE } AS SOON AS BASELINES ARE DETERMINED

→ CORRTAPE $V'=A'e^{i\phi'}$

(6) Calibrating LL and RR Data With INTEDIT

The last stage in the data processing for LL and RR correlators is the determination of $G' = g_S \exp(-i\phi_S)$, i.e., determinations of the gain factor (g_S) needed to put all amplitudes in units of 1000 counts per flux unit, and determination of the phase center (ϕ_S). We will now describe a simple way of accomplishing this.

We make use of INTSCRIB with the CPFU and SUM options. For the sample data that we are using to illustrate the data reduction procedure, the following program will allow us to determine the CPFU and mean phase for each calibrator in the default list (see Figure III-4):

```
//_EXEC_INTCOPY,INTAPE=3086,INNAME=CORRTAPE,
//_OUTUNIT=DISK,OUTNAME='&&DATA'
//SYSIN_DD_*
INCLUDE_14969_15028
//_EXEC_INTAVG,PARM='ARITH',INUNIT=DISK,INNAME='&&DATA',
//_OUTUNIT=DISK,OUTNAME='&&SBAND'
//SYSIN_DD_*
INCLUDE_SBAND
//_EXEC_INTSCRIB,PARM='CPFU,SUM,SORT,NOGRID,RANGE=2000',
//_INUNIT=DISK,INNAME='&&SBAND'
//_EXEC_INTAVG,PARM='ARITH',INUNIT=DISK,INNAME='&&DATA',
//_OUTUNIT=DISK,OUTNAME='&&XBAND'
//SYSIN_DD_*
INCLUDE_XBAND
//_EXEC_INTSCRIB,PARM='CPFU,SUM,SORT,NOGRID,RANGE=2000,
//_INUNIT=DISK,INNAME='&&XBAND'
```

(results shown in Figure III-14 (SBAND) and III-15 (XBAND)

Let us first discuss the determination of the phase center (ϕ_S) from the results of Figure III-14 and Figure III-15. All the calibrators shown are good phase calibrators and the average phase (ϕ') for each source for each correlator is obtained because of the SUM option. As discussed earlier, we determine ϕ_S from data on ϕ' by a fit to the data according to the formula

$$\phi_S = \overline{\phi'} \ .$$

We see no significant phase drifts in the data for each scan, so we obtain ϕ_S from averaging together the ϕ' for each source:

PHASE CENTER (ϕ_S)

CORRELATOR	1R2R	1L2L	1R3R	1L3L	2R3R	2L3L
SBAND	-76	-164	-166	-33	-91	49
XBAND	38	-9	68	97	153	74

---------- DATA FOR CONFIGURATION 1-18-19 ----------

SCAN	M	SOURCE	HA	RMS/100	AMP1R2R	PHI	AMP1L2L	PHI	AMP1R3R	PHI	AMP1L3L	PHI	AMP2R3R	PHI	AMP2L3L	PHI	NREC	TPOWER	LST
14970	SD	3C48	-03 19	000000	1518	-67	1542	-155	1335	-159	1468	-27	1263	-87	1256	53	7	655665	22 16 15
14980	SD	3C48	-01 40	000000	1397	-68	1492	-157	1267	-163	1394	-30	1204	-86	1193	53	6	666666	23 55 48
14984	SD	3C48	-00 59	000000	1467	-69	1490	-157	1210	-161	1308	-29	1193	-87	1143	52	7	656665	00 36 30
14998	SD	3C48	01 20	000000	1398	-80	1488	-167	1263	-174	1399	-41	1220	-86	1188	53	7	656665	02 56 21
15011	SD	3C48	03 30	000000	1561	-70	1531	-157	1361	-167	1428	-34	1232	-84	1185	55	9	655665	05 06 22
14973	SD	3C119	-05 44	000000	1606	-81	1567	-168	1391	-173	1489	-40	1250	-89	1269	51	11	656665	22 45 48
14987	SD	3C119	-03 24	000000	1561	-84	1555	-171	1326	-177	1464	-44	1264	-87	1241	52	9	555665	01 05 51
15006	SD	3C119	-00 14	000000	1487	-71	1452	-158	1216	-165	1365	-33	1151	-86	1137	54	7	666665	04 15 56
14986	SD	3C147	-04 43	000000	1675	-72	1544	-159	1475	-166	1544	-33	1279	-86	1249	54	8	655665	00 56 31
15000	SD	3C147	-02 24	000000	1617	-72	1526	-160	1349	-167	1428	-34	1243	-86	1208	54	7	656665	03 16 03
15013	SD	3C147	-00 14	000000	1499	-63	1501	-150	1285	-158	1357	-26	1185	-86	1145	54	7	666665	05 26 02
15022	SD	3C147	02 24	000000	1557	-62	1491	-149	1325	-157	1405	-24	1224	-86	1193	54	44	555665	08 05 25
14988	SD	CTA21	-02 01	000000	1427	-85	1551	-173	1338	-176	1456	-43	1244	-90	1238	50	8	655665	01 15 30
14991	SD	3C418	05 07	0000	1519	-67	1585	-154	1419	-163	1507	-29		0		0	10	655665	01 45 03
14993	SD	NRAO140	-01 28	000000	1457	-80	1571	-167	1346	-173	1442	-41	1271	-87	1225	53	8	656665	02 06 00
15010	SD	3C138	-00 23	000000	1515	-77	1502	-164	1283	-168	1376	-36	1211	-87	1180	54	7	666665	04 56 26
15021	SD	3C138	01 27	000000	1611	-80	1583	-168	1318	-172	1411	-39	1236	-86	1167	53	5	665665	06 47 06
15014	SD	DA267	-03 48	000000	1543	-77	1513	-164	1398	-170	1467	-37	1259	-88	1240	53	7	555665	05 36 30
15015	SD	P1116+12	-05 31	000000	1725	-66	1679	-155	1468	-157	1623	-22	1431	-93	1407	48	10	666666	05 45 52
15020	SD	P1116+12	-04 41	000000	1784	-76	1617	-164	1533	-165	1563	-33	1341	-92	1303	47	7	655665	06 36 20
15028	M	3C286	-04 14	0 0 0		0	1509	-168		0	1496	-37		0	1238	48	17	556665	09 15 48

********** AVERAGES FOR CONFIGURATION 1-18-19 **********
QTY-TYPE AVG: AMP,RMS = UNWTD ARITH, PHASE = VECTOR

SOURCE	RIGHT ASC	DECLINATION	AMP 1R2R	PHI	AMP 1L2L	PHI	AMP 1R3R	PHI	AMP 1L3L	PHI	AMP 2R3R	PHI	AMP 2L3L	PHI
3C48	01 36 10	+33 01 28	1469	-71	1509	-158	1288	-165	1400	-32	1223	-86	1194	53
3C119	04 30 44	+41 35 04	1552	-79	1525	-166	1312	-172	1439	-39	1222	-87	1216	52
3C147	05 40 31	+49 50 18	1587	-67	1516	-155	1359	-162	1434	-30	1233	-86	1199	54
CTA21	03 17 27	+16 22 49	1427	-85	1552	-173	1338	-176	1456	-43	1244	-90	1238	50
3C418	20 37 49	+51 13 43	1519	-67	1586	-154	1419	-163	1508	-29	0	0	0	0
NRAO140	03 34 49	+32 13 14	1458	-80	1572	-167	1347	-173	1442	-41	1272	-87	1225	53
3C138	05 19 36	+16 36 56	1563	-78	1543	-166	1301	-170	1394	-37	1224	-86	1174	53
DA267	09 25 20	+39 09 24	1544	-77	1514	-164	1398	-170	1468	-37	1259	-88	1241	53
P1116+12	11 17 31	+12 43 40	1755	-71	1648	-159	1501	-161	1593	-27	1386	-92	1355	48
3C286	13 29 52	+30 38 58	0	0	1509	-168	0	0	1497	-37	0	0	1239	48

END

Fig. III-14. An INTSCRIB display, with PARM='CPFU,SUM,SORT', of the calibrators on the CORRTAPE, so SBAND gains and phase centers can be determined.

---------- DATA FOR CONFIGURATION 1-18-19 ----------

SCAN	M	SOURCE	HA	RMS/100	AMP1R2R	PHI	AMP1L2L	PHI	AMP1R3R	PHI	AMP1L3L	PHI	AMP2R3R	PHI	AMP2L3L	PHI	NREC	TPOWER	LST
14970	XD	3C48	-03 19	000000	947	63	888	13	845	85	1064	113	818	159	847	81	7	666666	22 16 45
14980	XD	3C48	-01 39	000000	859	61	820	12	777	82	965	108	747	162	778	83	6	666666	23 56 18
14984	XD	3C48	-00 59	000000	1010	63	920	14	773	84	980	111	743	160	825	81	6	665666	00 36 30
14998	XD	3C48	01 20	000000	926	43	873	-7	804	58	1013	87	804	165	852	87	7	665666	02 56 51
15011	XD	3C48	03 30	000000	961	72	851	23	809	81	953	110	768	170	830	91	4	676666	05 06 55
14973	XD	3C119	-05 43	000000	1117	29	999	-17	931	54	1091	82	886	155	940	76	4	666666	22 47 00
14987	XD	3C119	-03 24	000000	1068	18	987	-30	945	38	1216	65	904	162	962	82	8	665666	01 05 51
15006	XD	3C119	-00 14	000000	997	57	884	7	793	72	1005	100	665	168	759	88	7	666656	04 16 26
14986	XD	3C147	-04 43	000000	1080	66	931	18	947	81	1124	110	853	166	942	88	4	665666	00 56 46
15000	XD	3C147	-02 23	000000	1026	56	919	7	894	72	1094	99	785	165	883	87	7	665666	03 16 33
15013	XD	3C147	-00 13	000000	940	65	871	16	761	76	934	105	691	168	752	90	7	666666	05 26 32
15022	XD	3C147	02 25	000000	996	84	890	35	829	98	997	126	731	166	806	87	20	566666	08 05 57
14988	XD	CTA21	-02 01	000000	1002	10	997	-40	897	40	1134	68	876	152	919	72	8	665666	01 16 00
14991	XD	3C418	05 10	000000	953	65	894	17	841	79	1026	108	887	168	896	90	4	665666	01 48 18
14993	XD	NRAO140	-01 28	000000	952	31	929	-19	773	50	997	78	783	163	827	84	7	665666	02 06 00
15010	XD	3C138	-00 23	000000	842	36	752	-12	709	59	859	86	662	160	711	81	6	776776	04 56 26
15021	XD	3C138	01 28	000000	920	29	818	-20	777	54	940	83	737	160	807	81	5	666666	06 47 36
15014	XD	DA267	-03 48	000000	1065	40	969	-9	972	59	1164	87	877	164	948	86	6	665666	05 36 30
15015	XD	P1116+12	-05 31	000000	1291	61	1167	10	1030	96	1216	126	1100	148	1117	70	5	676676	05 46 10
15020	XD	P1116+12	-04 41	000000	1307	40	1117	-7	1132	75	1286	102	986	150	1030	73	6	665666	06 36 30
15028	M	3C286	-04 14	0 0 0	1075	19		0	959	52		0	850	149		0	17	556665	09 15 48

********** AVERAGES FOR CONFIGURATION 1-18-19 **********
QTY-TYPE AVG: AMP,RMS = UNWTD ARITH, PHASE = VECTOR

SOURCE	RIGHT ASC	DECLINATION	AMP 1R2R	PHI	AMP 1L2L	PHI	AMP 1R3R	PHI	AMP 1L3L	PHI	AMP 2R3R	PHI	AMP 2L3L	PHI
3C48	01 36 10	+33 01 28	941	61	871	11	802	78	996	106	776	163	827	85
3C119	04 30 44	+41 35 04	1061	34	957	-14	890	54	1104	81	819	161	888	82
3C147	05 40 31	+49 50 18	1011	68	903	19	858	82	1038	110	765	166	846	88
CTA21	03 17 27	+16 22 49	1003	10	998	-40	898	40	1135	68	876	152	919	72
3C418	20 37 49	+51 13 43	953	65	895	17	842	79	1026	108	888	168	897	90
NRAO140	03 34 49	+32 13 14	952	31	929	-19	774	50	997	78	783	163	828	84
3C138	05 19 36	+16 36 56	882	32	786	-16	744	56	900	84	700	160	759	81
DA267	09 25 20	+39 09 24	1065	40	970	-9	972	59	1164	87	877	164	948	86
P1116+12	11 17 31	+12 43 40	1299	50	1142	1	1081	85	1252	114	1043	149	1074	71
3C286	13 29 52	+30 38 58	1075	19	0	0	960	52	0	0	850	149	0	0

END

Fig. III-15. An INTSCRIB display, with PARM='CPFU,SUM,SORT', of the calibrators on the CORRTAPE, so XBAND gains and phase centers can be determined.

Determination of g_S is somewhat similar. Because of our having used the CPFU option to get the results shown in Figures III-14 and 15, the average CPFU for each source is obtained. Now, however, we must face the problem that very few sources are good gain calibrators. This is partly because flux densities for many sources are poorly known and partly because many, if not most, of the sources vary with time. As can be seen from Figures III-14 and 15, the CPFU vary considerably. The user must make his amplitude calibration on the basis of what he thinks is best. One could average all CPFU, counting on the errors for poorly known sources being random and canceling; or else one can select a few sources believed to be steady, well measured objects. For this example, we will do the latter, using the data for 3C48, 3C119, 3C147, 3C418, NRAO140, 3C138, and 3C286 to obtain g_S = 1000/CPFU as follows:

SYSTEM GAIN FACTORS (g_S)

CORRELATOR	1R2R	1L2L	1R3R	1L3L	2R3R	2C36
SBAND	0.644	0.647	0.754	0.686	0.817	0.830
XBAND	1.102	1.133	1.176	0.987	1.247	1.183

Now we use INTEDIT to effectively multiply

$$V = G' \; V' = g_S A' \; \exp \; [i(\phi'-\phi_S)]$$

so the CORRTAPE can be transformed into the CALTAPE for all LL and RR correlators. The following program will accomplish this, with additional forms of data display so we can evaluate how good the results are:

```
//_EXEC_INTEDIT,INTAPE=3086,INNAME=CORRTAPE,
//_OUTTAPE=3087,OUTNAME=CALTAPE
//INTERP.SYSIN_DD_*
TRANSFER_14969_15028
PHICENT_14969_15028_SBAND:-76_-164_-166_-33_-91_49
PHICENT_14969_15028__XBAND;38_-9_68_97_153_74
MULTIPLY_14969_15028_SBAND;0.644_0.647_0.754_0.686_0.817_0.830
MULTIPLY_14969_15028_XBAND;1.102_1.133_1.176_0.987_1.247_1.183
```

```
//_EXEC_INTAVG,INTAPE=3087,INNAME=CALTAPE
//SYSIN_DD_*
INCLUDE_14969_15028_SBAND
END_REWIND
INCLUDE_14969_15028_XBAND
//_EXEC_INTSCRIB,PARM='CPFU,PLOT,NOGRID,RANGE=2000'
//_EXEC_INTSCRIB,PARM='LIST,SORT'
    (results shown in Figures III-16-18)
```

Note that PHICENT uses the determined values of ϕ_S as input, then effectively multiplies each V' by exp $(-i\phi_S)$ just as MULTIPLY multiplies V' by g_S.

Examining the INTSCRIB display of the results where the CPFU option was used, we see from Figure III-17 that the important amplitude calibrators are near 1000 CPFU and the phases are all close to zero. Finally, a simple INTSCRIB display of all the data, using the SORT option, allows us to examine the final amplitudes (A) and phases (Φ) for each scan for all sources. Since everything appears normal, we can declare that all LL and RR correlators have been transformed to the state $V = A \exp(i\Phi)$ and one could begin doing science with the data.

The user may find it convenient to use one of the features of the program INTBCAL, which we will discuss in the next section, to determine the phase centers. We will discuss this as one of the uses of INTBCAL.

As before we can schematically represent the CORRTAPE to CALTAPE transformation as follows:

```
VERB     PRI  SOURCE        SCAN1  SCAN2     LST1       LST2   SMASK XMASK

**************************************************************************************************************************************

TRANSFER 14969 15028;
TRANSFER   1               14969  15028   00 00 00   23 59 59  FFFF FFFF

0001000013A793A84000021C0FFFFFFFF000000000000000000000000000000000000000000000000000000000000000000040404040404040404040404000000000

**************************************************************************************************************************************

PHICENT 14969 15028 SBAND:-76 -164 -166 -33 -91 49
PHICENT    13              14969  15028   00 00 00   23 59 59  FFFF 0000
PHICENT FACTOR(S)    -0.21111  -0.45556  -0.46111  -0.09167  -0.25278   0.13611

000A000D3A793A84000021C0FFFF0000C0360B60C0749F49C0760B60C0177777C040B6084022D82D00000000000000000404040404040404040404000000000

**************************************************************************************************************************************

PHICENT 14969 15028 XBAND:38 -9 68 97 153 74
PHICENT    13              14969  15028   00 00 00   23 59 59  0000 FFFF
PHICENT FACTOR(S)     0.10556  -0.02500   0.18889   0.26944   0.42500   0.20556

000A000D3A793A84000021C00000FFFF401805808F666666403058054044FA4F406CCCCC40349F4900000000000000000404040404040404040404000000000

**************************************************************************************************************************************

MULTIPLY 14969 15028 SBAND:0.644 0.647 0.754 0.686 0.817 0.830
MULTIPLY  14               14969  15028   00 00 00   23 59 59  FFFF 0000
MULTIPLY FACTOR(S)     0.64400   0.64700   0.75400   0.68600   0.81700   0.83000

0009000E3A793A84000021C0FFFF000040A40D2F40A5A1CA40C1062440AF9D8240D126E940D47AE1000000000000000040404040404040404040400000000

**************************************************************************************************************************************

MULTIPLY 14969 15028 XBAND:1.102 1.133 1.176 0.987 1.247 1.183
MULTIPLY  14               14969  15028   00 00 00   23 59 59  0000 FFFF
MULTIPLY FACTOR(S)     1.10200   1.13300   1.17600   0.98700   1.24700   1.18300

0009000E3A793A84000021C00000FFFF4111A1CA411220C441120DE540FCAC084113F3864112ED91000000000000000040404040404040404040400000000

END OF EDIT CARDS



EDIT CARD ORDER FOLLOWING SORT/MERGE STEP
(CARDS ARE RE-SORTED INTERNALLY, IN ORDER OF PRIORITY, AS NEEDED)

0001000013A793A84000021C0FFFFFFFF000000000000000000000000000000000000000000000000000000000000000000040404040404040404040403000000000
TRANSFER  1 14969      0 15028  8640 FFFF FFFF *           * TRANSFER SCAN RANGE 14969 TO 15028

000A000D3A793A84000021C0FFFF0000C0360B60C0749F49C0760B60C0177777C040B6084022D82D00000000000000000404040404040404040404000000000
PHICENT  13 14969      0 15028  8640 FFFF 0000 *           * PHICENT FACTOR(S)   -0.211  -0.456  -0.461  -0.092  -0.253   0.136

000A000D3A793A84000021C00000FFFF401805808F666666403058054044FA4F406CCCCC40349F4900000000000000000404040404040404040404003000000
PHICENT  13 14969      0 15028  8640 0000 FFFF *           * PHICENT FACTOR(S)    0.106  -0.025   0.189   0.269   0.425   0.206

0009000E3A793A84000021C0FFFF000040A40D2F40A5A1CA40C1062440AF9D8240D126E940D47AE1000000000000000040404040404040404040400000000
MULTIPLY 14 14969      0 15028  8640 FFFF 0000 *           * MULTIPLY FACTOR(S)    0.644   0.647   0.754   0.686   0.817   0.830

0009000E3A793A84000021C00000FFFF4111A1CA411220C441120DE540FCAC084113F3864112ED91000000000000000040404040404040404040403000000
MULTIPLY 14 14969      0 15028  8640 0000 FFFF *           * MULTIPLY FACTOR(S)    1.102   1.133   1.176   0.987   1.247   1.183



    INTERFEROMETER EDITING PROGRAM - NRAO DUAL FREQUENCY INTERFEROMETER (S AND X BANDS) EDITING BEGINS AT 18 00 59 ON 04/05/73


INPUT FILE BEGINS AT HEADER 14969 LST 22 02 19 SIDEREAL DAY NO.  2448275

THE INPUT FILE:

THE DDNAME IS FT10F001
THE DSNAME IS HJELLMNG.CORR
THE UNIT NUMBER IS 133
THE VOLUMN SERIAL NUMBER IS 555555
THE DISPOSITION IS OLD

DCB PARAMETERS:
     RECFM IS VB (VB=>VSB)
     LRECL IS   204
     BLKSIZE IS  2248


EDIT CARD TRANSFER                 14969 15028 NOW ACTIVE AT SCAN 14969  N=  1
EDIT CARD PHICENT                  14969 15028 NOW ACTIVE AT SCAN 14969  N=  2
EDIT CARD PHICENT                  14969 15028 NOW ACTIVE AT SCAN 14969  N=  3
EDIT CARD MULTIPLY                 14969 15028 NOW ACTIVE AT SCAN 14969  N=  4
EDIT CARD MULTIPLY                 14969 15028 NOW ACTIVE AT SCAN 14969  N=  5

ALL EDIT CARDS READ AT SCAN 14969


THE OUTPUT FILE:

THE DDNAME IS FT08F001
THE DSNAME IS SYS73095.T173013.RF000.FIG16#18.CAL
THE UNIT NUMBER IS 136
THE VOLUMN SERIAL NUMBER IS 777777
THE DISPOSITION IS NEW

DCB PARAMETERS:
     RECFM IS VB (VB=>VSB)
     LRECL IS   204
     BLKSIZE IS  2248



EDITING TERMINATED BY END OF INPUT FILE

EDIT SYNOPSIS:

TRANSFER PERFORMED ON      948 RECORDS
MULTIPLY PERFORMED ON     1766 RECORDS
PHICENT  PERFORMED ON     1766 RECORDS

GETHDR WAS CALLED    66 TIMES
GETDTA WAS CALLED   883 TIMES
 GETBL WAS CALLED     1 TIMES

     0 A-D RECORDS WERE PROCESSED

   1309 RECORDS READ FROM INPUT FILE
   1009 RECORDS WRITTEN ON OUTPUT FILE
```

Fig. III-16. INTEDIT output describing the processing by which data are calibrated, to obtain the CALTAPE from the CORRTAPE.

