Heeschen

NATIONAL RADIO ASTRONOMY OBSERVATORY
Charlottesville, Virginia
August 3, 1971

MEMORANDUM

TO: Interferometer Group

FROM: M. C. H. Wright

SUBJECT: H-Line Interferometer - Calibration Procedure

Contents

Introduction

The reduction procedure is similar to that used for an interferometer at a fixed observing frequency. The basic equation for calibration is:

ϕ observed = ϕ source (structure and position of source and actual baseline)

$-\phi$ calculated (assumed position and baseline)

$+\phi$ instrument (changes in instrument and atmosphere)

For a line interferometer the phase ϕ is a function of frequency and some additional calibrations must be made. The following is a suggested procedure for carrying these out.

1) Interferometer Baseline

This calibration must also be made for an interferometer observing at a fixed frequency. The procedure is to observe calibrating sources (unresolved sources at known positions) over a range of HA and DEC which cover the positions of the sources being investigated. Assuming that the sources are unresolved and that the correct positions ($\underset{\sim}{r}$) have been given, the observed phase is then the sum of phase due to errors in the assumed baseline plus the instrumental phase.

$$\text{Thus } \phi \text{ observed} = \underset{\sim}{r} \cdot \underline{\Delta B} + \phi_o$$

If the calibrating sources are observed at the same frequency (not velocity) then a least squares solution can be made to obtain a correction for the assumed baseline and the residual phase ϕ_o is the instrumental phase which is a function of time and can be directly edited out of the data.

If the calibrating sources are observed over a range of observing frequencies, then the instrumental phase, ϕ_o, will be a function of frequency due to unequal cable lengths at the variable synthesis frequency, and a solution must be made to include this effect. (Clearly a better solution will be obtained if attempts are made to observe the calibrating sources within a short period of time when the instrumental phase is relatively stable and over a small range of frequencies.)

2. Instrumental Phase

Just as the determinations of the baseline is confused by the frequency dependence of the instrumental phase, the reverse is also true. Although a combined least squares solution may be made for baseline and frequency dependence a better solution will be obtained if a single source is observed in a short time over a wide range of frequencies.

Both of these calibrations are made independent of the frequency channel and either the broad band continuum channels or the added frequency channels should be made to obtain the greatest signal-to-noise ratio. Several passes through the data may be made to find a solution interatively,

i) correcting for the frequency dependence if a separate calibration has been made

ii) correcting for baseline errors

iii) editing the time dependence of the instrumental phase

iv) re-cycling as desired

3. Passband Correction

In addition to the frequency channel independent calibrations above, correction for the shape of the IF passband of the cross correlator may also be made.

The passband is determined as the shape of the spectrum resulting from the observation of a source without frequency structure. This passband shape may then be removed from other data. The same calibrators as were used to calibrate the baseline and instrumental phase may be used to determine the passband and this will be the best procedure for calibrating weak sources. However for strong sources the passband may be determined with greater precision by observing the same source off-frequency (i.e., at a frequency where it lacks frequency dependent structure). Calibration of strong absorption sources is discussed in section 4.

The IF passband correction is most clearly presented mathematically. The amplitude and phase response in frequency channel i:

i) <u>On source - on frequency</u>

$$= \underbrace{A_i(k)\ e^{j\phi(k)}}_{\substack{\text{structure of source (k)} \\ \text{k = spactial frequency}}} \times b_i \qquad \underbrace{e^{j\xi_i}}_{\text{IF passband}} \qquad \times \qquad \underbrace{e^{j\eta}}_{\substack{\text{instrumental} \\ \text{phase} \\ \text{+ baseline}}} \qquad (1)$$

ii) <u>Calibrator - on frequency</u>

$$= \underbrace{a}_{\text{unresolved, } \therefore \text{ constant amplitude}} \underbrace{(e^{-\tau_i})}_{\text{local absorption}} \times b_i\ e^{j\xi_i} \times \underbrace{e^{j\eta^1}}_{\substack{\text{instrumental} \\ \text{+ baseline}}} \qquad (2)$$

If there is no trouble from local absorption in the calibrator, then after correcting the baseline $\eta = \eta^1$ and <u>dividing</u> (1) by (2) gives us the source structure directly in units of the calibrator flux.

iii) If local absorption in the calibrator is a problem then the calibrator may be observed off frequency to give

$$a \times b_i\ e^{j\xi_i} \times e^{j\eta^1} + \underbrace{e^{j\Delta\eta}}_{\substack{\text{frequency dependence of} \\ \text{instrumental phase}}} \qquad (3)$$

We must now correct for baseline and phase-frequency dependence before dividing.

4. <u>Strong Absorption Sources</u>

The passband correction is limited by the noise in the individual frequency channels and for a strong source the calibration is best obtained from an <u>on-source</u>, <u>off-frequency</u> observation. In the case of finding the structure of the absorbing material this also eliminates the need to find the interferometer baseline.

The response in frequency channel i is:

i) <u>On source - on frequency</u>

$$= \underbrace{A(k)\ e^{j\phi(k)}}_{\text{source structure independent of frequency}} \times \underbrace{e^{\tau_i(k)} e^{j\Psi_i(k)}}_{\text{absorption \& frequency structure}} \times \underbrace{b_i\ e^{j\xi_i}}_{\text{IR passband}} \times \underbrace{e^{j\eta}}_{\text{instrumental phase}} \qquad (4)$$

ii) <u>On source - off frequency</u>

$$= A(k)\ e^{j\phi(k)} \times b_i e^{j\xi_i} \times \underbrace{e^{j(\eta + \Delta\eta)}}_{\text{frequency dependence of instrumental phase}} \qquad (5)$$

Dividing (4) by (5) gives:

$$e^{\tau_i(k)}\ e^{\,j\Psi_i(k)} \times e^{-j\Delta\eta}$$

and we need only correct for the phase-frequency dependence to obtain the absorption structure directly.

The source structure may be obtained separately from the continuum or added channels of the off-frequency observation and a baseline determination is then required.