---------- DATA FOR CONFIGURATION 1-18-19 ----------

SCAN	M	SOURCE	HA	RMS/100	AMP1R2R	PHI	AMP1L2L	PHI	AMP1R3R	PHI	AMP1L3L	PHI	AMP2R3R	PHI	AMP2L3L	PHI	NREC	TPOWER	LST
14970	SD	3C48	-03 19	000000	975	9	996	9	1005	7	1005	6	1031	4	1041	3	7	655665	22 16 15
14973	SD	3C119	-05 44	000000	1032	-5	1011	-4	1047	-7	1018	-7	1019	2	1052	2	11	656665	22 45 48
14980	SD	3C48	-01 40	000000	898	8	964	7	955	3	955	3	983	5	988	4	6	666666	23 55 48
14984	SD	3C48	-00 59	000000	943	6	962	7	911	5	896	4	974	4	943	3	7	656665	00 36 30
14986	SD	3C147	-04 43	000000	1077	4	998	5	1111	-0	1058	-0	1044	5	1036	5	8	655665	00 56 31
14987	SD	3C119	-03 24	000000	1003	-8	1003	-7	997	-11	1000	-11	1029	3	1028	3	9	555665	01 05 51
14988	SD	CTA21	-02 01	000000	915	-9	1001	-9	1007	-9	994	-10	1014	1	1026	0	8	655665	01 15 30
14991	SD	3C418	05 07	0000	976	9	1021	10	1066	3	1032	4		0		0	10	655665	01 45 03
14993	SD	NRAO140	-01 28	000000	935	-4	1012	-3	1011	-7	985	-7	1031	3	1013	4	8	656665	02 06 00
14998	SD	3C48	01 20	000000	898	-4	961	-3	951	-8	958	-8	995	5	986	4	7	656665	02 56 21
15000	SD	3C147	-02 24	000000	1040	4	986	4	1015	-1	978	-1	1015	5	1002	5	7	656665	03 16 03
15006	SD	3C119	-00 14	000000	955	5	936	6	916	1	933	0	939	5	942	5	7	666665	04 15 56
15010	SD	3C138	-00 23	000000	975	-1	969	0	965	-2	942	-3	988	4	976	5	7	666665	04 56 26
15011	SD	3C48	03 30	000000	1003	6	989	7	1024	-1	978	-1	1005	6	962	6	9	655665	05 06 22
15013	SD	3C147	-00 14	000000	965	13	970	14	968	7	929	7	966	5	949	5	7	666665	05 26 02
15014	SD	DA267	-03 48	000000	991	-1	977	-0	1051	-4	1004	-4	1026	3	1028	3	7	555665	05 36 30
15015	SD	P1116+12	-05 31	000000	1102	9	1077	9	1101	9	1102	11	1165	-2	1164	-1	10	666666	05 45 52
15020	SD	P1116+12	-04 41	000000	1141	0	1041	0	1147	1	1064	0	1088	-1	1076	-2	7	655655	06 36 20
15021	SD	3C138	01 27	000000	1036	-4	1021	-4	992	-6	965	-6	1008	5	966	4	5	665665	06 47 06
15022	SD	3C147	02 24	000000	1001	14	963	15	997	9	963	9	999	5	990	5	44	555665	08 05 25
15028	M	3C286	-04 14	0 0 0		0	975	-4		0	1026	-4		0	1027	-1	17	556665	09 15 48
14970	XD	3C48	-03 19	000000	1040	25	1005	22	992	17	1045	16	1018	6	1003	6	7	666666	22 16 45
14973	XD	3C119	-05 43	000000	1225	-8	1129	-8	1090	-14	1072	-15	1100	2	1110	2	4	666666	22 47 00
14980	XD	3C48	-01 39	000000	943	23	927	21	912	13	950	11	931	8	918	9	6	666666	23 56 18
14984	XD	3C48	-00 59	000000	1107	25	1038	23	907	16	964	14	923	6	970	7	6	665666	00 36 30
14986	XD	3C147	-04 43	000000	1188	28	1053	27	1110	13	1107	13	1061	13	1112	14	4	665666	00 56 46
14987	XD	3C119	-03 24	000000	1170	-20	1113	-21	1105	-30	1193	-31	1126	9	1134	8	8	665656	01 05 51
14988	XD	CTA21	-02 01	000000	1102	-28	1123	-31	1049	-28	1113	-29	1088	-1	1082	-2	8	665666	01 16 00
14991	XD	3C418	05 10	000000	1046	27	1011	26	985	11	1009	11	1103	15	1057	16	4	665666	01 48 18
14993	XD	NRAO140	-01 28	000000	1045	-7	1046	-9	905	-18	980	-19	974	9	972	10	7	665666	02 06 00
14998	XD	3C48	01 20	000000	1018	5	938	2	942	-9	995	-11	998	12	1006	13	7	665666	02 56 51
15000	XD	3C147	-02 23	000000	1127	18	1039	16	1050	4	1078	2	978	12	1043	13	7	665666	03 16 33
15006	XD	3C119	-00 14	000000	1092	19	997	16	928	3	987	2	826	15	895	14	7	666665	04 16 26
15010	XD	3C138	-00 23	000000	925	-2	847	-3	828	-9	844	-11	823	7	838	7	5	776776	04 56 26
15011	XD	3C48	03 30	000000	1053	34	962	32	946	13	935	13	956	18	981	17	4	676666	05 06 55
15013	XD	3C147	-00 13	000000	1034	27	985	25	892	8	920	8	860	15	887	15	7	666666	05 26 32
15014	XD	DA267	-03 48	000000	1173	2	1098	0	1142	-9	1147	-10	1092	11	1120	12	6	665666	05 36 30
15015	XD	P1116+12	-05 31	000000	1412	22	1312	19	1200	28	1185	29	1362	-5	1311	-4	5	676676	05 46 10
15020	XD	P1116+12	-04 41	000000	1425	2	1250	2	1323	6	1263	5	1218	-3	1208	-1	6	665666	06 36 30
15021	XD	3C138	01 28	000000	1011	-9	922	-10	911	-14	925	-14	913	7	952	6	5	666666	06 47 36
15022	XD	3C147	02 25	000000	1094	46	1005	44	971	30	982	28	909	12	953	13	20	566666	08 05 57
15028	M	3C286	-04 14	0 0 0	1181	-19		0	1127	-16		0	1058	-4		0	17	556665	09 15 48

END

Fig. III-17a. First part of INTSCRIB display, with PARM='CPFU,PLOT,NOGRID,RANGE=2000', of the scan average of calibrators on the CALTAPE.

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                        RHAND AMPLITUDES AND PHASES FOR CONFIGURATION 1-18-19
                     PLOT RANGES FOR AMP: 0 ->  2000 PER SYMBOL, PHASE: -180 -> +180

 SCAN SOURCE HA +--------+---CORR-+-1R2R---+--------+--------+---CORR-+-1R3R---+--------+--------+---CORR-+-2R3R---+--------+  LST
14970 3C48      I                 AP                I                 AP                I                 PA                IS 22 16
14973 3C119     I                 PA                I                P A                I                 X                 IS 22 45
14980 3C48      I               A  P                I                AP                 I                 X                 IS 23 55
14984 3C48      I                A P                I               A P                 I                 X                 IS 00 36
14986 3C147     I                 PA                I                 P A               I                  X                IS 00 56
14987 3C119     I                PA                 I                PA                 I                 PA                IS 01 05
14988 CTA21     I               AP                  I                PA                 I                 X                 IS 01 15
14991 3C418     I                 AP                I                 PA                X                                   IS 01 45
14993 NRAO140   I                AP                 I                PA                 I                 PA                IS 02 06
14998 3C48      I               A P                 I                X                  I                 X                 IS 02 56
15000 3C147     I                 PA                I                 X                 I                 AP                IS 03 16
15006 3C119     I                A P                I                AP                 I                A P                IS 04 15
15010 3C138     I                 X                 I                AP                 I                 X                 IS 04 56
15011 3C48      I                 AP                I                 X                 I                 AP                IS 05 06
15013 3C147     I                A P                I                A P                I                A P                IS 05 26
15014 DA267     I                 X                 I                 PA                I                 X                 IS 05 36
15015 P1116+12  I                  PA               I                  PA               I                 P  A              IS 05 45
15020 P1116+12  I                 P  A              I                 P  A              I                 P A               IS 06 36
15021 3C138     I                 PA                I                PA                 I                 X                 IS 06 47
15022 3C147     I                 AP                I                 AP                I                 AP                IS 08 05
15028 3C286     X                                   X                                   X                                   I  09 15
14970 3C48      I                  AP               I                 A P               I                 AP                IX 22 16
14973 3C119     I                P    A             I                P  A               I                 P A               IX 22 47
14980 3C48      I                A  P               I               A  P                I                A P                IX 23 56
14984 3C48      I                   AP              I               A   P               I                A P                IX 00 36
14986 3C147     I                    X              I                  PA               I                  X                IX 00 56
14987 3C119     I               P    A              I              P    A               I                  PA               IX 01 05
14988 CTA21     I              P    A               I              P   A                I                 P A               IX 01 16
14991 3C418     I                  A P              I                 AP                I                   X               IX 01 48
14993 NRAO140   I                P A                I               X                   I                 AP                IX 02 06
14998 3C48      I                 X                 I                X                  I                 AP                IX 02 56
15000 3C147     I                   X               I                 PA                I                 AP                IX 03 16
15006 3C119     I                   X               I                AP                 I              A   P                IX 04 16
15010 3C138     I                AP                 I              A P                  I              A   P                IX 04 56
15011 3C48      I                  A P              I                A P                I                A  P               IX 05 06
15013 3C147     I                  A P              I               A  P                I              A    P               IX 05 26
15014 DA267     I                 P  A              I                P   A              I                  PA               IX 05 36
15015 P1116+12  I                   P    A          I                    PA             I                 P      A          IX 05 46
15020 P1116+12  I                 P       A         I                  P    A           I                 P   A             IX 06 36
15021 3C138     I                PA                 I                AP                 I               A  P                IX 06 47
15022 3C147     I                   A  P            I                A   P              I               A  P                IX 08 05
15028 3C286     I               P    A              I               P   A               I                 PA                I  09 15
 SCAN SOURCE HA +--------+---CORR-+-1R2R---+--------+--------+---CORR-+-1R3R---+--------+--------+---CORR-+-2R3R---+--------+  LST
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                        LHAND AMPLITUDES AND PHASES FOR CONFIGURATION 1-18-19
                     PLOT RANGES FOR AMP: 0 ->  2000 PER SYMBOL, PHASE: -180 -> +180

 SCAN SOURCE HA +--------+---CORR-+-1L2L---+--------+--------+---CORR-+-1L3L---+--------+--------+---CORR-+-2L3L---+--------+  LST
14970 3C48      I                 AP                I                 AP                I                 PA                IS 22 16
14973 3C119     I                 X                 I                PA                 I                 PA                IS 22 45
14980 3C48      I                A P                I                AP                 I                 X                 IS 23 55
14984 3C48      I                A P                I               A P                 I                AP                 IS 00 36
14986 3C147     I                 X                 I                 PA                I                  X                IS 00 56
14987 3C119     I                PA                 I                PA                 I                 PA                IS 01 05
14988 CTA21     I                PA                 I                PA                 I                 X                 IS 01 15
14991 3C418     I                 AP                I                 PA                X                                   IS 01 45
14993 NRAO140   I                 X                 I                PA                 I                 X                 IS 02 06
14998 3C48      I                AP                 I                X                  I                 X                 IS 02 56
15000 3C147     I                 X                 I                 X                 I                 X                 IS 03 16
15006 3C119     I                A P                I                AP                 I                AP                 IS 04 15
15010 3C138     I                AP                 I                AP                 I                 X                 IS 04 56
15011 3C48      I                 AP                I                 X                 I                 AP                IS 05 06
15013 3C147     I                A P                I                A P                I                AP                 IS 05 26
15014 DA267     I                 X                 I                 X                 I                 PA                IS 05 36
15015 P1116+12  I                  X                I                  PA               I                 P  A              IS 05 45
15020 P1116+12  I                 PA                I                 PA                I                 PA                IS 06 36
15021 3C138     I                 X                 I                X                  I                AP                 IS 06 47
15022 3C147     I                A P                I                A P                I                 X                 IS 08 05
15028 3C286     I                 X                 I                 X                 I                 PA                I  09 15
14970 3C48      I                 A P               I                  AP               I                 AP                IX 22 16
14973 3C119     I                P  A               I                P A                I                 P A               IX 22 47
14980 3C48      I                A  P               I                A P                I                A P                IX 23 56
14984 3C48      I                  AP               I                A P                I                A P                IX 00 36
14986 3C147     I                  A P              I                  PA               I                  PA               IX 00 56
14987 3C119     I               P   A               I              P     A              I                  PA               IX 01 05
14988 CTA21     I              P    A               I              P    A               I                 PA                IX 01 16
14991 3C418     I                 A  P              I                 AP                I                  AP               IX 01 48
14993 NRAO140   I                P A                I               P A                 I                 AP                IX 02 06
14998 3C48      I                 X                 I                PA                 I                 AP                IX 02 56
15000 3C147     I                  AP               I                 PA                I                  X                IX 03 16
15006 3C119     I                 A P               I                 X                 I               A  P                IX 04 16
15010 3C138     I              A  P                 I              A P                  I              A   P                IX 04 56
15011 3C48      I                A   P              I                A P                I                 A P               IX 05 06
15013 3C147     I                 A P               I                A P                I               A   P               IX 05 26
15014 DA267     I                 P A               I                P   A              I                  PA               IX 05 36
15015 P1116+12  I                   P   A           I                    X              I                 P     A           IX 05 46
15020 P1116+12  I                 P    A            I                  P   A            I                 P   A             IX 06 36
15021 3C138     I                X                  I                X                  I                A P                IX 06 47
15022 3C147     I                 A   P             I                 A  P              I                A P                IX 08 05
15028 3C286     X                                   X                                   X                                   I  09 15
 SCAN SOURCE HA +--------+---CORR-+-1L2L---+--------+--------+---CORR-+-1L3L---+--------+--------+---COPP-+-2L3L---+--------+  LST
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Fig. III-17b. Second part of the INTSCRIB display, with PARM='CPFU,PLOT,NOGRID, RANGE=2000', of the scan averages of calibrators on the CALTAPE.

---------- DATA FOR CONFIGURATION 1-18-19 ----------

SCAN	M	SOURCE	HA	RMS/100	AMP1R2RPHI		AMP1L2LPHI		AMP1R3RPHI		AMP1L3LPHI		AMP2R3RPHI		AMP2L3LPHI		NREC	TPOWER	LST
14969	SD	P0056-17	-02 51	000000	643	-6	714	-6	701	-3	711	-4	823	-6	812	-4	8	665665	22 06 07
14979	SD	P0056-17	-01 12	000000	700	2	660	1	682	5	632	5	847	-7	785	-7	9	655665	23 45 18
15003	SD	P0056-17	02 49	000000	628	9	666	8	705	7	618	9	832	-4	772	-4	8	655665	03 47 08
14969	XD	P0056-17	-02 51	000000	110	0	140	0	92	-13	100	0	200	-3	136	-17	7	666666	22 06 07
14979	XD	P0056-17	-01 11	000000	128	39	144	34	128	39	113	45	131	-9	116	-31	9	776777	23 45 48
15003	XD	P0056-17	02 49	000000	155	15	202	33	174	24	161	30	245	12	177	-16	3	666666	03 47 08
14970	SD	3C48	-03 19	000000	9137	10	9060	9	9076	6	9216	6	9182	5	9299	5	7	655665	22 16 15
14980	SD	3C48	-01 40	000000	8410	8	8787	7	8640	4	8768	4	8797	4	8870	4	6	666666	23 55 48
14984	SD	3C48	-00 59	000000	8826	8	8771	7	8273	6	8250	6	8721	3	8529	3	7	656665	00 36 30
14998	SD	3C48	01 20	000000	8292	-9	8751	-10	8537	-11	8799	-11	8876	2	8863	2	7	656665	02 56 21
15011	SD	3C48	03 30	000000	9101	-3	8969	-3	9114	-7	8938	-8	8908	4	8795	3	9	655665	05 06 22
14970	XD	3C48	-03 19	000000	3175	20	3203	18	3294	11	3326	11	3319	10	3232	9	7	666666	22 16 45
14980	XD	3C48	-01 39	000000	2877	18	2957	17	3041	11	3031	9	3066	9	2977	9	6	666666	23 56 18
14984	XD	3C48	-00 59	000000	3411	21	3355	20	3046	14	3102	14	3076	6	3179	6	6	665666	00 36 30
14998	XD	3C48	01 20	000000	3064	-21	3147	-22	3123	-25	3185	-25	3306	3	3256	4	7	665666	02 56 51
15011	XD	3C48	03 30	000000	3144	3	3069	4	3115	-7	3029	-6	3169	10	3184	10	4	676666	05 06 55
14971	SD	D0224+67	-04 01	000000	1030	18	1125	18	1118	10	1052	9	1237	6	1154	9	9	555665	22 25 24
14985	SD	D0224+67	-01 40	000000	1222	13	1154	14	1127	7	1146	6	1166	6	1167	6	10	555665	00 45 41
14999	SD	D0224+67	00 38	000000	1081	9	1114	9	1082	4	1043	5	1200	2	1111	3	9	655665	03 05 19
15012	SD	D0224+67	02 49	000000	1016	10	1063	9	1086	6	1074	5	1210	1	1160	2	12	555665	05 15 43
14971	XD	D0224+67	-04 00	000000	1732	50	1850	52	1719	29	1766	31	1777	20	1751	19	5	666666	22 26 30
14985	XD	D0224+67	-01 40	000000	1945	32	1869	33	1873	16	1949	16	1696	16	1888	17	5	665666	00 46 26
14999	XD	D0224+67	00 39	000000	1831	23	1825	25	1787	15	1796	17	1650	9	1736	8	5	665666	03 06 25
15012	XD	D0224+67	02 50	000000	1700	29	1716	30	1770	18	1882	20	1737	10	1697	8	3	666666	05 16 58
14972	SD	NRA091	-03 26	000000	3727	6	3979	6	4016	5	3972	4	3951	1	3970	1	7	655665	22 36 23
15005	SD	NRA091	02 02	000000	3690	-4	3859	-4	3695	-5	3845	-5	3840	1	3810	1	7	655665	04 05 57
14972	XD	NRA091	-03 26	000000	2600	9	2781	9	2819	8	2772	9	2790	0	2710	0	7	666666	22 36 53
15005	XD	NRA091	02 03	000000	2619	-13	2704	-12	2578	-13	2697	-14	2862	2	2804	3	7	666666	04 06 27
14973	SD	3C119	-05 44	000000	5807	-3	5526	-3	5675	-7	5605	-7	5453	4	5646	4	11	656665	22 45 48
14987	SD	3C119	-03 24	000000	5622	-2	5492	-2	5429	-6	5542	-6	5553	4	5571	4	9	555665	01 05 51
15006	SD	3C119	-00 14	000000	5215	3	5095	3	4900	-1	5120	-1	4999	4	5068	3	7	666665	04 15 56
14973	XD	3C119	-05 43	000000	2493	-9	2402	-8	2419	-19	2280	-19	2394	8	2392	8	4	666666	22 47 00
14987	XD	3C119	-03 24	000000	2420	-10	2416	-10	2488	-21	2583	-22	2516	12	2482	12	8	665666	01 05 51
15006	XD	3C119	-00 14	000000	2161	6	2110	6	2031	-3	2111	-2	1828	10	1925	9	7	666666	04 16 26
14974	SD	P2149-28	01 06	000000	1944	4	1933	4	1987	10	1906	11	1933	-7	1963	-7	4	665665	22 57 25
14981	SD	P2149-28	02 15	000000	1838	-26	1909	-26	1976	-20	1904	-20	1939	-6	1881	-6	10	666666	00 06 20
14974	XD	P2149-28	01 07	000000	870	1	810	1	869	30	836	25	1002	-17	955	-18	4	666666	22 57 55
14981	XD	P2149-28	02 15	000000	880	-91	790	-89	844	-73	785	-68	895	-16	819	-18	5	776676	00 06 20
14975	SD	OV080	03 17	000000	1349	-7	1298	-7	1360	-0	1300	-1	1338	-6	1249	-7	10	655665	23 05 55
14975	XD	OV080	03 17	000000	1024	-26	974	-27	956	-16	965	-16	947	-7	912	-4	5	665666	23 06 40
14976	SD	BLLAC	01 14	000000	6560	1	5910	0	5960	-0	5860	0	6029	0	5920	0	8	666665	23 15 57
14976	XD	BLLAC	01 14	000000	7075	5	6668	4	6801	3	6544	4	6380	1	6730	1	6	665666	23 15 57
14977	SD	3C454.3	00 32	000000	10154	-4	10176	-4	10186	-3	10209	-4	10540	-1	10391	-1	8	655665	23 25 35
14990	SD	3C454.3	02 43	000000	9458	2	10777	2	10742	1	10952	1	10371	1	10790	1	10	655665	01 35 53
14997	SD	3C454.3	03 52	000000	10581	4	10758	3	11030	2	10779	2	11140	1	10910	0	12	655665	02 45 25
15004	SD	3C454.3	05 02	000000	11174	-3	10813	-3	11293	-6	10982	-5	11582	1	10895	2	12	666666	03 55 36
14977	XD	3C454.3	00 33	000000	11622	12	11616	11	11181	15	11100	15	11518	-4	11450	-4	7	666666	23 26 27
14990	XD	3C454.3	02 44	000000	12333	19	13664	19	13590	17	13733	17	13870	1	13644	1	4	665666	01 37 01
14997	XD	3C454.3	03 52	000000	13268	9	13616	8	13846	6	13174	6	14200	-0	13781	-1	3	666666	02 45 25
15004	XD	3C454.3	05 04	001000	13976	-9	13755	-7	13607	-4	13360	-11	14748	-6	14587	5	2	666666	03 57 28

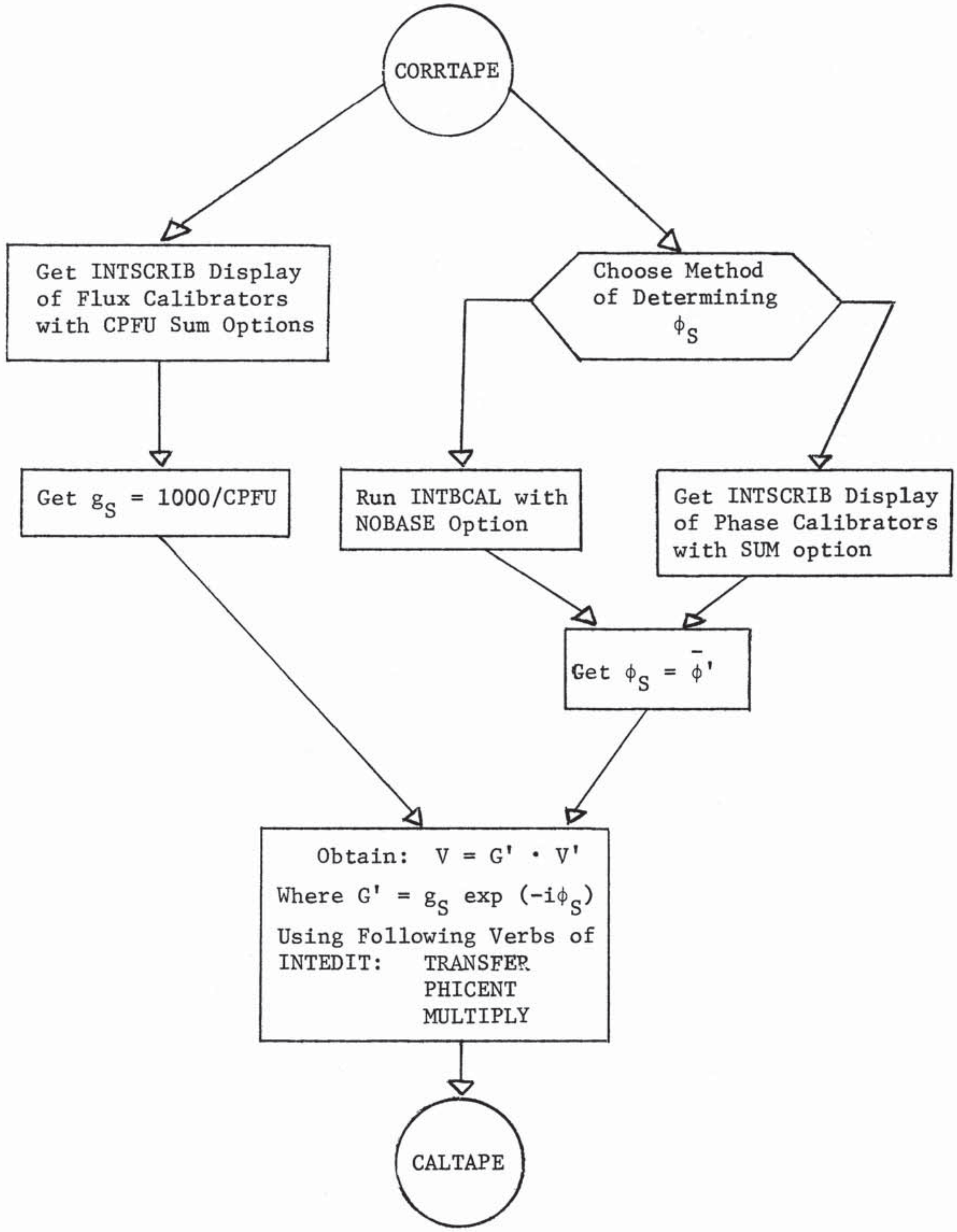
SCAN	M	SOURCE	HA	RMS/100	AMP1R2RPHI		AMP1L2LPHI		AMP1R3RPHI		AMP1L3LPHI		AMP2R3RPHI		AMP2L3LPHI		NREC	TPOWER	LST
14978	SD	P0114-21	-01 39	000000	2163	15	2207	14	2192	20	2180	21	2248	-5	2258	-5	8	655665	23 36 05
14983	SD	P0114-21	-00 48	000000	2396	-23	2206	-22	2338	-15	2233	-15	2332	-8	2261	-8	6	555665	00 26 41
14989	SD	P0114-21	00 10	000000	2350	0	2290	-1	2310	5	2258	5	2382	-6	2291	-6	8	655665	01 26 05
14978	XD	P0114-21	-01 39	000000	660	2	631	5	639	20	592	22	651	-21	588	-18	7	776777	23 36 05
14983	XD	P0114-21	-00 48	000000	784	-46	777	-44	764	-27	760	-27	765	-17	765	-20	6	665666	00 27 11
14989	XD	P0114-21	00 10	000000	766	-12	851	-9	800	3	771	3	836	-15	800	-18	7	665666	01 26 05
14982	SD	CYGX-3	03 45	000000	3911	10	3844	10	3949	7	3812	8	3940	1	3790	0	8	655665	00 16 28
14982	XD	CYGX-3	03 46	000000	2180	35	2099	35	2178	28	2097	28	2121	6	2108	8	3	665666	00 17 43
14986	SD	3C147	-04 43	000000	14199	11	12838	11	14195	4	13725	4	13215	7	13181	7	8	655665	00 56 31
15000	SD	3C147	-02 24	000000	13457	6	12643	6	12833	1	12662	1	12752	5	12710	5	7	656665	03 16 03
15013	SD	3C147	-00 14	000000	12328	13	12425	13	12143	8	11958	7	12091	4	11988	4	7	666665	05 26 02
15022	SD	3C147	02 24	000000	12587	7	12371	7	12509	5	12362	5	12486	2	12474	2	44	555665	08 05 25
14986	XD	3C147	-04 43	000000	5536	39	5163	40	5674	21	5403	22	5344	19	5519	20	4	665666	00 56 46
15000	XD	3C147	-02 23	000000	5109	17	4987	18	5256	4	5221	4	4872	12	5101	13	7	665666	03 16 33
15013	XD	3C147	-00 13	000000	4653	23	4762	24	4427	8	4504	9	4336	14	4375	14	7	666666	05 26 32
15022	XD	3C147	02 25	000000	4859	23	4883	24	4737	17	4818	17	4561	4	4702	6	20	566666	08 05 57
14988	SD	CTA21	-02 01	000000	4755	-5	5079	-5	5068	-5	5099	-5	5049	0	5150	0	8	655665	01 15 30
14988	XD	CTA21	-02 01	000000	1747	-23	1879	-25	1831	-20	1866	-20	1890	-1	1840	-1	8	665666	01 16 00
14991	SD	3C418	05 07	0000	4041	-2	4151	-2	4296	-3	4233	-2		0		0	10	655665	01 45 03
14991	XD	3C418	05 10	000000	3218	-15	3264	-15	3324	-16	3262	-15	3723	2	3486	4	4	665666	01 48 18
14992	SD	P0106+01	00 49	000000	2711	5	2606	6	2680	7	2567	7	2750	-1	2660	-1	6	655665	01 56 50
15007	SD	P0106+01	03 19	000000	2613	-3	2602	-2	2684	-3	2604	-4	2690	-0	2710	-0	10	655665	04 26 35
14992	XD	P0106+01	00 50	000000	4305	23	4205	23	4290	28	4212	27	4062	-5	4269	-4	6	665666	01 57 20
15007	XD	P0106+01	03 19	000000	4140	1	4042	2	4160	1	3990	0	4370	-1	4360	-0	4	666666	04 26 35
14993	SD	NRA0140	-01 28	000000	2613	-3	2783	-3	2747	-4	2728	-5	2771	2	2733	3	8	656665	02 06 00
14993	XD	NRA0140	-01 28	000000	2045	-12	2156	-13	1945	-17	2021	-17	2080	6	2033	6	7	665666	02 06 00
14994	SD	P0735+17	-05 19	000000	1957	-13	1897	-13	1959	-11	1898	-12	1920	-1	1910	-0	9	666665	02 16 39
14994	XD	P0735+17	-05 19	000000	1956	-29	1844	-29	1768	-29	1681	-26	1793	-4	1901	-2	3	666666	02 16 45
14995	SD	3C120	-02 06	000000	6222	-2	6695	-2	6710	0	6589	0	7100	-0	7041	-1	6	655665	02 25 38
14995	XD	3C120	-02 05	000000	13084	-11	13726	-12	13357	-5	13557	-5	14191	-7	14224	-6	7	665666	02 26 28
14996	SD	3C446	04 13	000000	5016	12	5318	12	5479	11	5503	12	5370	0	5370	-0	7	666666	02 37 49
14996	XD	3C446	04 13	000000	4265	-20	4508	-20	4775	-18	4326	-18	4604	-3	4261	-1	2	666666	02 37 38
15001	SD	D0742+10	-04 17	000000	4312	13	3823	15	4094	15	3881	15	4030	-1	4130	-0	7	655665	03 26 17
15019	SD	D0742+10	-01 17	000000	3810	-1	3850	-0	3770	-1	3861	-1	3750	1	3820	1	7	655665	06 26 05
15001	XD	D0742+10	-04 17	000000	3314	33	3052	36	3369	34	3128	34	3240	0	3310	1	7	665666	03 26 12
15019	XD	D0742+10	-01 17	000000	2955	-6	3052	-5	2772	-5	3032	-5	2820	0	3020	0	7	665666	06 26 35
15002	SD	P0607-15	-02 32	000000	1480	-0	1540	-0	1515	5	1435	5	1566	-5	1445	-5	8	655665	03 35 30
15002	XD	P0607-15	-02 32	000000	2663	3	2837	4	2577	17	2545	18	2800	-12	2771	-12	8	665666	03 36 00
15008	SD	P0438-43	-00 03	000000	6461	1	6180	0	6433	10	6253	10	6513	-9	6232	-10	7	666776	04 36 15
15008	XD	P0438-43	-00 02	010000	3134	-3	2383	-27	2630	1	2521	-2	3877	-24	3421	-26	6	787787	04 36 45
15009	SD	P0614-34	-01 30	000000	2137	-12	1991	-13	1996	-5	1945	-4	2101	-6	2004	-7	8	666666	04 45 25
15018	SD	P0614-34	00 00	000000	2097	-5	2056	-4	2060	1	2000	2	2118	-5	1998	-5	7	666665	06 16 35
15009	XD	P0614-34	-01 29	000000	941	-31	863	-25	821	-3	830	0	917	-20	848	-21	8	776777	04 45 55
15018	XD	P0614-34	00 00	000000	999	-18	1044	-17	950	-1	1000	-2	1022	-16	1050	-16	7	666666	06 16 13
15010	SD	3C138	-00 23	000000	5501	-1	5471	-1	5346	-3	5360	-4	5441	4	5443	4	7	666665	04 56 26
15021	SD	3C138	01 27	000000	5785	-8	5788	-8	5497	-8	5485	-8	5556	3	5393	2	5	665665	06 47 06

Fig. III-18. INTSCRIB display, with PARM='LIST,SORT', of the scan averages, sorted in order of frequency, for all the data on the CALTAPE.

SCAN	M	SOURCE	HA	RMS/100	AMP1R2RPHI		AMP1L2LPHI		AMP1R3RPHI		AMP1L3LPHI		AMP2R3RPHI		AMP2L3LPHI		NREC	TPOWER	LST
15010	XD	3C138	-00 23	000000	2592	-2	2373	-3	2319	-9	2363	-11	2305	7	2347	7	6	776776	04 56 26
15021	XD	3C138	01 28	000000	2831	-9	2583	-10	2551	-14	2590	-14	2557	7	2666	6	5	666666	06 47 36
15014	SD	DA267	-03 48	000000	4760	-1	4690	-0	5049	-4	4820	-4	4927	3	4939	3	7	555665	05 36 30
15014	XD	DA267	-03 48	000000	12558	2	11749	0	12228	-9	12282	-10	11687	11	11988	12	6	665666	05 36 30
15015	SD	P1116+12	-05 31	000000	1874	9	1831	9	1872	9	1874	11	1980	-2	1980	-1	10	666666	05 45 52
15020	SD	P1116+12	-04 41	000000	1940	0	1770	0	1950	1	1810	0	1850	-1	1830	-2	7	655665	06 36 20
15015	XD	P1116+12	-05 31	000000	1695	22	1574	19	1440	28	1422	29	1635	-5	1573	-4	5	676676	05 46 10
15020	XD	P1116+12	-04 41	000000	1711	2	1500	2	1588	6	1516	5	1462	-3	1450	-1	6	665666	06 36 30
15016	SD	P1055+01	-05 01	000000	3494	-28	3095	-28	3441	-23	3230	-23	3391	-5	3361	-5	12	666666	05 55 33
15016	XD	P1055+01	-05 01	000000	3942	-78	3409	-80	3453	-62	3358	-64	3925	-17	3939	-16	5	666666	05 55 33
15017	SD	P0859-14	-02 55	000000	2536	-10	2775	-9	2790	-5	2718	-5	2847	-4	2853	-6	8	655665	06 05 43
15017	XD	P0859-14	-02 54	000000	1966	-34	2013	-33	1839	-16	1897	-18	2049	-17	2043	-17	8	666666	06 06 13
15023	M	1216+48	-03 45	0 0 0		0	939	-58		0	938	-60		0	1025	1	17	555665	08 31 51
15023	M	1216+48	-03 45	0 0 0	1058	-178		0	984	176		0	1064	4		0	17	555665	08 31 51
15024	M	1242+41	-04 02	0 0 0		0	1115	24		0	1079	20		0	1280	2	14	555665	08 40 33
15024	M	1242+41	-04 02	0 0 0	698	59		0	673	48		0	597	11		0	14	555665	08 40 33
15025	M	1244+49	-03 57	0 0 0		0	753	152		0	768	159		0	844	-6	14	555665	08 48 35
15025	M	1244+49	-03 57	0 0 0	193	108		0	225	117		0	455	-20		0	14	555665	08 48 35
15026	M	1315+34	-04 18	0 0 0		0	494	24		0	522	20		0	519	4	17	555665	08 57 27
15026	M	1315+34	-04 18	0 0 0	602	59		0	553	46		0	529	10		0	17	555665	08 57 27
15027	M	1317+52	-04 11	0 0 0		0	438	-2		0	333	2		0	997	12	13	555665	09 06 45
15027	M	1317+52	-04 11	0 0 0	508	54		0	471	40		0	540	13		0	13	555665	09 06 45
15028	M	3C286	-04 14	0 0 0		0	9847	-4		0	10363	-4		0	10380	-1	17	556665	09 15 48
15028	M	3C286	-04 14	0 0 0	6144	-19		0	5861	-16		0	5501	-4		0	17	556665	09 15 48

END

Fig. III-18 continued.


CORRTAPE
Get INTSCRIB Display of Flux Calibrators with CPFU Sum Options
Choose Method of Determining ϕ_S
Get g_S = 1000/CPFU
Run INTBCAL with NOBASE Option
Get INTSCRIB Display of Phase Calibrators with SUM option
Get $\phi_S = \bar{\phi}'$
Obtain: $V = G' \cdot V'$
Where $G' = g_S \exp(-i\phi_S)$
Using Following Verbs of INTEDIT: TRANSFER PHICENT MULTIPLY
CALTAPE

(b) INTBCAL

(1) Determination of Baselines

Most of the time, the user need not worry about baseline calibration because NRAO staff will always determine the appropriate corrections after each telescope move. However, occasionally the user may want to determine them himself because he needs better than average phase calibration. In addition, the user should be aware of what is involved because, at the very least, some residual phase errors in his data will be due to imperfections in the assumed baselines.

A program called INTBCAL is used to determine accurate baselines. Using data for all LL and RR correlators, it takes phase calibrator data at the stage where the visibility function is described by

$$g_D g_P g_A A'' \exp\left[i(\phi'' + \Delta\phi_P + \Delta\phi_C)\right]$$

so the final calibrated phase, Φ, differs from $\phi'' + \Delta\phi_P + \Delta\phi_C$ such that

$$\Phi = \phi'' + \Delta\phi_P + \Delta\phi_C + \Delta\phi_B - \phi_S + \text{NOISE}.$$

Since, for calibrators observed at the reference position, $\Phi = 0$, one solves for $\Delta\phi_B = 2\pi\, \Delta\underset{\sim}{B} \cdot \underset{\sim}{s}_o$ and ϕ_S, in a least squares sense, using the equation

$$\phi'' + \Delta\phi_P + \Delta\phi_C + 2\pi\Delta\underset{\sim}{B} \cdot \underset{\sim}{s}_o - \phi_S + \text{NOISE} = 0 \qquad \text{III-(13)}$$

The program INTBCAL that performs this least squares solution is controlled by INCLUDE/EXCLUDE cards and requires input in the form of scan averaged phases. There are a number of PARM options that can be used, the most important of which are PARM='NOK', and PARM='NOBASE'. Under circumstances requiring exceptional accuracy, one includes in Equation III-(13) the so-called k, ℓ and m terms which correct for errors introduced by telescope geometry (see Wade, C. M., Ap. J., 162, 381, 1970). We will, however, discuss only the case where determination of $\Delta \underset{\sim}{B} = (\Delta B_x, \Delta B_y, \Delta B_z)$ and ϕ_S are sufficient. For further details consult the Users Guide.

To illustrate the use of INTBCAL, let us apply it to the phase calibrators used in the scan range 14969-15028 that we have been using in our examples. Because most of the sources are phase calibrators, we can determine baselines using the following program:

```
//_EXEC_INTAVG,INTAPE=3086,INNAME=CORRTAPE
//SYSIN_DD_*
INCLUDE_14969_15028
EXCLUDE_1216+48
EXCLUDE_1242+41
EXCLUDE_1244+49
EXCLUDE_1315+34
EXCLUDE_1317+52
//_EXEC_INTBCAL,PARM='NOK'
//SYSIN_DD_*
INCLUDE
```

(results shown in Figures III-19-24)

Under most circumstances one simply uses an INCLUDE card for every good phase calibrator observed. In this case we have excluded the few sources that are not standard phase calibrators.

Note that INTBCAL requires the input of the scan averages calculated by INTAVG. The resulting output from INTBCAL contains all the information needed to evaluate the solution obtained. As seen in Figure III-19, one first gets a listing of the original baselines which we will need to correct. The solutions for $\Delta B_x, \Delta B_y, \Delta B_z$, the baseline corrections, the improved baselines, the phase centers (ϕ_S) and the rms fits of the solution are then printed out for all correlators and all frequencies (Figures III-20 and 21). Because the RR and LL correlators

INITIAL BASELINES ARE AS FOLLOWS:

		BX	BY	BZ	K
SBAND	BL12	-4785.5898	-15086.9443	6421.5098	0.0
	BL13	-4533.3594	-14292.7246	6083.5498	0.0
	BL23	-252.2295	-794.2197	337.9600	0.0
	42FT	40491.0791	74762.6895	-55965.2793	58.7998
XBAND	BL12	-14356.7695	-45260.8330	19264.5293	0.0
	BL13	-13600.0781	-42878.1738	18250.6494	0.0
	BL23	-756.6385	-2382.6592	1013.8799	0.0
	42FT	121473.2373	224288.0684	-167895.8379	0.0

Fig. III-19. First part of INTBCAL output showing the initial baselines before solution is obtained from phase calibrator data on the CORRTAPE (PAC only).

BASELINE PARAMETERS FOR 85-1,2 S RR

THREE SOLUTION FIT PARAMETERS ARE 1.2699 136.8572 1.2699. SOLUTION 3 CHOSEN.

QUANTITY	CHANGE	NEW VALUE	ERROR
PHASE CENTER	-73.	-73.	4. DEGREES
BX	-0.0100	-4785.5998	0.0155
BY	0.0259	-15086.9184	0.0062
BZ	0.0251	6421.5349	0.0086
K	0.0	0.0	0.0244
L	0.0	0.0	0.0244
M	0.0	0.0	0.0244

BASELINE PARAMETERS FOR 85-1,2 S LL

THREE SOLUTION FIT PARAMETERS ARE 112.4070 1.2128 1.2127. SOLUTION 3 CHOSEN.

QUANTITY	CHANGE	NEW VALUE	ERROR
PHASE CENTER	-161.	-161.	4. DEGREES
BX	-0.0089	-4785.5988	0.0150
BY	0.0268	-15086.9175	0.0059
BZ	0.0262	6421.5359	0.0084
K	0.0	0.0	0.0236
L	0.0	0.0	0.0236
M	0.0	0.0	0.0236

BASELINE PARAMETERS FOR 85-1,3 S RR

THREE SOLUTION FIT PARAMETERS ARE 112.9693 1.0724 1.0725. SOLUTION 2 CHOSEN.

QUANTITY	CHANGE	NEW VALUE	ERROR
PHASE CENTER	-163.	-163.	4. DEGREES
BX	-0.0076	-4533.3670	0.0142
BY	0.0167	-14292.7080	0.0057
BZ	0.0039	6083.5537	0.0079
K	0.0	0.0	0.0224
L	0.0	0.0	0.0224
M	0.0	0.0	0.0224

BASELINE PARAMETERS FOR 85-1,3 S LL

THREE SOLUTION FIT PARAMETERS ARE 1.1264 1.1264 1.1264. SOLUTION 3 CHOSEN.

QUANTITY	CHANGE	NEW VALUE	ERROR
PHASE CENTER	-29.	-29.	4. DEGREES
BX	-0.0100	-4533.3694	0.0144
BY	0.0179	-14292.7068	0.0057
BZ	0.0016	6083.5514	0.0081
K	0.0	0.0	0.0228
L	0.0	0.0	0.0228
M	0.0	0.0	0.0228

BASELINE PARAMETERS FOR 85-2,3 S RR

THREE SOLUTION FIT PARAMETERS ARE 0.0492 0.0480 0.0492. SOLUTION 2 CHOSEN.

QUANTITY	CHANGE	NEW VALUE	ERROR
PHASE CENTER	-93.	-93.	1. DEGREES
BX	0.0043	-252.2251	0.0031
BY	0.0077	-794.2120	0.0013
BZ	0.0233	337.9833	0.0017
K	0.0	0.0	0.0048
L	0.0	0.0	0.0048
M	0.0	0.0	0.0048

BASELINE PARAMETERS FOR 85-2,3 S LL

THREE SOLUTION FIT PARAMETERS ARE 0.0478 0.0478 0.0478. SOLUTION 3 CHOSEN.

QUANTITY	CHANGE	NEW VALUE	ERROR
PHASE CENTER	47.	47.	1. DEGREES
BX	0.0028	-252.2266	0.0031
BY	0.0074	-794.2124	0.0012
BZ	0.0240	337.9840	0.0017
K	0.0	0.0	0.0047
L	0.0	0.0	0.0047
M	0.0	0.0	0.0047

Fig. III-20. Part of INTBCAL output showing the properties of the solutions for SBAND correlators.

BASELINE PARAMETERS FOR 85-1,2 X RR

THREE SOLUTION FIT PARAMETERS ARE 9.4462 9.4462 313.5977. SOLUTION 2 CHOSEN.

QUANTITY	CHANGE	NEW VALUE	ERROR
PHASE CENTER	45.	45.	11. DEGREES
BX	0.0011	-14356.7685	0.0423
BY	0.0744	-45260.7586	0.0167
BZ	0.0815	19264.6108	0.0247
K	0.0	0.0	0.0666
L	0.0	0.0	0.0666
M	0.0	0.0	0.0666

BASELINE PARAMETERS FOR 85-1,2 X LL

THREE SOLUTION FIT PARAMETERS ARE 9.4178 48.6568 39.5340. SOLUTION 1 CHOSEN.

QUANTITY	CHANGE	NEW VALUE	ERROR
PHASE CENTER	0.	0.	11. DEGREES
BX	-0.0090	-14356.7785	0.0427
BY	0.0730	-45260.7600	0.0171
BZ	0.0739	19264.6032	0.0249
K	0.0	0.0	0.0671
L	0.0	0.0	0.0671
M	0.0	0.0	0.0671

BASELINE PARAMETERS FOR 85-1,3 X RR

THREE SOLUTION FIT PARAMETERS ARE 8.0785 8.0785 305.3679. SOLUTION 2 CHOSEN.

QUANTITY	CHANGE	NEW VALUE	ERROR
PHASE CENTER	77.	77.	10. DEGREES
BX	-0.0062	-13600.0843	0.0391
BY	0.0485	-42878.1254	0.0155
BZ	0.0194	18250.6688	0.0228
K	0.0	0.0	0.0616
L	0.0	0.0	0.0616
M	0.0	0.0	0.0616

BASELINE PARAMETERS FOR 85-1,3 X LL

THREE SOLUTION FIT PARAMETERS ARE 8.2383 8.2383 49.7666. SOLUTION 2 CHOSEN.

QUANTITY	CHANGE	NEW VALUE	ERROR
PHASE CENTER	108.	108.	11. DEGREES
BX	-0.0143	-13600.0925	0.0399
BY	0.0465	-42878.1273	0.0160
BZ	0.0141	18250.6635	0.0233
K	0.0	0.0	0.0627
L	0.0	0.0	0.0627
M	0.0	0.0	0.0627

BASELINE PARAMETERS FOR 85-2,3 X RR

THREE SOLUTION FIT PARAMETERS ARE 0.4199 0.4199 0.4187. SOLUTION 3 CHOSEN.

QUANTITY	CHANGE	NEW VALUE	ERROR
PHASE CENTER	150.	150.	2. DEGREES
BX	0.0074	-756.6811	0.0088
BY	0.0270	-2382.6322	0.0035
BZ	0.0588	1013.9387	0.0049
K	0.0	0.0	0.0139
L	0.0	0.0	0.0139
M	0.0	0.0	0.0139

BASELINE PARAMETERS FOR 85-2,3 X LL

THREE SOLUTION FIT PARAMETERS ARE 0.2647 0.2647 156.2890. SOLUTION 2 CHOSEN.

QUANTITY	CHANGE	NEW VALUE	ERROR
PHASE CENTER	71.	71.	2. DEGREES
BX	0.0002	-756.6882	0.0071
BY	0.0265	-2382.6326	0.0028
BZ	0.0682	1013.9481	0.0039
K	0.0	0.0	0.0111
L	0.0	0.0	0.0111
M	0.0	0.0	0.0111

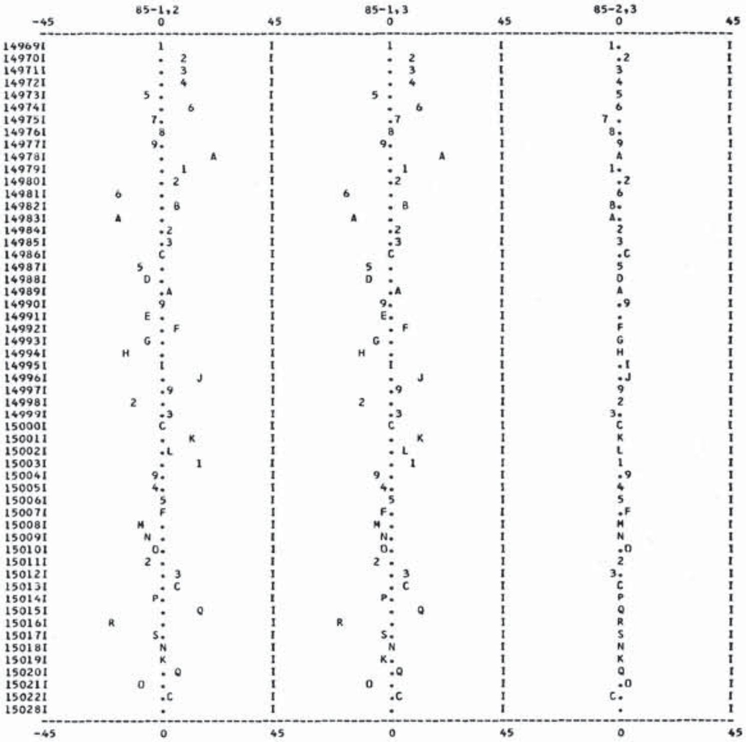
Fig. III-21. Part of INTBCAL output showing the properties of the solutions for the XBAND correlators.

OBASELINE PARAMETERS AVERAGED USING LL AND RR, S AND (X/3) AND CLOSURE

	BASELINE 1,2	BASELINE 1,3	BASELINE 2,3	DIFF
AVERAGE BASELINE FOR BX	-4785.5952	-4533.3655	-252.2271	-0.0027
CLOSED BASELINE	-4785.5939	-4533.3668	-252.2271	0.0000
AVERAGE BASELINE FOR BY	-15086.9189	-14292.7081	-794.2115	0.0007
CLOSED BASELINE	-15086.9192	-14292.7077	-794.2115	0.0000
AVERAGE BASELINE FOR BZ	6421.5356	6083.5540	337.9824	-0.0008
CLOSED BASELINE	6421.5360	6083.5536	337.9824	0.0000

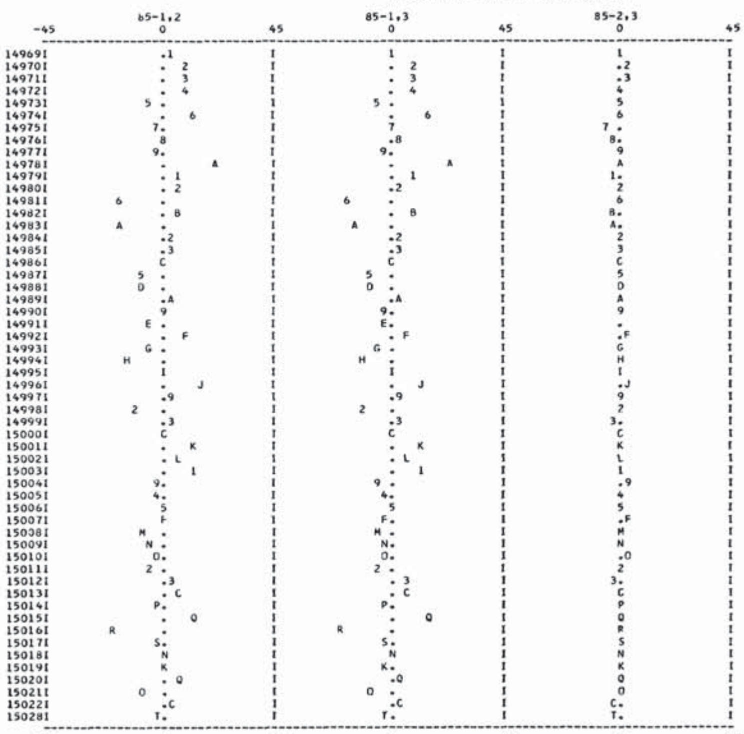
Fig. III-22. Part of INTBCAL output showing the baseline solutions obtained, averaging the results for both frequencies and using the closure condition.

PLOTS FOR S BAND RR POLARIZATION



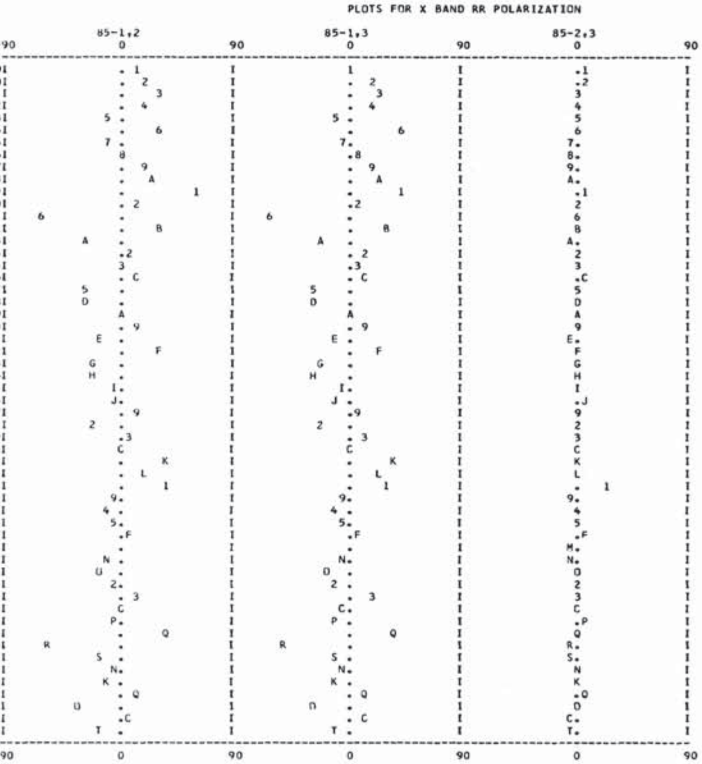
TIME	SOURCE	HA	DEC
14969	P0056-17	-2.86	-17.2
14970	3C48	-3.33	33.0
14971	D0224+67	-4.02	67.2
14972	NRAO91	-3.45	15.1
14973	3C119	-5.75	41.6
14974	P2149-28	1.12	-28.6
14975	OV080	3.29	8.1
14976	BLLAC	1.24	42.2
14977	3C454.3	0.55	16.0
14978	P0114-21	-1.66	-21.0
14979	P0056-17	-1.21	-17.2
14980	3C48	-1.67	33.0
14981	P2149-28	2.26	-28.6
14982	CYGX-3	3.75	40.9
14983	P0114-21	-0.81	-21.0
14984	3C48	-0.99	33.0
14985	D0224+67	-1.68	67.2
14986	3C147	-4.73	49.8
14987	3C119	-3.41	41.6
14988	CTA21	-2.03	16.4
14989	P0114-21	0.18	-21.0
14990	3C454.3	2.72	16.0
14991	3C418	5.12	51.2
14992	P0106+01	0.83	1.4
14993	NRAO140	-1.48	32.2
14994	P0735+17	-5.33	17.8
14995	3C120	-2.10	5.3
14996	3C446	4.22	-5.1
14997	3C454.3	3.88	16.0
14998	3C48	1.34	33.0
14999	D0224+67	0.64	67.2
15000	3C147	-2.41	49.8
15001	D0742+10	-4.30	10.3
15002	P0607-15	-2.55	-15.7
15003	P0056-17	2.82	-17.2
15004	3C454.3	5.05	16.0
15005	NRAO91	2.04	15.1
15006	3C119	-0.25	41.6
15007	P0106+01	3.32	1.4
15008	P0438-43	-0.09	-43.6
15009	P0614-34	-1.50	-34.9
15010	3C138	-0.39	16.6
15011	3C48	3.50	33.0
15012	D0224+67	2.82	67.2
15013	3C147	-0.24	49.8
15014	DA267	-3.81	39.2
15015	P1116+12	-5.53	12.7
15016	P1055+01	-5.03	1.7
15017	P0859-14	-2.92	-14.1
15018	P0614-34	0.02	-34.9
15019	D0742+10	-1.30	10.3
15020	P1116+12	-4.69	12.7
15021	3C138	1.46	16.6
15022	3C147	2.42	49.8
15028	3C286	-4.23	30.6

PLOTS FOR S BAND LL POLARIZATION

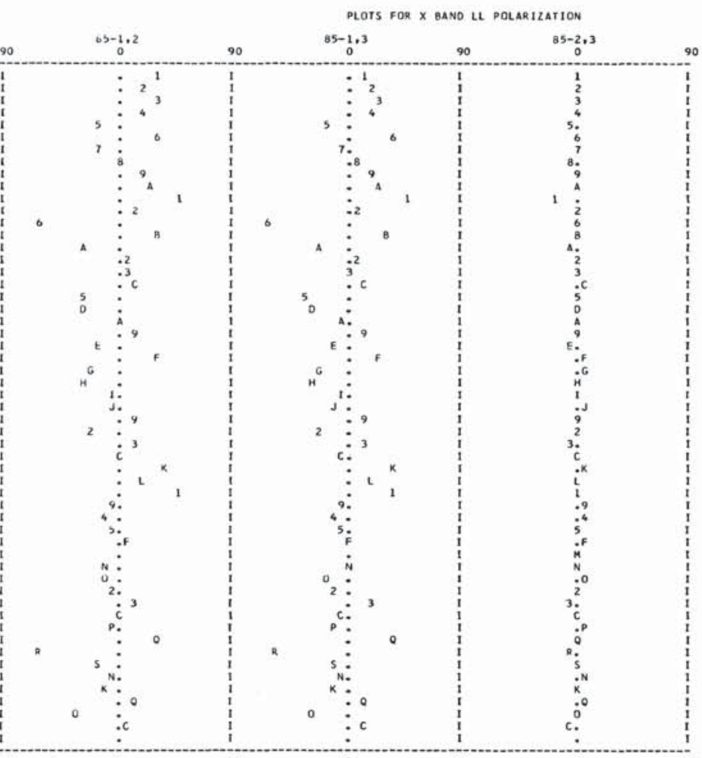


TIME	SOURCE	HA	DEC
14969	P0056-17	-2.86	-17.2
14970	3C48	-3.33	33.0
14971	D0224+67	-4.02	67.2
14972	NRAO91	-3.45	15.1
14973	3C119	-5.75	41.6
14974	P2149-28	1.12	-28.6
14975	OV080	3.29	8.1
14976	BLLAC	1.24	42.2
14977	3C454.3	0.55	16.0
14978	P0114-21	-1.66	-21.0
14979	P0056-17	-1.21	-17.2
14980	3C48	-1.67	33.0
14981	P2149-28	2.26	-28.6
14982	CYGX-3	3.75	40.9
14983	P0114-21	-0.81	-21.0
14984	3C48	-0.99	33.0
14985	D0224+67	-1.68	67.2
14986	3C147	-4.73	49.8
14987	3C119	-3.41	41.6
14988	CTA21	-2.03	16.4
14989	P0114-21	0.18	-21.0
14990	3C454.3	2.72	16.0
14991	3C418	5.12	51.2
14992	P0106+01	0.83	1.4
14993	NRAO140	-1.48	32.2
14994	P0735+17	-5.33	17.8
14995	3C120	-2.10	5.3
14996	3C446	4.22	-5.1
14997	3C454.3	3.88	16.0
14998	3C48	1.34	33.0
14999	D0224+67	0.64	67.2
15000	3C147	-2.41	49.8
15001	D0742+10	-4.30	10.3
15002	P0607-15	-2.55	-15.7
15003	P0056-17	2.82	-17.2
15004	3C454.3	5.05	16.0
15005	NRAO91	2.04	15.1
15006	3C119	-0.25	41.6
15007	P0106+01	3.32	1.4
15008	P0438-43	-0.09	-43.6
15009	P0614-34	-1.50	-34.9
15010	3C138	-0.39	16.6
15011	3C48	3.50	33.0
15012	D0224+67	2.82	67.2
15013	3C147	-0.24	49.8
15014	DA267	-3.81	39.2
15015	P1116+12	-5.53	12.7
15016	P1055+01	-5.03	1.7
15017	P0859-14	-2.92	-14.1
15018	P0614-34	0.02	-34.9
15019	D0742+10	-1.30	10.3
15020	P1116+12	-4.69	12.7
15021	3C138	1.46	16.6
15022	3C147	2.42	49.8
15028	3C286	-4.23	30.6

Fig. III-23. Part of INTBCAL output showing plots of SBAND calibrator phases as a function of time, after the new baseline solutions have been applied.



Time	SOURCE	HA	DEC
14969	P0056-17	-2.86	-17.2
14970	3C48	-3.32	33.0
14971	D0224+67	-4.00	67.2
14972	NRAO91	-3.44	15.1
14973	3C119	-5.73	41.6
14974	P2149-28	1.12	-28.6
14975	OV080	3.30	8.1
14976	BLLAC	1.24	42.2
14977	3C454.3	0.56	16.0
14978	P0114-21	-1.66	-21.0
14979	P0056-17	-1.20	-17.2
14980	3C48	-1.66	33.0
14981	P2149-28	2.26	-28.6
14982	CYGX-3	3.77	40.9
14983	P0114-21	-0.81	-21.0
14984	3C48	-0.99	33.0
14985	D0224+67	-1.67	67.2
14986	3C147	-4.73	49.8
14987	3C119	-3.41	41.6
14988	CTA21	-2.02	16.4
14989	P0114-21	0.18	-21.0
14990	3C454.3	2.74	16.0
14991	3C418	5.17	51.2
14992	P0106+01	0.83	1.4
14993	NRAO140	-1.48	32.2
14994	P0735+17	-5.33	17.8
14995	3C120	-2.09	5.3
14996	3C446	4.22	-5.1
14997	3C454.3	3.88	16.0
14998	3C48	1.34	33.0
14999	D0224+67	0.66	67.2
15000	3C147	-2.40	49.8
15001	D0742+10	-4.30	10.3
15002	P0607-15	-2.54	-15.7
15003	P0056-17	2.82	-17.2
15004	3C454.3	5.08	16.0
15005	NRAO91	2.05	15.1
15006	3C119	-0.24	41.6
15007	P0106+01	3.32	1.4
15008	P0438-43	-0.09	-43.6
15009	P0614-34	-1.50	-34.9
15010	3C138	-0.39	16.6
15011	3C48	3.51	33.0
15012	D0224+67	2.84	67.2
15013	3C147	-0.23	49.8
15014	DA267	-3.81	39.2
15015	P1116+12	-5.52	12.7
15016	P1055+01	-5.03	1.7
15017	P0859-14	-2.91	-14.1
15018	P0614-34	0.01	-34.9
15019	D0742+10	-1.29	10.3
15020	P1116+12	-4.68	12.7
15021	3C138	1.47	16.6
15022	3C147	2.42	49.8
15028	3C286	-4.23	30.6



Time	SOURCE	HA	DEC
14969	P0056-17	-2.86	-17.2
14970	3C48	-3.32	33.0
14971	D0224+67	-4.00	67.2
14972	NRAO91	-3.44	15.1
14973	3C119	-5.73	41.6
14974	P2149-28	1.12	-28.6
14975	OV080	3.30	8.1
14976	BLLAC	1.24	42.2
14977	3C454.3	0.56	16.0
14978	P0114-21	-1.66	-21.0
14979	P0056-17	-1.20	-17.2
14980	3C48	-1.66	33.0
14981	P2149-28	2.26	-28.6
14982	CYGX-3	3.77	40.9
14983	P0114-21	-0.81	-21.0
14984	3C48	-0.99	33.0
14985	D0224+67	-1.67	67.2
14986	3C147	-4.73	49.8
14987	3C119	-3.41	41.6
14988	CTA21	-2.02	16.4
14989	P0114-21	0.18	-21.0
14990	3C454.3	2.74	16.0
14991	3C418	5.17	51.2
14992	P0106+01	0.83	1.4
14993	NRAO140	-1.48	32.2
14994	P0735+17	-5.33	17.8
14995	3C120	-2.09	5.3
14996	3C446	4.22	-5.1
14997	3C454.3	3.88	16.0
14998	3C48	1.34	33.0
14999	D0224+67	0.66	67.2
15000	3C147	-2.40	49.8
15001	D0742+10	-4.30	10.3
15002	P0607-15	-2.54	-15.7
15003	P0056-17	2.82	-17.2
15004	3C454.3	5.08	16.0
15005	NRAO91	2.05	15.1
15006	3C119	-0.24	41.6
15007	P0106+01	3.32	1.4
15008	P0438-43	-0.09	-43.6
15009	P0614-34	-1.50	-34.9
15010	3C138	-0.39	16.6
15011	3C48	3.51	33.0
15012	D0224+67	2.84	67.2
15013	3C147	-0.23	49.8
15014	DA267	-3.81	39.2
15015	P1116+12	-5.52	12.7
15016	P1055+01	-5.03	1.7
15017	P0859-14	-2.91	-14.1
15018	P0614-34	0.01	-34.9
15019	D0742+10	-1.29	10.3
15020	P1116+12	-4.68	12.7
15021	3C138	1.47	16.6
15022	3C147	2.42	49.8
15028	3C286	-4.23	30.6

Fig. III-24. Part of INTBCAL output showing plots of XBAND calibrator phases as functions of time, after the new baseline solutions have been applied.

should have identical baseline errors, and because the errors for the same correlators should differ by only a factor of three for XBAND and SBAND, one can improve the solutions by averaging, with results as shown in Figure III-22. One additional constraint is that of closure, e.g., $B_x(12) = B_x(13) + B_x(23)$. Using these conditions one obtains the best averaged and closed baselines as shown in Figure III-22 (for SBAND only, to get XBAND multiply by 3).

INTBCAL then applies the baseline corrections to each correlator individually, corrects for the phase center, and then plots the resulting phases as shown in Figures III-23 and 24. We see that the fits for this set of data are very good; one seldom sees less phase noise. Note that phase noise scales roughly with baseline length and frequency.

With the results on ΔB_x, ΔB_y, ΔB_z, one can use INTEDIT or INTCORR to generate the CORRTAPE where data are in the stage $V' = A' \exp(i\phi')$.

(2) Determining Phase Centers with INTBCAL

It is best not to use the phase center (ϕ_S) determined by INTBCAL at the same time the baseline solutions are obtained. This is because the accuracy is greatly improved when one uses the baselines determined from all the data and then solves only for the phase centers. This is easily done using INTBCAL with the PARM='NOBASE' option. In this case the program as listed above is modified so that: (1) PARM = 'NOBASE' is on the EXEC card; (2) one adds a //BASLINES_DD_* card which says baselines are to be read in; and (3) one adds a set of 8 cards punched in the format 4F(15.3), with each card giving B_x, B_y, B_z and k for the appropriate pair. The eight cards are in the order S12, S13, S23, a card with four zeroes, X12, X13, X23 and another card with four zeroes*. We will not show an example of the results, since they are the same as for Figures III-19-24, except better phase centers are obtained.

Obviously INTBCAL, when used only to determine ϕ_S for each correlator, is useful whenever one is using INTEDIT to calibrate data.

---

* A vestige of an old system involving a pair between 85-1 and a remote 42-foot telescope.

(c) INTCLEAN to Diagnose and Partially Clean Data.

The first step in automatic data processing is use of INTCLEAN to obtain

(1) A listing of diagnostic messages of varying severity based upon fault information noted on tape; and

(2) A summary of available diagnostic messages, their severity and the number of times each fault was found.

A sample of diagnostic messages for real data is given in Figure III-8; and a sample of the diagnostic summary for the same data is given in Figure III-9.

In addition to the diagnostic features of INTCLEAN, the program will also automatically delete (flag as bad) all data with faults with severity code of 3 (number of asterisks) or more.

Examining Figure III-8, we see that the data diagnostics always give the following for each scan: scan number, LST at time header is written, source name, right ascension and declination of reference position precessed to date of observation, and the mode. In addition, whenever a fault was detected by system monitors or the DDP116, details concerning the fault are recorded and INTCLEAN gives a display of the following for each occurrence of such faults: the LST, the severity code, the correlator, telescope, or receiver involved, a description of the fault, the word in the data record where the faulty data are located and finally the contents of that word.

In doing partial cleaning of the data, INTCLEAN automatically deletes all data with fault messages at severity level 3 or greater. It also flags data records where correlators rms' are in excess of 1000 for high gain settings and 200 for medium or low gain settings.

In many cases INTCLEAN will accomplish all the cleaning that is desired, but there are many possible problems for which no automatic cleaning is possible. When this occurs, one does manual cleaning with

INTEDIT starting with either the raw data tape or the output subjected to partial cleaning by INTCLEAN. Any problem where bad data (particularly headers) must be replaced by good data must be solved with INTEDIT. In addition, one frequently needs to delete data for reasons that cannot be written into a program.

INTCLEAN has a default input specification of a temporary disk data set '&&OUTNAME' so it will accept the default output of INTCOPY, but one usually specifies its output characteristics. One may also alter the severity threshold for automatic deletion by the PARM option, PARM='DELETE=...' (default=3) and the maximum allowable rms for high gain, PARM='MAXRMS=...' (default=1000). MAXRMS/5 is used for medium and low gain settings.

As an example,

```
//_EXEC_INTCLEAN,INTAPE=3085,INNAME=RAWTAPE,
//_OUTUNIT=DISK,OUTNAME='&&CLEAN',
//_PARM='DELETE=3,MAXRMS=1000'
```

(results shown in Figures III-8 and 9)

will pass the diagnosed and partially cleaned data on to a temporary disk data set '&&CLEAN'. If further use of INTEDIT is needed, it can take input from '&&CLEAN', otherwise the '&&CLEAN' data can then be processed by INTCORR.

The place of INTCLEAN in the data processing is shown in the flow diagram in Figure III-1.

(d) INTCORR to Apply Automatic Corrections

INTCORR is a program that can be used to apply all the automatic corrections, in particular the corrections associated with PHASE, CLOCK,AMPCOR, and BASELINE in INTEDIT. In this case, the CLOCK correction is based upon a predicted clock error derived from a formula in the program. The constants for AMPCOR are the standard values of 0.07 at SBAND and 0.19 at XBAND.

BASELINE corrections, however, are applied only if new baselines are supplied. The PHASE, CLOCK and AMPCOR corrections are applied by default. To suppress them one must specify PARM='NOPHASE,NOCLOCK, NOAMPCOR'.

The following program, applied to the segment of data that we have been using in the examples, illustrates the usual use of INTCORR:

```
//_EXEC_INTCORR,INUNIT=DISK,INNAME='&&CLEAN,
//_OUTTAPE=3086,OUTNAME=CORRTAPE,OUTDISP=NEW
//BASLINES_DD_*
-4785.5938   -15086.9192    6421.5360    0.0
-4533.3667   -14292.7077    6083.5536    0.0
- 252.2271   - 794.2115      337.9823    0.0
```

(results shown in Figure III-25)

where B_x, B_y, B_z, and k have been supplied (Format 4F15.0) for the SBAND pairs 12, 13, and 23, respectively (XBAND assumed larger by a factor of three) and the final corrected output is written on CORRTAPE.

As we see from Figure III-25, the output describes what corrections have been applied with what parameters. In addition, when baselines have been up-dated, both the old and new baselines are listed.

Next the INTCORR output gives for each scan the following information derived from each scan header and the adjacent A/D record: scan number, source name, LST, RA and DEC precessed to time of observation, temperature (in °C), dew point, vapor pressure, the LO index, the predicted clock error, PACB indicating that PHASE,AMPCOR,CLOCK, and BASELINE corrections have been applied to the data, partial information about the contents of word 22 (where bits 9 through 12 record whether P, A, C, or B have been applied, bit 14 contains 1 if INTCORR has been applied, and bit 16 is a 1 if the header is bad and a 0 if it is not), the year and the Julian day and fractions of a day. In the WD22 column the last symbol gives the contents of bits 14 and 16.

INTCORR

```
FUNCTIONS BEING APPLIED ARE:

AMPCOR  (SBAND=0.070 XBAND=0.190)
PHASE
CLOCK
BASELINE - UPDATED BASELINES ARE:

 BX=    -4785.5938    -4533.3667    -252.2271   -14356.7814   -13600.1001    -756.6813
 BY=   -15086.9192   -14292.7077    -794.2115   -45260.7576   -42878.1231   -2382.6345
 BZ=     6421.5360     6083.5536     337.9823    19264.6080    18250.6608    1013.9469
  K=        0.0           0.0          0.0           0.0           0.0           0.0

INTCORR INPUT DATA SET ATTRIBUTES

DDNAME IS       FT09F001
DSNAME IS       SYS73095.T173013.RF000.FIG25#28.CLEAN
UNIT NUM IS     137
VOL SER NUM IS886688
DISP IS         OLD
RECFM IS        VB   (VB=>VSB)
LRECL IS          204
BLKSIZE IS       2248
COND CODE IS        0

TAPE BASELINES ARE

 BX     -4785.5898    -4533.3594    -252.2295   -14356.7695   -13600.0781    -756.6885
 BY    -15086.9443   -14292.7246    -794.2197   -45260.8330   -42878.1738   -2382.6592
 BZ      6421.5098     6083.5498     337.9600    19264.5293    18250.6494    1013.8799
  K         0.0           0.0          0.0           0.0           0.0           0.0

SPACINGS  19 18  1
```

SCAN	SOURCE	LST	RA	DEC	TEMP	DEW PT	VP	LO	CLOCK	PACB	WD22	YEAR	JULIAN DATE
14969	P0056-17	22 02 19	00 57 47.885	-17 09 11.153	13.9	13.2	2.693	7500031.	6S	PACB	00F4	1972	2441590.61560
14970	3C48	22 12 57	01 36 10.042	33 01 28.523	13.8	12.7	2.665	7500031.	6S	PACB	00F4	1972	2441590.62297
14971	0D224+67	22 22 11	02 26 37.778	67 13 43.748	13.5	12.8	2.672	7500031.	6S	PACB	00F4	1972	2441590.62936
14972	NRAO91	22 33 05	02 03 23.640	15 06 35.769	13.5	12.8	2.669	7500031.	6S	PACB	00F4	1972	2441590.63690
14973	3C119	22 42 19	04 30 44.725	41 35 04.435	13.5	12.8	2.668	7500031.	6S	PACB	00F4	1972	2441590.64330
14974	P2149-28	22 55 37	21 50 31.717	-28 36 07.966	13.4	12.8	2.669	7500030.	6S	PACB	00F4	1972	2441590.65251
14975	OV080	23 02 21	19 48 47.528	08 03 14.026	13.5	12.7	2.664	7500031.	6S	PACB	00F4	1972	2441590.65718
14976	BLLAC	23 12 09	22 01 37.565	42 09 01.644	13.4	12.8	2.669	7500031.	6S	PACB	00F4	1972	2441590.66396
14977	3C454.3	23 21 47	22 52 38.915	16 00 24.373	13.5	12.8	2.672	7500031.	6S	PACB	00F4	1972	2441590.67063
14978	P0114-21	23 32 17	01 15 34.390	-21 00 25.771	13.5	12.7	2.664	7500031.	6S	PACB	00F4	1972	2441590.67790
14979	P0056-17	23 41 00	00 57 47.885	-17 09 11.153	13.5	12.8	2.672	7500031.	6S	PACB	00F4	1972	2441590.68394
14980	3C48	23 52 59	01 36 10.042	33 01 28.523	13.1	12.8	2.668	7500030.	6S	PACB	00F4	1972	2441590.69225
14981	P2149-28	00 02 31	21 50 31.717	-28 36 07.966	13.1	12.8	2.668	7500031.	6S	PACB	00F4	1972	2441590.69884
14982	CYGX-3	00 13 55	20 31 28.134	40 52 09.041	13.1	12.7	2.667	7500031.	6S	PACB	00F4	1972	2441590.70674
14983	P0114-21	00 23 51	01 15 34.390	-21 00 25.771	13.1	12.8	2.672	7500031.	6S	PACB	00F4	1972	2441590.71362
14984	3C48	00 33 11	01 36 10.042	33 01 28.523	13.1	12.9	2.674	7500031.	6S	PACB	00F4	1972	2441590.72008
14985	0D224+67	00 42 08	02 26 37.778	67 13 43.748	13.1	12.7	2.667	7500031.	6S	PACB	00F4	1972	2441590.72628
14986	3C147	00 53 12	05 40 31.109	49 50 18.958	13.2	12.7	2.665	7500031.	6S	PACB	00F4	1972	2441590.73395
14987	3C119	01 01 33	04 30 44.725	41 35 04.435	13.0	12.5	2.652	7500031.	6S	PACB	00F4	1972	2441590.73973
14988	CTA21	01 11 41	03 17 27.758	16 22 49.362	13.1	12.4	2.649	7500031.	6S	PACB	00F4	1972	2441590.74674
14989	P0114-21	01 22 16	01 15 34.390	-21 00 25.771	13.0	12.4	2.649	7500031.	6S	PACB	00F4	1972	2441590.75408
14990	3C454.3	01 32 20	22 52 38.915	16 00 24.373	13.0	12.5	2.650	7500030.	6S	PACB	00F4	1972	2441590.76105
14991	3C418	01 42 15	20 37 49.514	51 13 43.615	13.2	12.4	2.646	7500032.	6S	PACB	00F4	1972	2441590.76791
14992	P0106+01	01 54 01	01 07 16.785	01 26 32.816	13.0	12.3	2.644	7500031.	6S	PACB	00F4	1972	2441590.77606
14993	NRAO140	02 02 11	03 34 49.775	32 13 14.300	13.1	12.5	2.652	7500032.	6S	PACB	00F4	1972	2441590.78172
14994	P0735+17	02 13 26	07 36 33.679	17 46 07.564	13.1	12.4	2.648	7500031.	6S	PACB	00F4	1972	2441590.78951
14995	3C120	02 22 39	04 31 45.718	05 18 04.124	13.1	12.3	2.644	7500031.	6S	PACB	00F4	1972	2441590.79590
14996	3C446	02 35 05	22 24 24.193	-05 05 09.777	13.1	12.4	2.646	7500031.	6S	PACB	00F4	1972	2441590.80450
14997	3C454.3	02 41 36	22 52 38.915	16 00 24.373	13.1	12.4	2.649	7500031.	6S	PACB	00F4	1972	2441590.80902
14998	3C48	02 53 03	01 36 10.042	33 01 28.523	13.1	12.5	2.650	7500031.	6S	PACB	00F4	1972	2441590.81695
14999	0D224+67	03 02 06	02 26 37.778	67 13 43.748	13.1	12.5	2.652	7500031.	6S	PACB	00F4	1972	2441590.82322
15000	3C147	03 12 45	05 40 31.109	49 50 18.958	13.1	12.7	2.665	7500032.	6S	PACB	00F4	1972	2441590.83059
15001	0D742+10	03 22 23	07 44 03.960	10 15 19.818	13.1	12.5	2.652	7500031.	6S	PACB	00F4	1972	2441590.83727
15002	P0607-15	03 31 42	06 08 28.358	-15 42 03.280	13.1	12.5	2.652	7500032.	6S	PACB	00F4	1972	2441590.84371
15003	P0056-17	03 44 18	00 57 47.885	-17 09 11.153	13.1	12.5	2.652	7500030.	6S	PACB	00F4	1972	2441590.85244
15004	3C454.3	03 52 10	22 52 38.915	16 00 24.373	13.1	12.7	2.664	7500031.	6S	PACB	00F4	1972	2441590.85787
15005	NRAO91	04 02 38	02 03 23.640	15 06 35.769	13.1	12.7	2.664	7500030.	6S	PACB	00F4	1972	2441590.86514
15006	3C119	04 12 37	04 30 44.725	41 35 04.435	13.1	12.5	2.650	7500031.	6S	PACB	00F4	1972	2441590.87205
15007	P0106+01	04 23 01	01 07 16.785	01 26 32.616	13.0	12.7	2.664	7500032.	7S	PACB	00F4	1972	2441591.37925
15008	P0433-43	04 32 56	04 39 27.461	-43 35 55.415	13.0	12.5	2.650	7500032.	7S	PACB	00F4	1972	2441590.88612
15009	P0614-34	04 41 37	06 15 38.313	-34 55 18.102	13.1	12.4	2.649	7500032.	7S	PACB	00F4	1972	2441590.89212
15010	3C133	04 53 07	05 19 36.798	16 36 56.171	13.1	12.5	2.650	7500032.	7S	PACB	00F4	1972	2441590.90010
15011	3C48	05 03 14	01 36 10.042	33 01 28.523	13.1	12.4	2.645	7500031.	7S	PACB	00F4	1972	2441590.90710
15012	0D224+67	05 12 10	02 26 37.778	67 13 43.748	12.7	12.4	2.648	7500031.	7S	PACB	00F4	1972	2441590.91329
15013	3C147	05 22 44	05 40 31.109	49 50 18.958	12.7	12.3	2.644	7500032.	7S	PACB	00F4	1972	2441590.92060
15014	DA267	05 33 10	09 25 20.958	39 09 24.560	12.7	12.5	2.650	7500031.	7S	PACB	00F4	1972	2441590.92784
15015	P1116+12	05 41 51	11 17 31.736	12 43 40.183	12.7	12.5	2.652	7500031.	7S	PACB	00F4	1972	2441590.93385
15016	P1055+01	05 51 14	10 57 05.229	01 42 49.495	12.7	12.4	2.649	7500031.	7S	PACB	00F4	1972	2441590.94035
15017	P0859-14	06 01 55	09 00 59.524	-14 08 51.580	12.8	12.4	2.648	7500031.	7S	PACB	00F4	1972	2441590.94774
15018	P0614-34	06 12 25	06 15 38.313	-34 55 18.102	12.8	12.3	2.644	7500031.	7S	PACB	00F4	1972	2441590.95501
15019	0D742+10	06 22 47	07 44 03.960	10 15 19.818	12.8	12.0	2.622	7500032.	7S	PACB	00F4	1972	2441590.96219
15020	P1116+12	06 33 02	11 17 31.738	12 43 40.183	12.8	12.0	2.625	7500032.	7S	PACB	00F4	1972	2441590.96930
15021	3C138	06 44 47	05 19 36.798	16 36 56.171	12.7	11.7	2.605	7500031.	7S	PACB	00F4	1972	2441590.97744
15022	3C147	07 49 06	05 40 31.161	49 50 19.020	8.5	6.4	2.235	7500031.	7S	PACB	00F4	1972	2441591.02198
15023	1216+46	08 27 33	12 17 45.540	48 39 31.142	7.7	4.8	2.114	7500031.	7S	PACB	00F4	1972	2441591.04860
15024	1242+41	08 37 00	12 43 30.837	40 57 08.789	7.9	5.3	2.150	7500031.	7S	PACB	00F4	1972	2441591.05515
15025	1244+49	08 45 01	12 45 52.324	49 39 15.062	7.7	4.9	2.121	7500031.	7S	PACB	00F4	1972	2441591.06070
15026	1315+34	08 53 08	13 16 20.620	34 34 27.203	7.3	4.8	2.110	7500031.	7S	PACB	00F4	1972	2441591.06633
15027	1317+52	09 03 27	13 18 37.490	51 56 49.939	7.5	4.5	2.087	7500031.	7S	PACB	00F4	1972	2441591.07347
15028	3C286	09 11 30	13 29 52.309	30 38 58.546	7.0	4.5	2.087	7500031.	7S	PACB	00F4	1972	2441591.07904

```
 65 HEADERS
892 DATA
 61 A/D
  0 TTY
  0 AVE
  0 PTING
  0 UNKNOWN

INTCORR OUTPUT DATA SET ATTRIBUTES

DDNAME IS       FT08F001
DSNAME IS       SYS73095.T173013.RF000.FIG25#28.CORR
UNIT NUM IS     134
VOL SER NUM IS666666
DISP IS         NEW
RECFM IS        VB   (VB=>VSB)
LRECL IS          204
BLKSIZE IS       2248
COND CODE IS        0
```

Fig. III-25. Display of the automatic data processing that has been applied to scans 14969 through 15028 by INTCORR.

Finally, at the end there is a summary of the number of records of all types that have been written on the OUTUNIT. In Figure III-25, there were 60 headers, 817 data records, 56 A/D records, no operator message (TTY, typed in by operator while observing), no averaged records, no pointing data records, and no unidentifiable types of records.

If BASELINES had not been available, we would have used the output CORRTAPE (with only PAC applied) as input to INTBCAL to determine baselines; however, once baselines have been updated the CORRTAPE output lacks only gain and phase center calibration--which can be accomplished either as discussed earlier by INTEDIT or by use of INTCAL. The final result of INTCORR is data in the CORRTAPE stage $[V' = A' \exp(i\phi')]$.

The place of INTCORR in the data processing is shown in the flow diagram in Figure III-1.

(e) INTCAL to Calibrate LL and RR Correlators

INTCAL determines the system gains and phase centers (g_S and ϕ_S) from data which has been cleaned and corrected, then applies these to the data. In other words, starting with data in the CORRTAPE stage, it determines g_S and ϕ_S and then produces the data in the CALTAPE stage, for LL and RR correlators only, from

$$V = g_S\, A' \exp(i\phi' - i\phi_S)$$

(see Figure III-1).

For obvious reasons, INTCAL operates on a number of assumptions. In particular, it may not work properly if: (1) serious faults remain in the data, particularly bad calibrator data; (2) not enough gain and phase calibrators with names identifiable by the program are included in the data; or (3) the gains and/or phase centers are anything but slowly varying or discontinuous functions of time.

INTCAL reads the input data and searches for data on a standard list of phase calibrators and a standard list of flux calibrators. It assumes that the phase calibrators have been observed at the reference position and that they have names as listed in Figure III-26. A shorter list of flux calibrators, also shown in Figure III-26, with S and X-BAND flux densities and weights, is also assumed to have some members amongst the data to be processed by INTCAL. Finally, the gains and phase centers are evaluated as running means over specified convolution times which are also listed in Figure III-26. Whenever INTCAL is used, the lists of phase calibrators, flux calibrators, and convolution times are printed out as in Figure III-26.

INTCAL reads the input data and stores the CPFU's and phases of the calibrators as a function of time. Up to seven days of data can be processed at a single pass. Given the stored calibrator data, the program calculates smooth curves for g_S and ϕ_S, evaluated at every sidereal half hour, using a weighted average of the calibrator observations and specified convolution times. The weights are computed from a combination of those specified (for the flux calibrators) and the length of time which separates the calibrator observations from the current time. The default convolution times are four hours for ϕ_S and six hours for g_S; they can be changed by specifying PARM='PCONV=..., GCONV=...' in the EXEC cards of INTCEN. The corrections are graphically displayed (asterisk curves in Figure III-27) and applied to all the data to form a completely calibrated data set in the CALTAPE [$V = A \exp(i\Phi)$] stage. Corrections that are applied to LL correlators are also applied to the LR and RL channels of the same correlator and frequency.

Input to INTCAL consists of the uncalibrated data in the CORRTAPE stage and the usual INCLUDE/EXCLUDE cards. Also, a list of phase calibrators (up to 100) and a list of flux calibrators (up to 30 with their SBAND and XBAND fluxes and relative weights) can be entered if the default lists are not adequate. An optional list of times at which discontinuities occurred can also be specified.

INTCAL

INTERFEROMETER GAIN AND PHASE CALIBRATION

INPUT FLAGS

DO THE PHASE CALIBRATION
DO THE GAIN CALIBRATION
APPLY THE PHASE AND/OR GAIN CORRECTION TO THE OBSERVATIONS
INCLUDE THE CALIBRATION ERRORS

PHASE CALIBRATORS

P0056-00	P2134+00	P0106+01	P0114-21	3C48
NRAO91	D0224+67	P0229+13	P0237-23	CTA21
NRAO140	NRAO150	P0403-13	P0413-21	P0420-01
3C119	3C120	P0438-43	NRAO190	P0451-28
3C138	3C147	P0556+28	P0605-08	P0607-15
P0614-34	DA207	OI318	D0727-11	P0735+17
P0736+01	OI363	D0742+10	P0743-00	3C191
P0834-20	P0859-14	P0906+01	DA267	3C222
A0952+17	3C232	3C236	P1015-31	P1055+01
P1116+12	3C256	P1127-14	P1148-00	P1151-34
NRAO389	3C268.3	P1237-10	P1245-19	3C279
3C287	3C286	P1345+12	OQ323	3C298
3C309.1	P1508-05	P1510-08	D1548+05	D1555+00
P1607+26	DA406	3C343	3C343.1	3C345
NRAO530	3C371	3C395	OV080	3C418
P2127+04	P2128-12	P2145+06	P2149-28	BLLAC
P2203-18	3C446	CTA102	3C454	3C454.3
P2345-16				

FLUX DENSITY CALIBRATORS

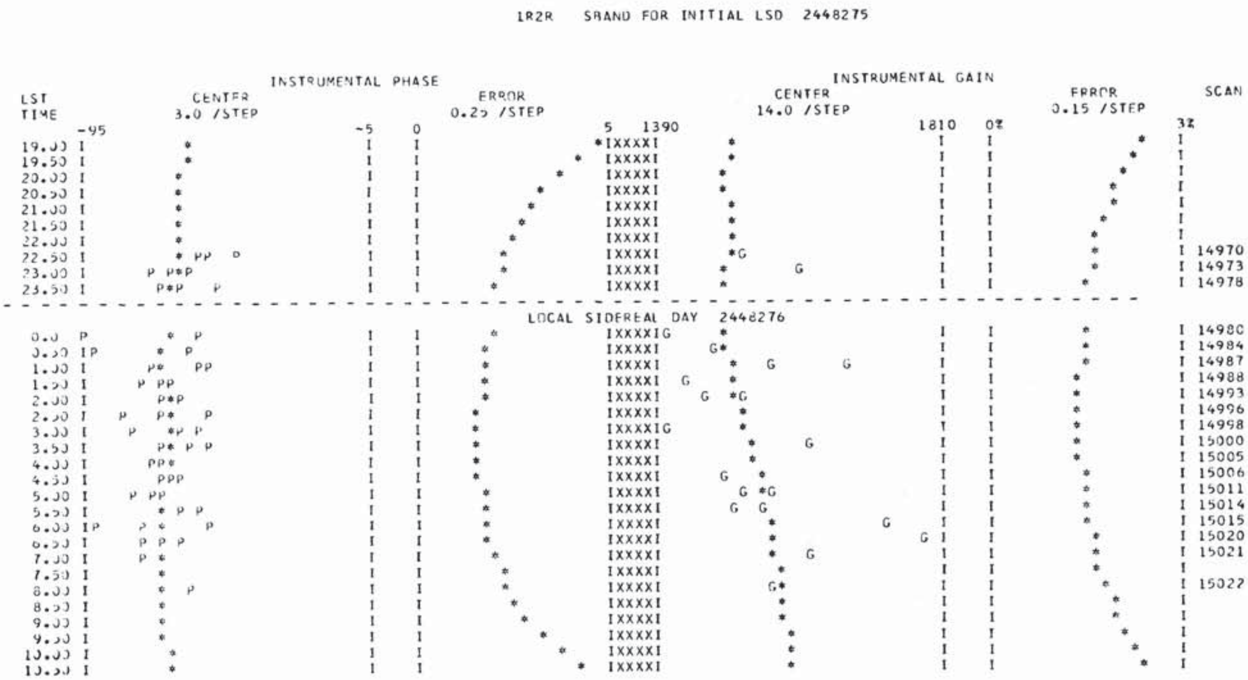
SOURCE	SBAND	XBAND	WT
3C48	9.000	3.300	1.00
CTA21	5.000	1.700	0.80
NRAO140	2.700	2.100	0.60
P0413-21	1.600	0.850	0.50
P0420-01	1.300	1.500	0.70
3C119	5.400	2.200	0.50
P0451-28	2.200	2.000	0.50
3C138	5.600	2.800	0.60
3C147	12.700	5.000	0.80
D0727-11	2.600	4.800	0.50
P0834-20	2.500	2.600	0.60
DA267	4.800	10.700	0.70
P1015-31	2.200	1.000	0.50
P1116+12	1.700	1.200	0.50
P1127-14	6.400	4.500	0.70
3C287	4.600	2.200	0.70
3C286	10.100	5.200	1.00
P1345+12	3.800	2.400	0.60
3C309.1	5.300	2.500	0.50
DA406	2.400	2.100	0.70
NRAO530	3.900	4.600	0.60
3C395	3.200	2.200	0.90
3C418	4.000	3.300	0.80
P2128-12	1.700	1.600	0.80

CONVOLUTION TIMES IN HOURS FOR SMOOTHING

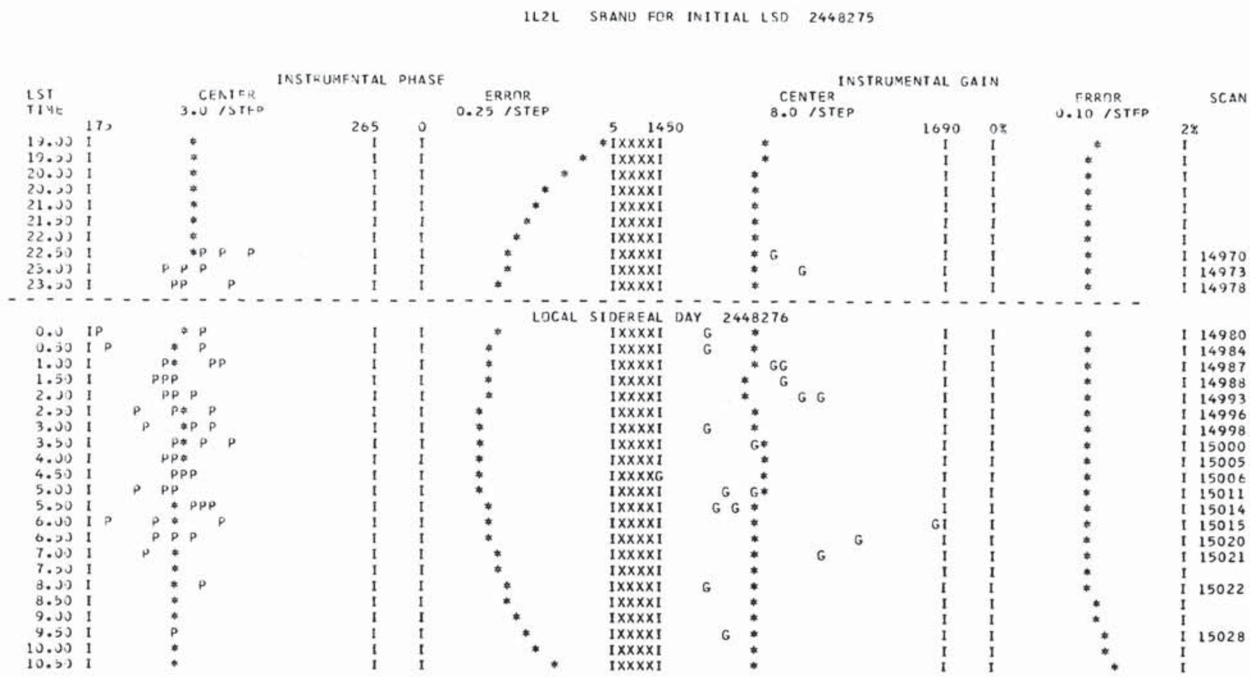
CORRELATOR		PHASE	GAIN
1R2R	SBAND	4.00	6.00
1L2L	SBAND	4.00	6.00
1R3R	SBAND	4.00	6.00
1L3L	SBAND	4.00	6.00
2R3R	SBAND	4.00	6.00
2L3L	SBAND	4.00	6.00
1R42	SBAND	4.00	6.00
1L42	SBAND	4.00	6.00
1R2R	XBAND	4.00	6.00
1L2L	XBAND	4.00	6.00
1R3R	XBAND	4.00	6.00
1L3L	XBAND	4.00	6.00
2R3R	XBAND	4.00	6.00
2L3L	XBAND	4.00	6.00
1R42	XBAND	4.00	6.00
1L42	XBAND	4.00	6.00

Fig. III-26. First page of the INTCAL output showing names and assumed properties of gain and phase calibrators, together with the convolution times to be used for gain and phase calibration.

(a)



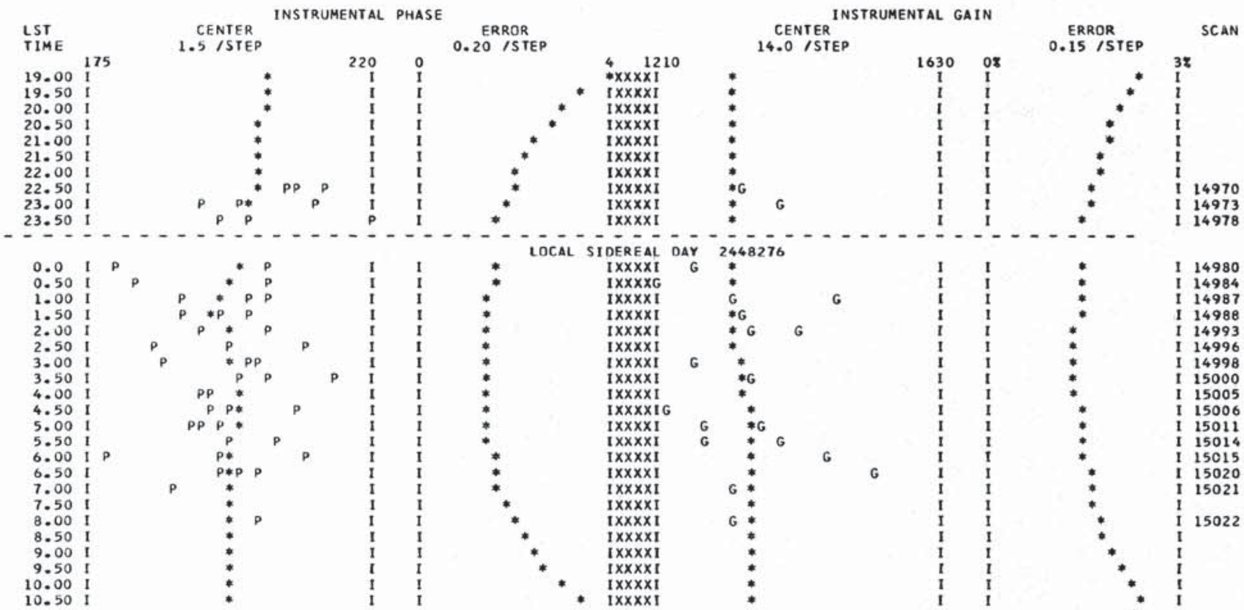
(b)



Figs. III-27a-ℓ. Portion of INTCAL output where the gain and phase calibration solutions that have been obtained are plotted as a function of LST, together with the data points used to obtain the solutions.

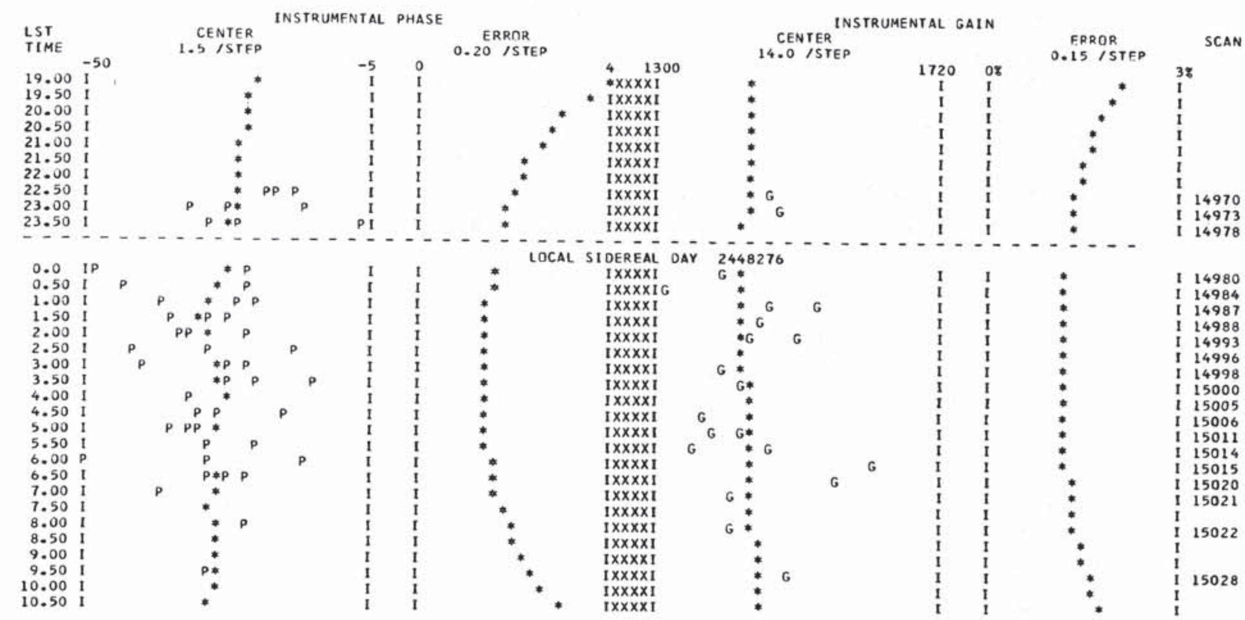
1R3R SBAND FOR INITIAL LSD 2448275

(c)



1L3L SBAND FOR INITIAL LSD 2448275

(d)



(e)

```
                                                   2R3R   SBAND FOR INITIAL LSD  2448275

                          INSTRUMENTAL PHASE                                         INSTRUMENTAL GAIN
LST               CENTER                        ERROR                          CENTER                        ERROR         SCAN
TIME            1.0 /STEP                    0.15 /STEP                      14.0 /STEP                    0.15 /STEP
  -100                            -70    0                   3   1150                        1570   0%                  3%
19.00 I            *                I    I             *     IXXXXI     *                       I    I        *          I
19.50 I            *                I    I           *       IXXXXI     *                       I    I       *           I
20.00 I           *                 I    I          *        IXXXXI     *                       I    I       *           I
20.50 I           *                 I    I         *         IXXXXI     *                       I    I       *           I
21.00 I           *                 I    I        *          IXXXXI     *                       I    I      *            I
21.50 I           *                 I    I       *           IXXXXI     *                       I    I      *            I
22.00 I           *                 I    I      *            IXXXXI     *                       I    I      *            I
22.50 I           * P  P P          I    I      *            IXXXXI     * G                     I    I      *            I 14970
23.00 I    PP     *   P             I    I     *             IXXXXI     *G                      I    I      *            I 14973
23.50 I       P   P*                I    I     *             IXXXXI     *                       I    I      *            I 14978
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
                                                    LOCAL SIDEREAL DAY  2448276
 0.0  I     P     *    P            I    I     *             IXXXXI   G *                       I    I      *            I 14980
 0.50 I   P       *  P              I    I     *             IXXXXI  G  *                       I    I      *            I 14984
 1.00 I           *    PPP          I    I     *             IXXXXI     * GG                    I    I      *            I 14987
 1.50 I      P     PP               I    I     *             IXXXXI     *G                      I    I      *            I 14988
 2.00 I           P* P              I    I     *             IXXXXI     *  G                    I    I      *            I 14993
 2.50 I          P P                I    I     *             IXXXXI     *                       I    I      *            I 14996
 3.00 I           *PPP              I    I     *             IXXXXI    G*                       I    I      *            I 14998
 3.50 I      P    P     P           I    I     *             IXXXXI     *G                      I    I      *            I 15000
 4.00 I           * P               I    I     *             IXXXXI      *                      I    I      *            I 15005
 4.50 I  P        P   P             I    I     *             IXXXXG      *                      I    I       *           I 15006
 5.00 I     P    *   P              I    I     *             IXXXXI   G G*                      I    I       *           I 15011
 5.50 I           *P  PP            I    I     *             IXXXXI  G   *G                     I    I       *           I 15014
 6.00 I        P  P                 I    I     *             IXXXXI      *            G         I    I       *           I 15015
 6.50 I      P    *P                I    I     *             IXXXXI      *     G                I    I        *          I 15020
 7.00 I           * P               I    I     *             IXXXXI     G*                      I    I        *          I 15021
 7.50 I           *                 I    I     *             IXXXXI      *                      I    I         *         I
 8.00 I           * P               I    I     *             IXXXXI    G *                      I    I         *         I 15022
 8.50 I            *                I    I      *            IXXXXI      *                      I    I          *        I
 9.00 I            *                I    I      *            IXXXXI      *                      I    I          *        I
 9.50 I           *                 I    I       *           IXXXXI      *                      I    I           *       I
10.00 I           *                 I    I        *          IXXXXI      *                      I    I            *      I
10.50 I           *                 I    I         *         IXXXXI      *                      I    I             *     I
```

(f)

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                                                   2L3L   SBAND FOR INITIAL LSD  2448275

                          INSTRUMENTAL PHASE                                         INSTRUMENTAL GAIN
LST               CENTER                        ERROR                          CENTER                        ERROR         SCAN
TIME            1.0 /STEP                    0.15 /STEP                      14.0 /STEP                    0.10 /STEP
       40                          70    0                   3   1130                        1550   0%                  2%
19.00 I           *                 I    I              *    IXXXXI      *                      I    I                *  I
19.50 I           *                 I    I            *      IXXXXI     *                       I    I               *   I
20.00 I           *                 I    I           *       IXXXXI     *                       I    I              *    I
20.50 I           *                 I    I         *         IXXXXI     *                       I    I             *     I
21.00 I           *                 I    I        *          IXXXXI     *                       I    I             *     I
21.50 I           *                 I    I       *           IXXXXI     *                       I    I            *      I
22.00 I           *                 I    I       *           IXXXXI     *                       I    I            *      I
22.50 I           *P   P   P        I    I      *            IXXXXI     *  G                    I    I           *       I 14970
23.00 I    P      *    P            I    I      *            IXXXXI     *   G                   I    I           *       I 14973
23.50 I      P   PP                 I    I     *             IXXXXI     *                       I    I           *       I 14978
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
                                                    LOCAL SIDEREAL DAY  2448276
 0.0  I    P      *   P             I    I     *             IXXXXI    G*                       I    I           *       I 14980
 0.50 I   P       *  P              I    I     *             IXXXXIG    *                       I    I          *        I 14984
 1.00 I           *   P  P          I    I     *             IXXXXI    *  GG                    I    I          *        I 14987
 1.50 I      P     PP               I    I     *             IXXXXI    *  G                     I    I          *        I 14988
 2.00 I           P*  P             I    I     *             IXXXXI     *G                      I    I          *        I 14993
 2.50 I           PP                I    I     *             IXXXXI    *                        I    I          *        I 14996
 3.00 I           *PPP              I    I     *             IXXXXI   G *                       I    I           *       I 14998
 3.50 I      P    P    P            I    I     *             IXXXXI     G                       I    I           *       I 15000
 4.00 I           *PP               I    I     *             IXXXXI     *                       I    I           *       I 15005
 4.50 I P         P   P             I    I     *             IXXXXIG    *                       I    I           *       I 15006
 5.00 I    P     *   P              I    I     *             IXXXXI  GG *                       I    I           *       I 15011
 5.50 I           *P  PP            I    I     *             IXXXXIG    * G                     I    I            *      I 15014
 6.00 I      P P  *P                I    I     *             IXXXXI     *            G          I    I            *      I 15015
 6.50 I     P    *PP                I    I     *             IXXXXI     *      G                I    I             *     I 15020
 7.00 I          *  P               I    I     *             IXXXXI  G  *                       I    I             *     I 15021
 7.50 I           *                 I    I     *             IXXXXI     *                       I    I              *    I
 8.00 I           * P               I    I     *             IXXXXI    G*                       I    I              *    I 15022
 8.50 I           *                 I    I      *            IXXXXI     *                       I    I               *   I
 9.00 I           *                 I    I      *            IXXXXI     *                       I    I                *  I
 9.50 I           *P                I    I       *           IXXXXI     * G                     I    I                *  I 15028
10.00 I           *                 I    I       *           IXXXXI     *                       I    I                 * I
10.50 I           *                 I    I        *          IXXXXI     *                       I    I                  *I
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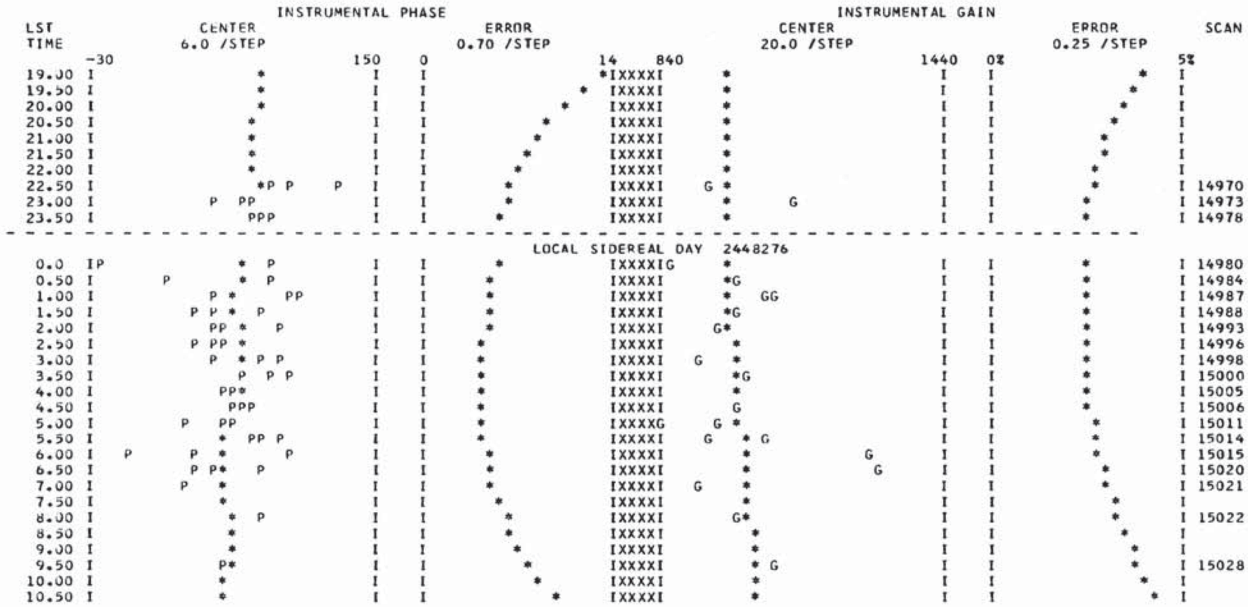
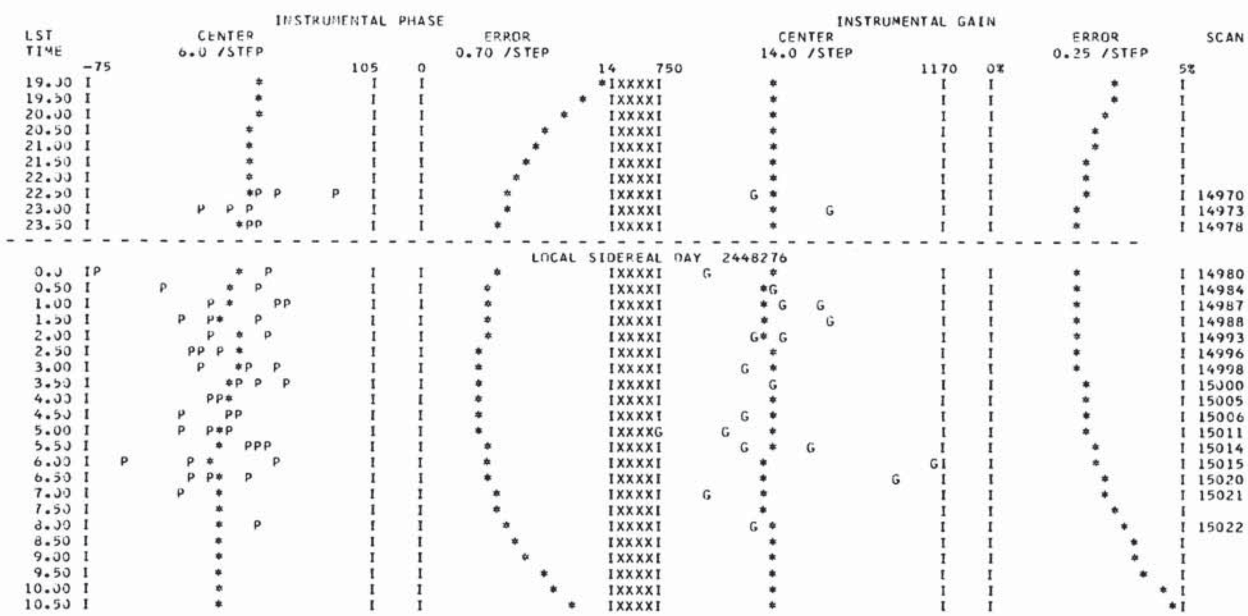
1R2R XBAND FOR INITIAL LSD 2448275

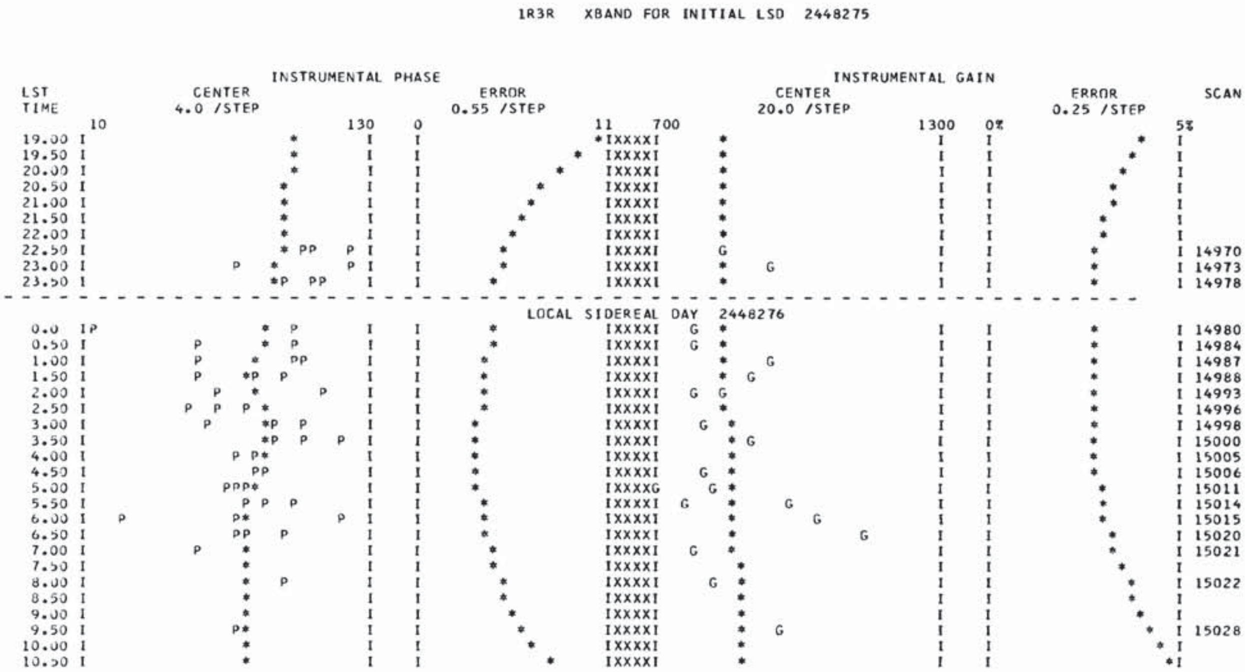


(g)

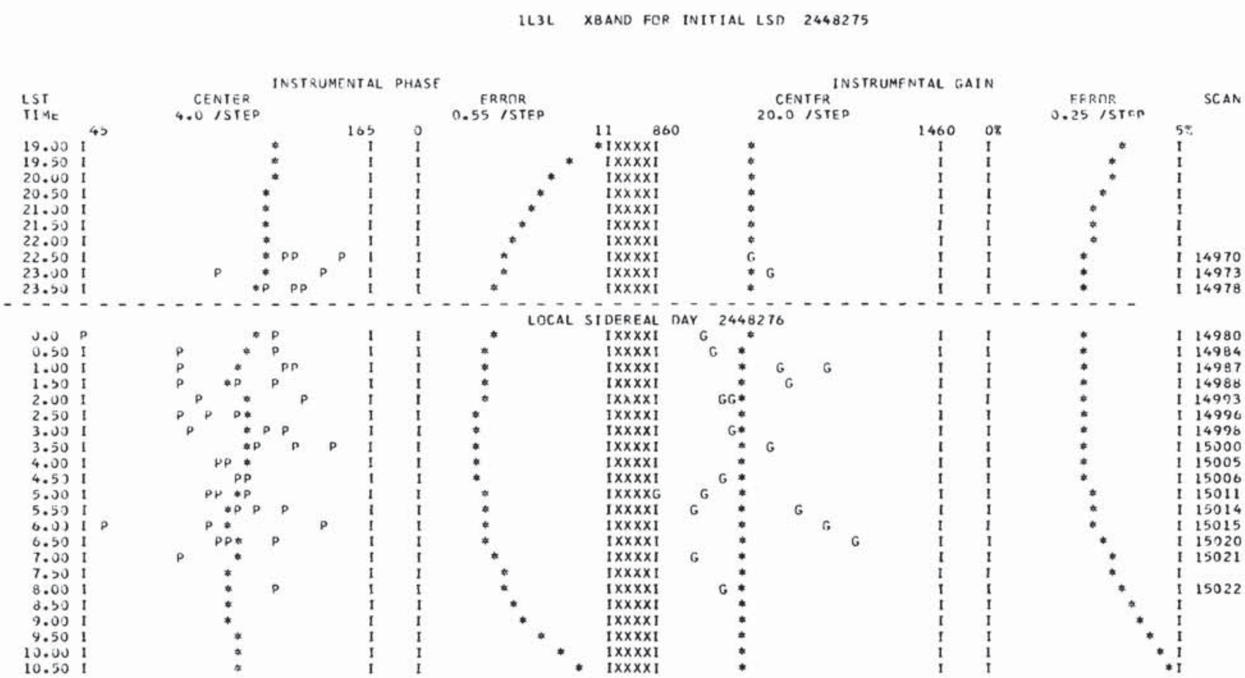
IL2L XBAND FOR INITIAL LSD 2448275



(h)


1R3R XBAND FOR INITIAL LSD 2448275
INSTRUMENTAL PHASE
INSTRUMENTAL GAIN
LST TIME
CENTER 4.0 /STEP
ERROR 0.55 /STEP
CENTER 20.0 /STEP
ERROR 0.25 /STEP
SCAN
10
130
0
11
700
1300
0%
5%
LOCAL SIDEREAL DAY 2448276

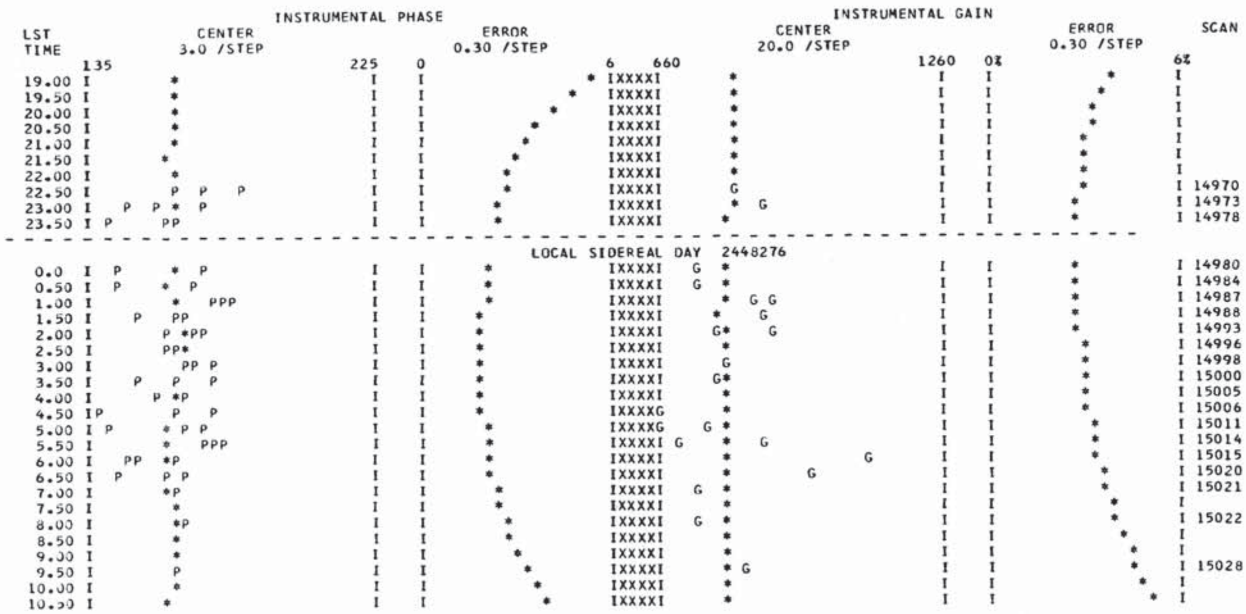
(i)


1L3L XBAND FOR INITIAL LSD 2448275
INSTRUMENTAL PHASE
INSTRUMENTAL GAIN
LST TIME
CENTER 4.0 /STEP
ERROR 0.55 /STEP
CENTER 20.0 /STEP
ERROR 0.25 /STEP
SCAN
45
165
0
11
860
1460
0%
5%
LOCAL SIDEREAL DAY 2448276

(j)

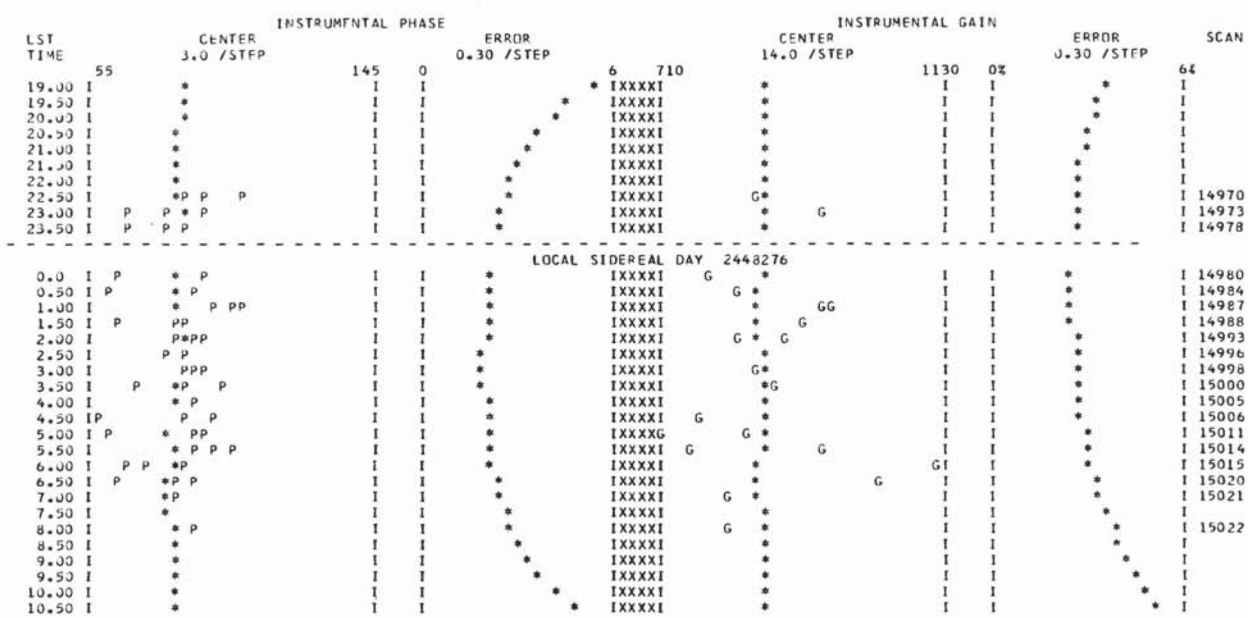
2R3R XBAND FOR INITIAL LSD 2448275

(k)



2L3L XBAND FOR INITIAL LSD 2448275

(ℓ)



---------- DATA FOR CONFIGURATION 1-18-19 ----------

SCAN	M	SOURCE	HA	RMS/100	AMP1R2RPHI		AMP1L2LPHI		AMP1R3RPHI		AMP1L3LPHI		AMP2R3RPHI		AMP2L3LPHI		NREC	TPOWER	LST
14969	SD	P0056-17	-02 51	000000	610	2	700	2	691	3	690	2	820	-2	800	-1	8	665665	22 06 07
14979	SD	P0056-17	-01 12	000000	660	3	640	2	661	4	612	6	844	-6	774	-6	9	655665	23 45 18
15003	SD	P0056-17	02 49	000000	610	18	648	17	698	13	601	15	840	-1	750	-2	8	655665	03 47 08
14969	XD	P0056-17	-02 51	000000	117	20	125	29	80	7	89	27	190	3	130	-4	7	666666	22 06 07
14979	XD	P0056-17	-01 11	000000	127	45	136	36	120	42	98	45	120	-5	107	-22	9	776777	23 45 48
15003	XD	P0056-17	02 49	000000	178	52	193	69	148	48	150	53	237	22	170	-3	3	666666	03 47 08
14970	SD	3C48	-03 19	000000	8783	9	8971	9	9048	7	9053	6	9282	4	9377	3	7	655665	22 16 15
14980	SD	3C48	-01 40	000000	8089	8	8679	7	8595	3	8601	3	8850	5	8900	4	6	666666	23 55 48
14984	SD	3C48	-00 59	000000	8494	6	8663	7	8205	5	8070	4	8767	4	8532	3	7	656665	00 36 30
14998	SD	3C48	01 20	000000	8088	-4	8653	-3	8561	-8	8629	-8	8962	5	8875	4	7	656665	02 56 21
15011	SD	3C48	03 30	000000	9033	6	8904	7	9220	-1	8810	-1	9047	6	8839	6	9	655665	05 06 22
14970	XD	3C48	-03 19	000000	3432	25	3316	22	3273	17	3450	16	3360	6	3310	6	7	666666	22 16 45
14980	XD	3C48	-01 39	000000	3113	23	3060	21	3012	13	3137	11	3073	8	3029	9	6	666666	23 56 18
14984	XD	3C48	-00 59	000000	3654	25	3428	23	2994	16	3182	14	3049	6	3203	7	6	665666	00 36 30
14998	XD	3C48	01 20	000000	3360	5	3261	2	3110	-9	3285	-11	3295	12	3321	13	7	665666	02 56 51
15011	XD	3C48	03 30	000000	3477	34	3174	32	3121	13	3088	13	3156	18	3239	17	4	676666	05 06 55
14971	SD	D0224+67	-04 01	000000	983	17	1103	18	1098	10	1032	9	1234	5	1159	7	9	555665	22 25 24
14985	SD	D0224+67	-01 40	000000	1170	11	1123	12	1102	4	1112	4	1156	6	1157	6	10	555665	00 45 41
14999	SD	D0224+67	00 38	000000	1045	13	1081	14	1085	6	1007	7	1202	4	1103	5	9	655665	03 05 19
15012	SD	D0224+67	02 49	000000	996	18	1034	17	1092	12	1049	11	1222	4	1162	4	12	555665	05 15 43
14971	XD	D0224+67	-04 00	000000	1862	54	1896	54	1697	34	1825	35	1785	16	1783	15	5	666666	22 26 30
14985	XD	D0224+67	-01 40	000000	2077	33	1911	33	1841	15	1998	14	1678	15	1892	16	5	665666	00 46 26
14999	XD	D0224+67	00 39	000000	2008	45	1887	45	1775	26	1842	28	1642	16	1763	15	5	665666	03 06 25
15012	XD	D0224+67	02 50	000000	1878	55	1772	53	1775	35	1920	36	1724	17	1710	15	3	666666	05 16 58
14972	SD	NRA091	-03 26	000000	3572	5	3928	6	3998	5	3892	5	3980	1	4000	0	7	655665	22 36 23
15005	SD	NRA091	02 02	000000	3646	3	3821	5	3720	0	3780	0	3890	4	3808	4	7	655665	04 05 57
14972	XD	NRA091	-03 26	000000	2792	13	2879	12	2792	13	2873	12	2823	-3	2761	-2	7	666666	22 36 53
15005	XD	NRA091	02 03	000000	2899	16	2806	14	2587	4	2783	3	2863	11	2863	12	7	666666	04 06 27
14973	SD	3C119	-05 44	000000	5577	-5	5462	-4	5658	-7	5499	-7	5504	2	5685	2	11	656665	22 45 48
14987	SD	3C119	-03 24	000000	5418	-8	5420	-7	5385	-11	5404	-11	5559	3	5556	3	9	555665	01 05 51
15006	SD	3C119	-00 14	000000	5160	5	5056	6	4950	1	5040	0	5070	5	5089	5	7	666665	04 15 56
14973	XD	3C119	-05 43	000000	2696	-8	2484	-8	2398	-14	2360	-15	2421	2	2442	2	4	666666	22 47 00
14987	XD	3C119	-03 24	000000	2575	-20	2449	-21	2432	-30	2625	-31	2477	9	2496	8	8	665666	01 05 51
15006	XD	3C119	-00 14	000000	2403	19	2193	16	2043	3	2171	2	1819	15	1969	14	7	666666	04 16 26
14974	SD	P2149-28	01 06	000000	1857	11	1910	12	1974	15	1854	16	1945	-4	1964	-4	4	665665	22 57 25
14981	SD	P2149-28	02 15	000000	1755	-18	1872	-17	1959	-14	1860	-15	1951	-2	1874	-4	10	666666	00 06 20
14974	XD	P2149-28	01 07	000000	936	30	823	29	857	49	863	43	1004	-10	965	-10	4	666666	22 57 55
14981	XD	P2149-28	02 15	000000	943	-63	797	-60	828	-53	801	-50	891	-9	831	-10	5	776676	00 06 20
14975	SD	OV080	03 17	300000	1284	5	1275	5	1342	8	1270	7	1340	-2	1241	-3	10	655665	23 05 55
14975	XD	OV080	03 17	000000	1104	16	1001	14	933	13	988	11	960	2	924	6	5	665666	23 06 40
14976	SD	BLLAC	01 14	000000	6303	8	5835	9	5930	5	5751	5	6066	3	5945	3	8	666665	23 15 57
14976	XD	BLLAC	01 14	000000	7654	34	6896	32	6748	22	6794	21	6419	8	6867	9	6	665666	23 15 57
14977	SD	3C454.3	00 32	000000	9763	1	10065	2	10130	0	10010	-0	10614	2	10441	1	8	655665	23 25 35
14990	SD	3C454.3	02 43	000000	9117	8	10628	9	10660	4	10687	3	10430	5	10794	5	10	655665	01 35 53
14997	SD	3C454.3	03 52	000000	10300	14	10629	15	11029	9	10561	9	11241	5	10923	5	12	655665	02 45 25
15004	SD	3C454.3	05 02	000000	11041	10	10729	11	11388	4	10794	5	11749	5	10922	6	12	666666	03 55 36
14977	XD	3C454.3	00 33	000000	12590	35	12007	32	11090	29	11523	28	11575	2	11677	2	7	666666	23 26 27
14990	XD	3C454.3	02 44	000000	13247	46	13951	45	13304	31	14012	30	13633	11	13680	12	4	665666	01 37 01
14997	XD	3C454.3	03 52	000000	14538	49	14103	47	13776	32	13559	32	14196	12	14048	12	3	666666	02 45 25
15004	XD	3C454.3	05 04	000000	15529	36	14314	34	14400	20	13786	20	14818	5	14976	16	1	666666	03 57 28

SCAN	M	SOURCE	HA	RMS/100	AMP1R2RPHI		AMP1L2LPHI		AMP1R3RPHI		AMP1L3LPHI		AMP2R3RPHI		AMP2L3LPHI		NREC	TPOWER	LST
14978	SD	P0114-21	-01 39	000000	2064	15	2166	15	2170	20	2136	21	2266	-4	2247	-5	8	655665	23 36 05
14983	SD	P0114-21	-00 48	000000	2292	-24	2167	-22	2307	-16	2171	-16	2336	-7	2258	-7	6	555665	00 26 41
14989	SD	P0114-21	00 10	300000	2260	-0	2250	-0	2293	3	2191	2	2383	-3	2274	-4	8	655665	01 26 05
14978	XD	P0114-21	-01 39	000000	698	9	639	10	626	25	604	24	648	-20	582	-16	7	776777	23 36 05
14983	XD	P0114-21	-00 48	000000	838	-39	784	-38	739	-23	773	-25	740	-16	771	-19	6	665666	00 27 11
14989	XD	P0114-21	00 10	000000	801	-4	860	-3	771	3	770	0	808	-9	790	-13	7	665666	01 26 05
14982	SD	CYGX-3	03 45	000000	3755	20	3790	21	3919	14	3730	15	3949	4	3775	3	8	655665	00 16 28
14982	XD	CYGX-3	03 46	000000	2335	74	2150	72	2128	54	2164	53	2112	15	2129	17	3	665566	00 17 43
14986	SD	3C147	-04 43	000000	13689	4	12675	5	14120	-0	13440	-0	13270	5	13161	5	8	655665	00 56 31
15000	SD	3C147	-02 24	000000	13218	4	12534	4	12900	-1	12431	-1	12891	5	12727	5	7	656665	03 16 03
15013	SD	3C147	-00 14	000000	12258	13	12331	14	12304	7	11809	7	12279	5	12061	5	7	666665	05 26 02
15022	SD	3C147	02 24	000000	12718	14	12239	15	12674	9	12233	9	12698	5	12573	5	44	555665	08 05 25
14986	XD	3C147	-04 43	000000	5944	28	5268	27	5554	13	5539	13	5305	13	5564	14	4	665666	00 56 46
15000	XD	3C147	-02 23	000000	5638	18	5193	16	5251	4	5394	2	4891	12	5218	13	7	665666	03 16 33
15013	XD	3C147	-00 13	000000	5170	27	4926	25	4464	8	4600	8	4303	15	4439	15	7	666666	05 26 32
15022	XD	3C147	02 25	000000	5473	46	5028	44	4859	30	4913	28	4546	12	4768	13	20	566666	08 05 57
14988	SD	CTA21	-02 01	000000	4575	-9	5008	-9	5037	-9	4974	-10	5070	1	5130	0	8	655665	01 15 30
14988	XD	CTA21	-02 01	000000	1874	-28	1910	-31	1784	-28	1893	-29	1850	-1	1840	-2	8	665666	01 16 00
14991	SD	3C418	05 07	0000	3904	9	4086	10	4266	3	4128	4		0		0	10	655665	01 45 03
14991	XD	3C418	05 10	000000	3452	27	3336	26	3251	11	3330	11	3641	15	3490	16	4	665666	01 48 18
14992	SD	P0106+01	00 49	000000	2609	9	2551	10	2660	7	2508	7	2761	2	2651	2	6	655665	01 56 50
15007	SD	P0106+01	03 19	000000	2579	7	2566	8	2714	3	2564	3	2724	3	2714	3	10	655665	04 26 35
14992	XD	P0106+01	00 50	000000	4615	42	4293	41	4222	36	4285	35	4001	4	4285	5	6	665666	01 57 2C
15007	XD	P0106+01	03 19	000000	4590	37	4183	35	4195	24	4120	22	4371	10	4473	10	4	666666	04 26 35
14993	SD	NRA0140	-01 28	000000	2526	-4	2734	-3	2730	-7	2661	-7	2784	3	2737	4	8	656665	02 06 00
14993	XD	NRA0140	-01 28	000000	2195	-7	2198	-9	1900	-18	2058	-19	2046	9	2041	10	7	665666	02 06 00
14994	SD	P0735+17	-05 19	000000	1888	-18	1860	-17	1945	-15	1846	-15	1931	-2	1900	-1	9	666665	02 16 39
14994	XD	P0735+17	-05 19	000000	2118	-36	1876	-37	1736	-34	1701	.-32	1773	-7	1918	-5	3	666666	02 16 45
14995	SD	3C120	-02 06	000000	6024	-4	6605	-4	6688	-3	6440	-3	7150	1	7040	-0	6	655665	02 25 38
14995	XD	3C120	-02 05	000000	14257	-10	14162	-12	13228	-7	13903	-9	14136	-5	14450	-4	7	665666	02 26 28
14996	SD	3C446	04 13	000000	4871	23	5248	24	5470	18	5382	19	5418	5	5364	4	7	666666	02 37 49
14996	XD	3C446	04 13	000000	4651	21	4656	20	4736	10	4424	9	4590	10	4332	11	2	666666	02 37 38
15001	SD	D0742+10	-04 17	300000	4244	8	3908	8	4292	9	3986	9	4071	-2	4122	-2	7	655665	03 26 17
15019	SD	D0742+10	-01 17	000000	3803	-3	3802	-2	3814	-3	3796	-3	3810	1	3830	1	7	655665	06 26 05
15001	XD	D0742+10	-04 17	000000	3662	26	3179	26	3370	30	3219	30	3251	-5	3387	-4	7	665666	03 26 12
15019	XD	D0742+10	-01 17	000000	3299	-10	3147	-12	2804	-10	3067	-11	2790	-1	3050	-1	7	665666	06 26 35
15002	SD	P0607-15	-02 32	000000	1452	-3	1510	-2	1512	3	1402	3	1576	-5	1435	-5	8	655665	03 35 30
15002	XD	P0607-15	-02 32	000000	2941	2	2950	0	2576	16	2622	15	2808	-14	2837	-13	8	665666	03 36 00
15008	SD	P0438-43	-00 05	000000	6473	-13	6179	-14	6605	-7	6200	-7	6690	-8	6283	-8	3	666776	04 34 15
15008	XD	P0438-43	-00 05	00		0		0		0		0	3899	-19	3734	-23	2	777777	04 34 15
15009	SD	P0614-34	-01 30	000000	2112	-13	1974	-13	2018	-5	1907	-5	2129	-5	2013	-7	8	666666	04 45 25
15018	SD	P0614-34	00 00	000000	2094	-4	2022	-3	2080	1	1970	2	2144	-4	2004	-4	7	666665	06 16 35
15009	XD	P0614-34	-01 29	000000	1043	-29	894	-27	813	-5	840	0	902	-21	857	-21	8	776777	04 45 55
15018	XD	P0614-34	00 00	000000	1118	-13	1064	-15	950	-1	1001	-3	1011	-14	1052	-14	7	666666	06 16 13
15010	SD	3C138	-00 23	000000	5460	-1	5429	0	5404	-2	5276	-3	5535	4	5466	5	7	666665	04 56 26
15021	SD	3C138	01 27	000000	5802	-4	5720	-4	5558	-6	5405	-6	5648	5	5413	4	5	665665	06 47 06

Fig. III-28. INTSCRIB display of scan averages for all data on CALTAPE generated with INTCAL.

SCAN	M	SOURCE	HA	RMS/100	AMP1R2RPHI		AMP1L2LPHI		AMP1R3RPHI		AMP1L3LPHI		AMP2R3RPHI		AMP2L3LPHI		NREC	TPOWER	LST
15010	XD	3C138	-00 23	000000	2346	-9	2292	-6	2310	-12	2304	-13	2311	6	2312	6	6	776776	04 56 26
15021	XD	3C138	01 28	000000	2531	-23	2510	-22	2514	-21	2549	-22	2581	2	2641	2	5	666666	06 47 36
15014	SD	DA267	-03 48	000000	4786	5	4738	5	4980	0	4889	0	4856	5	4910	5	7	555665	05 36 30
15014	XD	DA267	-03 48	000000	11260	17	11362	18	12103	1	12026	2	11761	17	11824	18	6	665666	05 36 30
15015	SD	P1116+12	-05 31	000000	1892	16	1862	15	1855	13	1908	14	1950	0	1980	1	10	666666	05 45 52
15020	SD	P1116+12	-04 41	000000	1952	6	1791	6	1936	5	1843	4	1830	1	1840	1	7	655665	06 36 20
15015	XD	P1116+12	-05 31	000000	1521	39	1535	39	1438	38	1404	40	1652	3	1563	4	5	676676	05 46 10
15020	XD	P1116+12	-04 41	000000	1546	19	1459	21	1572	16	1500	16	1494	4	1437	6	6	665666	06 36 30
15016	SD	P1055+01	-05 01	000000	3500	-22	3132	-22	3405	-19	3273	-19	3353	-3	3342	-2	12	666666	05 55 33
15016	XD	P1055+01	-05 01	000000	3536	-61	3316	-60	3415	-51	3296	-52	3950	-9	3894	-9	5	666666	05 55 33
15017	SD	P0859-14	-02 55	000000	2548	-5	2809	-5	2760	-1	2760	-1	2814	-3	2839	-5	8	655665	06 05 43
15017	XD	P0859-14	-02 54	000000	1769	-21	1967	-17	1829	-6	1876	-8	2059	-13	2032	-13	8	666666	06 06 13
15023	M	1216+48	-03 45	0 0 0		0	949	-54		0	946	-56		0	1015	3	17	555665	08 31 51
15023	M	1216+48	-03 45	0 0 0	930	-164		0	951	-173		0	1065	9		0	17	555665	08 31 51
15024	M	1242+41	-04 02	0 0 0		0	1125	29		0	1088	24		0	1268	3	14	555665	08 40 33
15024	M	1242+41	-04 02	0 0 0	612	74		0	650	59		0	596	16		0	14	555665	08 40 33
15025	M	1244+49	-03 57	0 0 0		0	761	157		0	775	163		0	835	-5	14	555665	08 48 35
15025	M	1244+49	-03 57	0 0 0	170	122		0	219	128		0	456	-15		0	14	555665	08 48 35
15026	M	1315+34	-04 18	0 0 0		0	500	29		0	526	24		0	515	5	17	555665	08 57 27
15026	M	1315+34	-04 18	0 0 0	529	74		0	535	57		0	529	16		0	17	555665	08 57 27
15027	M	1317+52	-04 11	0 0 0		0	443	2		0	335	5		0	987	13	13	555665	09 06 45
15027	M	1317+52	-04 11	0 0 0	447	69		0	455	51		0	539	19		0	13	555665	09 06 45
15028	M	3C286	-04 14	0 0 0		0	9950	0		0	10430	-0		0	10270	1	17	556665	09 15 48
15028	M	3C286	-04 14	0 0 0	5400	-4		0	5653	-5		0	5492	2		0	17	556665	09 15 48

Fig. III-28 continued.

Data File Inputs to INTCAL

Name of File	Required or Optional	Information	Max. No. of Cards	Format
SYSIN	Required	INCLUDE/EXCLUDE Cards	40	FREE
DATA.AMPCALS	Optional*	Source Name XBAND Flux XBand Flux WEIGHT	30	A10,3F10.3
DATA.PHICALS	Optional*	Source Name	100	8A10
DATA.JUMPS	Optional	Correlator Number**	12	212,5(I8,IX,F5.2)

* If not supplied, a default list is used.

**Correlator No. 1-6: SBAND; 1R2R 1L2L 1R2R 1L3L 2R3R 2L3L

9-14: XBAND; 1R2R 1L2L 1R2R 1L3L 2R3R 2L3L

e.g., sample input card:

14 2 2448248 5.75 2448249 7.53

meaning that XBAND 2L3L underwent two jumps, one at LST = 5^h40^m, LSD = 2448248 and another at LST = 7^h32^m, LSD = 2448249.

The following program was used to obtain an example of INTCAL output:

```
//_EXEC_INTCAL,INTAPE=3086,INNAME=CORRTAPE,
//_OUTTAPE=3087,OUTNAME=CALTAPE,OUTDISP=NEW
//_SYSIN_DD_*
INCLUDE_14969_15028
//_EXEC_INTAVG,INTAPE=3087,INNAME=CALTAPE,
//_PARM='ARITH'
```

```
//SYSIN_DD_*
INCLUDE_SBAND
END_REWIND
INCLUDE_XBAND
//_EXEC_INTSCRIB,PARM='LIST,SORT'
```

(results shown in Figures III-26, 27 and 28).

In Figure III-26 the lists of phase calibrators, flux calibrators, and convolution times are shown. In Figure III-27 we see, for each correlator and frequency, plots of the following as functions of LST: (1) a plot of the phase center solution (ϕ_S) obtained from the phase calibrators; (2) a plot of the individual scan average phase (P) for each phase calibrator, (3) a plot of the gain solution (CPFU) obtained from the flux calibrator data; and (4) a plot of the individual scan average gains (CPFU) for the flux calibrators.

In the example being used so many calibrators are involved that the solutions are unusually good. We also see that there were negligible drifts with time.

Finally, the INTSCRIB display of all the results in Figure III-28 gives us the scan average amplitude (A) and phase (Φ) for each scan and correlator. Note that, indeed, all the phases are close to zero and the indicated flux densities are, on the average, as they should be.

The place of INTCAL in the data processing is shown in the flow diagram in Figure III-1.

(f) INTRED to Completely Process Interferometer Data

The aim of the automatic programs like INTCLEAN, INTCORR, and INTCAL is to make it possible to process interferometer data as quickly as possible. Under many circumstances they can be coupled together to complete all data processing during a single run on the 360/50. Because of this there is a program called INTRED (referring to interferometer data reduction) which is used to automatically process the data on all interferometer data tapes when they arrive in Charlottesville. INTRED is automatically run by the computer operators and accomplishes the following purposes.

(1) A copy of all the data on each 7-track telescope tape (headers, A/D records, data records, etc.) is written on a 9-track archive tape that serves as back-up raw data storage in case something happens to other copies of the data.

(2) Another copy of all the raw data is written on another 9-track magnetic tape which is assigned to a particular observer. This tape corresponds to the RAWTAPE discussed in this chapter; however, it will be assigned a name consisting of the word RAW and letters identifying a particular observer, e.g., RAWRMHJ.

(3) Another copy of the raw data is written on a disk data set named INTERF.DUALFREQ.TODAYDTA. Every run of INTRED causes the contents of this data set to be replaced by the contents of the new telescope tape.

(4) A listing of record type, scan number and LST for data which have been flagged as bad by the DDP116 is produced. The usual listing of the numbers of the different types of records written on the data tapes is also given.

(5) An INTINDEX display of the data is obtained.

(6) An INTSCRIB display, with PARM='LIST', is given for all 30-second data records on the data tape.

(7) INTCLEAN is run on the raw data and the output is passed to a temporary disk data set (&&CLEAN). This provides the user with a diagnostic message listing and summary. Partial cleaning is also carried out, with a record of the deletions being a part of the data diagnostics.

(8) INTCORR is run on the output from INTCLEAN. The output of INTCORR, with either PHASE, AMPCOR, and CLOCK corrections applied, or

these plus BASELINE corrections, is written on a 9-track magnetic tape that we have called CORRTAPE in this chapter; however, it will be assigned a name consisting of the word CORR and letters identifying a particular observer, e.g., CORRRMHJ. The observer should note that INTCORR will not process the scans in which baseline parameters are fouled up; it simply passes the data with only PAC applied. The INTINDEX-like output of INTCORR will inform the user when such situations occur.

(9) INTCAL is run on the output of INTCORR, and the results are written on a tape that is called CALTAPE in this chapter; however, it will be assigned a name consisting of the word CAL and letters identifying a particular observer, e.g., CALRMHJ. Since INTCAL is fairly prone to failure because of data problems that cannot be cured with INTCLEAN and INTCORR, sometimes this step will not be executed and the observer will have to run a judicious combination of INTEDIT and INTCAL to obtain a proper CALTAPE.

(10) To facilitate the capability of the user to get rapid access to his CALTAPE output, a copy of this output is written on a disk data set called INTERF.DUALFREQ.TODAYCAL. Each separate run of INTRED causes the contents of this data set to be replaced.

(11) INTSCRIB with CPFU,PLOT,SORT,NOGRID, and RANGE = 2000 options is run on scan averaged (using INTAVG) INTCAL output so one can evaluate whether the CPFU are close to 1000 and the phases are near zero for all calibrators.

(12) Finally, an INTSCRIB is run with LIST and SORT options on all INTCAL output which has been scan averaged and separated by frequency. From this the user can quickly evaluate many of the results obtained for all of the sources.

(13) Finally an INTCORAV display is given for all calibrated data scans.

Given the INTRED output, with the data processing results recorded on RAWTAPE, CORRTAPE and CALTAPE, the user can evaluate whether the results are satisfactory for all stages. If they are not, he can go back to the last stage at which he is satisfied (or the RAWTAPE) and carry out his own data processing with appropriate combinations of all the available interferometer programs.

If polarization calibration is desired, the user will still need to use INTPCAL and INTPCOR to carry the LR and RL correlators from the CORRTAPE stage to the CALTAPE stage. Obviously the first CALTAPE generated is applicable only to LL and RR correlators and a second CALTAPE must be generated with calibrated LR and RL correlators.

(g) Calibration of LR and RL Correlators

Earlier in this chapter we discussed the theoretical principles underlying polarization observations and polarization calibration for the interferometer. The calibration of LR and RL correlators is, in practice, accomplished by a combination of two programs: INTPCAL to determine the instrumental polarization constants and INTPCOR to apply these constants to the calibration of LR and RL correlators.

(1) INTPCAL to Determine Instrumental Polarization Parameters

The polarization calibration of LR and RL correlators begins with the data at a stage where LL and RR correlators are fully calibrated (V_{LL} and V_{RR}), but LR and RL correlators are in the V'_{LR} and V'_{RL} states. That is, all cleaning and correcting has been accomplished.*

It is assumed that all the dual-mode data was liberally interspersed with at least 15 or 20-minute observations of polarization calibrators (see Appendix 2) with known values of m (degree of linear

* The LR and RL visibilities functions have also been multiplied by g_S exp $(-\phi_S)$ for the associated LL correlators.

polarization) and χ (position angle). It is also assumed that all sources have negligible circular polarization so that the assumption by which three complex gains per correlator were reduced to two is valid. INTPCAL solves for complex constants (not functions of time) designated GG and DD for a particular correlator. In terms of the known m and χ and Equations III-12, the GG's and DD's are determined from

$$\left.\begin{aligned} \frac{V_{LR}}{V_{LL}} &= m \exp(2i\chi) = GG_{LR} \cdot \frac{V'_{LR}}{V_{LL}} + DD_{LR} \\ \text{and} \quad \frac{V_{RL}}{V_{LL}} &= m \exp(-2i\chi) = GG_{RL} \cdot \frac{V'_{RL}}{V_{LL}} + DD_{RL} . \end{aligned}\right\} \qquad \text{III-(13)}$$

Comparing with Equation III-(12), this means that

$$GG_{LR} = G'_{LR}$$

$$GG_{RL} = G'_{RL}$$

$$DD_{LR} = G'_{LR,I}/G'_{LL}$$

$$DD_{RL} = G'_{RL,I}/G'_{LL} \quad .$$

Once the GG's and DD's have been determined for each LR and RL correlator, Equation III-(13) can be used to calibrate all data taken in dual-mode during the same time period.

For a complete discussion of polarized data processing, the user should consult the documentation written by J.F.C. Wardle concerning the use of INTPCAL. We will now present a very brief discussion of this usage.

There are two critical problems that must be solved in order to calibrate polarization data: (1) You need regular interspersed observations of good polarization calibrators; and (2) you must decide what segments of the observations are to be considered to have the same values for the complex gains, e.g., jumps and drifts of parameters must be represented by successive segments of time during each of which constant parameters are assumed. Unfortunately, there are only about half a dozen SBAND calibrators with polarization parameters that are generally agreed upon; and only 2 or 3 XBAND calibrators have the same status. As if this were not enough of a problem, because of the relatively poor signal-to-noise it is difficult to identify changes in the instrumental polarization parameters. Perhaps the situation may improve considerably in the near future, but at the moment it is a difficult problem.

Aside from these difficulties, the calibration of LR and RL correlators is quite straightforward. Let us consider an example whereby scans 17257 through 17313 have been taken in dual mode; furthermore, observations of 3C48, 3C286, and 3C147 have been liberally interspersed throughout. The program INTPCAL can be used to determine the GG's and DD's for all LR and RL correlators for both frequencies using the following program:

```
//_EXEC_INTPCAL,INTAPE=3087,INNAME=TCALTAPE
//DUMP.SYSIN_DD_*
INCLUDE_17257_17313_3C48
INCLUDE_17257_17313_3C286
INCLUDE_17257_17313_3C147
//POLAR.SYSIN_DD_*
INCLUDE_17257_17313
//CALTABLE_DD_*
```

11	3	0	0	1	4	2	0	0	1
3C48		2.09		60.0		1.0	SBAND		
3C286		9.23		30.9		1.0	SBAND		
3C147		0.66		46.75		1.0	SBAND		
3C48		5.7		-70.0		1.0	XBAND		
3C286		11.5		32.0		1.0	XBAND		

where the first card read into CALTABLE specifies desired parameters for the solution and its output while the remaining cards give the sources, their values of m and χ, and their relative weights.

The five parameters to be specified for each frequency for which one desires solutions are:

(i) LAMBDA = wavelength involved, specified as 11 if 2695 MHz is involved and 4 if 8085 MHz is involved.

(ii) NUMBER = number of calibrators for which data is to be supplied for a particular frequency.

(iii) CARDS = -2 if you want no punch output
= -1 if you want solution according to weights assigned calibrators, resulting GG's and DD's to be punched out on cards.
= 0 if you want solution with equal weight to all calibrators, resulting GG's and DD's being punched on cards.

(iv) CYCLE ≠ 0 if you want the solution repeated successively leaving out one calibrator at a time (useful if you are unsure about quality of some calibrators).
= 0 if you want only one solution using all calibrators.

(v) DELAY = 0 if you want a solution for each of the ten delay steps.
= 1 if you want results for all delay steps averaged together.
= 2 if you want a solution with two delay steps, one averaging all delay steps before cross-over and one averaging all delay steps after cross-over.

In the sample program the first card read into CALTABLE has

11 so that 11-cm data is processed first

3 because data for 3 SBAND calibrators will be read in

0 so that unweighted solution is obtained and associated GG's and DD's punched on cards

0 so that only one solution is obtained

1 so that all delay steps are averaged together

then

4 so that 3.7-cm data is processed next

2 because data for 2 XBAND calibrators will be read in,

with the remaining XBAND options chosen to be the same as for SBAND.

In practice, it has not yet been conclusively shown that there is any advantage to considering solutions for the ten delay steps separately. Therefore, use of DELAY = 1 is recommended. The other options are up to the user, and one usually tries a number of combinations in the process of obtaining a final solution.

The present version of INTPCAL contains many more options and many more pages of output than the observer usually needs; therefore, we will not show examples of the output in figures. However, we can summarize what is obtained:

(i) A listing of the assumed parameters for each calibrator.

(ii) A tabulation of the number of data records, and the amplitude and phase for V_{LL}, V'_{LR}/V_{LL}, V'_{RL}/V_{LL}, and V_{RR}/V_{LL} for each correlator, and the delay steps chosen. With a page devoted to each calibrator, this data shows the input to the solutions for the GG's and DD's.

(iii) A table giving the real and imaginary parts, the amplitude and phase, the number of data records, and the rms error of the amplitudes for solutions for LR and RL correlators for each delay combination chosen. The GG's and DD's are described as "GAIN" and "DEFLECTION".

(iv) Another page in which

(A) All delay steps are averaged whether or not they had previously.

(B) Closure is checked.

(C) Average closure differences are shown.

(v) A presentation of the calibrated results for each source, i.e., V_{LL}, V_{LR}/V_{LL}, V_{RL}/V_{LL}, and V_{RR}/V_{LL} are tabulated in detail for each correlator and chosen delay steps. In addition, for each source the assumed values of m, χ, $|Q|$, and $|U|$ are listed together with what their values are if obtained after the solution is applied to the data. In addition, the rms (for m) and $|m_{OBS}-m_{CAL}|$ are calculated.

(vi) Finally, tables of polarization parameters as functions of hour angle and declination are presented so that unusually bad data points may be detected.

When two frequencies are evaluated, this output is repeated for the second frequency.

The format for (LAMBDA,NUMBER,CARDS,CYCLE,DELAY) for first 11 then 4 centimeter data is (10I5).

After the options are read in by the first card supplied to CALTABLE, one reads in: source name, m, χ, and a relative weight for each calibrator in the format(A10,3F10.2). When two frequencies are to be processed, first the cards for SBAND calibrators are provided, then those for XBAND calibrators.

Note that INTPCAL does not write the calibrated data on tape or disk data set.

<u>(2) INTPCOR to Apply Polarization Calibration</u>

Given the cards for the GG's and DD's punched out by INTPCAL, INTPCOR is used to apply the polarization calibration to both calibrators and other sources, writing the results on tape. For example,

```
//_EXEC_INTPCOR,INTAPE=3087,INNAME=CALTAPE,
//_OUTTAPE=3187,OUTNAME=CALTAPE,OUTDISP=NEW
//SYSIN_DD_*
INCLUDE_17257_17313
//INSTRPOL_DD_*
11    1    4    1
     {Set of GG's and DD's}
//_EXEC_INTAVG,INTAPE=3187,INNAME=CALTAPE
//SYSIN_DD_*
INCLUDE_17257_17313
//_EXEC_INTSCRIB,PARM='XPOL'
//_EXEC_INTPOLAV
```

where the first card in the INSTRPOL data file gives LAMBDA and DELAY for both frequencies in format (4I5), and the GG's and DD's are then read in. After INTPCOR has written V_{LL},V_{RR},V_{LR}, and V_{RL} on the CALTAPE, so that on this tape all data is in the form $V = A \exp(i\phi)$, INTAVG,INTSCRIB (with XPOL option) and INTPOLAV are used to obtain information about the final calibrated LR and RL data.

APPENDIX 1*

POSITIONS AND FLUX DENSITIES† FOR AMPLITUDE AND PHASE CALIBRATORS

Source	α_{1950}	δ_{1950}	$\sigma(\alpha)$	$\sigma(\delta)$	S_{2695}	S_{8085}	Weight For Fluxes
P0056-00	00ʰ56ᵐ31ˢ.76	-00°09'18".4	0ˢ.02	0".5	1.8	1.1	0.2
**P0106+01	01 06 04.48	+01 19 01.0	0.04	1.0	2.6	4.1	0.4
P0114-21	01 14 25.91	-21 07 53.4	0.03	1.0	2.3	0.7	0.3
*****3C48	01 34 49.82	+32 54 20.7	0.01	0.2	9.0	3.3	1.0
***NRAO91	02 02 07.41	+14 59 50.5	0.01	0.3	3.8	2.7	0.4
D0224+67	02 24 41.13	+67 07 39.9	0.03	0.1	1.2	1.9	0.1
*P0237-23	02 37 52.77	-23 22 04.8	0.02	0.7	5.1	2.1	0.2
*****CTA21	03 16 09.12	+16 17 40.3	0.04	0.7	5.0	1.7	0.8
****NRAO140	03 33 22.40	+32 08 36.8	0.01	0.2	2.7	2.1	0.6
*NRAO150	03 55 45.25	+50 49 20.6	0.02	0.1	5.9	9.7	0.1
P0403-13	04 03 14.02	-13 16 20.8	0.04	1.2	2.7	1.7	0.2
**P0413-21	04 13 53.65	-21 03 52.0	0.03	1.1	1.6	0.85	0.5
***P0420-01	04 20 43.53	-01 27 28.1	0.02	0.7	1.3	1.5	0.7
***3C119	04 29 07.88	+41 32 08.6	0.05	0.7	5.4	2.2	0.5
*3C120	04 30 31.62	+05 14 59.2	0.03	0.5	6.7	12.8	0.1
**P0438-43	04 38 43.24	-43 38 56.2	0.03	0.7	5.8	2.7	0.2
NRAO190	04 40 05.30	-00 23 20.6	0.05	1.2	2.6	2.0	0.2
***P0451-28	04 51 15.14	-28 12 29.9	0.02	0.6	2.2	2.0	0.5
****3C138	05 18 16.52	+16 35 27.3	0.01	0.2	5.6	2.8	0.6
*****3C147	05 38 43.50	+49 49 42.9	0.02	0.1	12.7	5.0	0.8
P0556+28	05 56 30.94	+28 18 09.9	0.01	0.2	0.45	0.20	0.1
*P0605-08	06 05 35.97	-08 34 18.4	0.03	1.0	3.1	3.7	0.2
P0607-15	06 07 26.02	-15 42 04.2	0.03	0.9	1.5	2.7	0.1
P0614-34	06 14 48.81	-34 55 08.6	0.02	0.5	1.7	0.9	0.3
DA207	06 21 41.88	+32 06 47.1	0.01	0.2	1.0	0.44	0.3
OI318	07 11 05.62	+35 39 52.6	0.01	0.2	1.8	1.2	0.2
**D0727-11	07 27 58.13	-11 34 53.5	0.03	0.9	2.6	4.8	0.5
**P0735+17	07 35 14.12	+17 49 09.5	0.01	0.3	2.0	1.8	0.4
**P0736+01	07 36 42.51	+01 44 00.3	0.02	0.4	2.1	1.6	0.4
*OI363	07 38 00.17	+31 19 02.5	0.01	0.2	2.3	1.9	0.2
*D0742+10	07 42 48.46	+10 18 32.9	0.01	0.3	3.9	3.0	0.3
**P0743-00	07 43 21.04	-00 36 55.3	0.02	0.4	1.3	1.6	0.4
***P0834-20	08 34 24.65	-20 06 31.4	0.03	0.8	2.5	2.6	0.6
**P0859-14	08 59 54.96	-14 03 38.6	0.03	0.9	2.7	1.7	0.4
**P0906+01	09 06 35.19	+01 33 48.1	0.02	0.5	0.98	1.1	0.4
***DA267	09 23 55.29	+39 15 24.3	0.01	0.2	4.8	10.7	0.7
3C232	09 55 25.39	+32 38 23.4	0.01	0.2	0.90	0.66	0.3
***3C236	10 03 05.39	+35 08 48.1	0.01	0.2	2.1	0.95	0.4
**P1015-31	10 15 53.44	-31 29 12.5	0.02	0.6	2.2	1.0	0.5
*P1116+12	11 16 20.74	+12 51 06.6	0.06	1.2	1.7	1.2	0.5
***P1127-14	11 27 35.69	-14 32 54.9	0.03	0.9	6.4	4.5	0.7
*P1148-00	11 48 10.10	-00 07 12.9	0.05	0.9	2.4	1.3	0.4
P1151-34	11 51 49.42	-34 48 46.4	0.02	0.7	4.2	2.2	0.2
*3C268.3	12 03 54.08	+64 30 18.7	0.03	0.1	2.0	0.60	0.4

* The number of asterisks reflect overall reliability as both amplitude and phase calibrators.

† Except for 3C48 and 3C286, none of the flux densities listed here are to be relied upon, since most either change with time or are poorly determined.

Source	α_{1950}	δ_{1950}	$\sigma(\alpha)$	$\sigma(\delta)$	S_{2695}	S_{8085}	Weight For Fluxes
P1237-10	$12^h37^m07^s.29$	$-10°07'00''.6$	0.03	1.0	1.4	0.85	0.2
**P1245-19	12 45 45.22	-19 42 57.6	0.03	0.8	3.6	1.5	0.5
*3C279	12 53 35.82	-05 31 07.4	0.02	0.6	13.0	12.5	0.1
****3C287	13 28 15.96	+25 24 37.0	0.01	0.2	4.6	2.2	0.7
*****3C286	13 28 49.68	+30 45 58.3	0.01	0.2	10.1	5.2	1.0
****P1345+12	13 45 06.19	+12 32 20.0	0.01	0.3	3.8	2.4	0.6
OQ323	14 13 56.29	+34 58 29.5	0.01	0.2	1.6	0.88	0.2
3C298	14 16 38.86	+06 42 19.4	0.03	0.7	2.6	1.0	0.3
***3C309.1	14 58 56.61	+71 52 11.3	0.04	0.1	5.3	2.5	0.5
P1508-05	15 08 14.97	-05 31 49.4	0.02	0.4	2.7	2.0	0.2
*P1510-08	15 10 08.88	-08 54 46.7	0.03	1.0	2.5	2.6	0.2
D1548+05	15 48 06.90	+05 36 12.4	0.02	0.4	2.3	2.2	0.1
D1555+00	15 55 17.68	+00 06 44.2	0.02	0.7	1.4	1.5	0.3
*P1607+26	16 07 09.29	+26 49 18.7	0.01	0.2	3.0	0.95	0.2
****DA406	16 11 47.92	+34 20 20.0	0.01	0.2	2.4	2.1	0.7
***3C345	16 41 17.61	+39 54 11.3	0.01	0.2	8.7	10.6	0.3
***NRAO530	17 30 13.48	-13 02 45.6	0.07	1.6	3.9	4.6	0.6
**3C371	18 07 18.55	+69 48 57.0	0.03	0.1	1.8	2.1	0.2
*****3C395	19 01 02.29	+31 55 14.2	0.01	0.2	3.2	2.2	0.9
*OV080	19 47 40.13	+07 59 36.9	0.02	0.4	1.3	0.9	0.2
****3C418	20 37 07.41	+51 08 36.0	0.06	0.8	4.0	3.3	0.8
***P2128-12	21 28 52.76	-12 20 23.3	0.04	1.2	1.7	1.6	0.7
P2145+06	21 45 36.05	+06 43 40.4	0.06	1.3	3.9	3.0	0.2
P2149-28	21 49 10.57	-28 42 36.5	0.02	0.6	1.9	0.8	0.1
*3C446	22 23 11.02	-05 12 17.3	0.02	0.4	5.2	3.8	0.2
BLLAC	22 00 39.37	+42 02 08.8	0.01	0.2	6.0	6.2	0.1
3C454.3	22 51 29.52	+15 52 53.7	0.02	0.3	11.0	10.0	0.1
P2345-16	23 45 27.61	-16 47 50.1	0.03	1.0	3.2	3.6	0.1

APPENDIX 2

LIST OF POLARIZATION CALIBRATORS[†]

Source	m	χ	m	χ
	2695 MHz		8085 MHz	
*****3C48	2.09	60.0	5.74	-70.5
*****3C147	0.70	44.0	1.45	- 7.5
*****3C286	9.20	30.9	11.0	31.7
*3C309.1	2.0	84.0	---	---
*P0237-23	2.1	137.0	4.6	-30.2
*P1127-14	2.4	29.0	3.2	-38
*CTA102	5.3	17.1	---	---
*3C287	3.1	-75.5	---	---

[†]The asterisks next to each source name denote the extent to which different observers agree on the polarization constants.

APPENDIX 3

NAMES OF DEFAULT INPUT AND OUTPUT DISK DATA SETS FOR STANDARD PROGRAMS

Program	Input Name	Output Name
INTLOOK	&&OUTNAME	---
INTSCRIB	&&OUTNAME	---
INTCOPY	&&OUTPUT	&&OUTNAME
INTAVG	&&OUTPUT	&&OUTNAME
INTINDEX	&&OUTNAME	---
INTCORAV	&&OUTNAME	---
INTPOLAV	&&OUTNAME	---
INTBCAL	&&OUTNAME	---
INTCLEAN	&&OUTNAME	&&CLEAN
INTCORR	&&CLEAN	&&CORR
INTCAL	&&CORR	&&CAL
INTMAP	&&OUTNAME	&&OUTMAP

APPENDIX 4

PEOPLE TO TALK TO ABOUT PROBLEMS OR TO OBTAIN INFORMATION

IN GREEN BANK

Name	Type of Problem
Jane Gordon	Dorm room assignments, transportation on site.
Operator On Duty	Operating status of instrument, recent problems.
Len Howell	Over-all problems with mechanical operation of instrument.
Jim Coe William Shank James Oliver	Electronics problems.
Ron Weimer	Digital problems involving DDP116.
Ed Fomalont	Observers "friend" for interferometer, instructions concerning observing procedures, scientific considerations involved in observing.
Dave Hogg	Scheduling of interferometer time, changes in observing programs.

IN CHARLOTTESVILLE

Name	Type of Problem
Donna Beamer	Obtaining user number for 360/50.
Phyllis Jackson	Arrangements concerning NRAO's share of publication page charges and preprints for NRAO files.

Name	Type of Problem
Ann Jackson (or Computer Operators)	Checking out magnetic tapes.
Linda Blankenship	Problems involved in setting up and running standard interferometer programs, aid in solving data processing problems.
Bill Meredith	Serious data processing problems where detailed knowledge of contents and algorithms of standard interferometer programs is needed, documentation on program contents.
George Conant	On-line programs for DDP116.
Bob Hjellming	Observers "friend" for interferometer data processing, interferometer documentation, scientific considerations involved in data processing.

APPENDIX 5

CHECK LIST OF THINGS TO BE DONE BEFORE, DURING AND AFTER OBSERVING

Months Ahead of Observing Time

1. Prepare observing request specifying
   - a) Scientific justification for program.
   - b) Sources to be observed.
   - c) Amount of time and LST range desired.
   - d) Desired configuration or configurations.
   - e) Special equipment needed. (If special equipment is involved, consultation with Green Bank personnel considerably ahead of time is absolutely necessary.)
2. Send copies of observing request to
   - a) D. E. Hogg (Green Bank).
   - b) D. S. Heeschen (Charlottesville).
   - c) W. E. Howard (Charlottesville).

Weeks Ahead of Observing Time

1. Make arrangements with W. E. Howard concerning NRAO subsidy for travel to Green Bank.
2. Arrange for lodging and transportation needs on Green Bank site (Jane Gordon).
3. Take care of detailed planning of observing program with schedule of observing time in hand (will be sent to you by D. E. Hogg). Be sure scientific objectives are compatible with practical details of scheduling (see Chapter II).

Day Ahead of Observing Time

1. Inform Wade Davis (head computer operator) or Ann Jackson in Charlottesville concerning disposition of daily INTRED output.

2. Check with Ed Fomalont (Green Bank), George Grove (Green Bank), Linda Blankenship (Charlottesville), or Ann Jackson (Charlottesville) about status of accurate baselines and whether the good baselines will be read in by either the DDP116 in Green Bank or during INTRED processing in Charlottesville.

3. Check with Ed Fomalont (Green Bank) or George Grove (Green Bank) concerning accuracy of pointing solutions being used.

4. Punch out program deck, where possible keeping at least 12 hours and preferably 24 hours ahead of the observing. Check for hour angle and mountain limitations. Assign dump times for disk to tape transfer by DDP116 (see Chapter II).

While Observing

1. Be present, if possible, whenever program decks are loaded into DDP116 (at beginning of program and after each dump). Errors may be detected that need immediate fixing by the observer before the observing can commence again.

2. Keep operators informed of your location and telephone extension at all times.

3. Initial the form kept by the operators indicating the name of the observing program, the observers involved, their home institutions, and which observers are students (if any).

4. Inform operator concerning your wishes about disposition of: teletype output, analog records, and observing logs.

5. Periodically throughout the program acquaint yourself with status of equipment and possible problems.

6. Periodically examine the on-line data display (see Chapter II) for all sources,but most importantly calibrators. Even if you are not interested in evaluating your scientific results on-line, you can detect many mal-functions simply by noting that the data does not look "right".

7. Changes in the observing program can be made within minutes, if desired (a key punch machine is in the building), with the only price being a few minutes loss of observing time during the re-loading process.

After Observing (or Interspersed with Observing Where Possible)

1. Evaluate your data output through examination of at least the INTRED output.

2. Carry out data processing for each successive day of observing. INTRED will always be applying INTCLEAN, INTCORR, and INTCAL to the data for each day. With a little bit of work, evaluating the data and taking care of problems not solvable with these automatic programs, the user can usually keep the data processing no more than one day out of step with the observing. This is very useful both for learning about problems early and for keeping track of whether desired scientific objectives are being obtained.

3. The observer may chose to produce synthesis maps of day to day results. This is the simplest and most complete way of obtaining most scientific results.

Weeks to Months After Observing

1. Complete analysis of data.

2. When writing scientific papers involving data taken on NRAO instruments the authors must fulfill one of the conditions under which they are granted observing time. They must acknowledge the extent to which NRAO equipment is involved and either by footnote or acknowledgement include the sentence: "The National Radio Astronomy Observatory is operated by Associated Universities, Inc. under contract with the National Science Foundation".

3. After papers are written and submitted to a journal, the authors should discuss arrangements concerning NRAO's payment of part of the page charges, and pre-prints for the NRAO files, with Phyllis Jackson in Charlottesville.

4. When magnetic data tapes are no longer needed, inform Ann Jackson so they can be re-used.

5. Finally, the observer is cautioned that most people find it most convenient, if not absolutely necessary, to carry out all data reduction and analysis in Charlottesville. Those attempting to do so on computers at their own institutions face many difficult problems.