NATIONAL RADIO ASTRONOMY OBSERVATORY
SOCORRO, NEW MEXICO
VERY LARGE ARRAY PROGRAM

VLA TEST MEMORANDUM NO. 125

PRELIMINARY POLARIZATION CALIBRATION OF THE VLA AT 6 CM

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1.0 INTRODUCTION

On March 14-15 we had an observing run in which the astronomical objective was to measure the integrated linear polarization of strong variable sources at 6 cm and 2 cm. Of the 36 hours allotted, approximately 16 hours were lost due to power glitches and Modcomp hardware problems. A further 25 percent of the time was lost because there were an insufficient number of antennas working completely at 2 cm for long enough periods of time to calibrate the instrument.

There were a total of 6 antennas (1, 3, 7, 8, 10, 11) available most of the time. Four principle calibrators were used for determining the instrumental polarization: 3C84, 3C286, 3C287 and DA276. These sources were tracked continuously for about 1 to 2 hours through the meridian. The observations were conducted at 4900 MHz using the 12 MHz bandwidth.

2.0 SUMMARY

(1) The antenna polarizations (referenced to antenna 1A) range in magnitude from 0.5 to over 3 percent for the antennas available during our observing run.

(2) The correlator polarizations exhibit temporal variations of up to 1 percent over 2 hours. Antenna 3C, 7C and 10C are noticeably bad with variations in the 0.5 to 1.0 percent range. The variation in correlator (polarization) phase is up to 100 degrees over two hours. Our observations indicate that most instrumental polarizations may vary in time.

(3) Antenna 3 polarization showed no difference when the antenna was located on two different stations.

(4) There still remain significant variations in the A-C phase differences. These variations tend to be jumps which may be related to the fact that some of these retrofitted antennas were not properly calibrated. Certainly the large change in phase after the power to the antennas was turned off is annoying.

(5) There was no evidence of instrumental polarization dependence on elevation over the 20^{o} to 80^{o} elevation range with an amplitude greater than one to one and a half percent. More data is needed.

(6) It is possible to calibrate the instrumental polarization to about 1 percent or slightly better in amplitude and about 40 degrees or better in angle. This 1 percent limit is due to time variations in the instrumental polarizations (see [2] above). If these time variations can be prevented it should be possible to calibrate to better than 1 percent. Calibration in absolute phase is possible to about 5 degrees.

(7) It is definitely possible to calibrate and measure the polarization of point sources. However, for weakly polarized sources the results are greatly influenced by the uncertainty in the instrumental polarization. Our observations suggest that it is possible to map source polarization to the level of about one percent.

3.0 A-C PHASE DRIFT

There were significant changes in the phase difference between parallel bands during these observations. Figure 1 exhibits the AA-CC phase of all antennas with antenna 1. The phase stability of some antennas over several hours can be as good as a few degrees. However there are several significant changes. Most baselines showed a difference in the AA-CC phase before and after the power failure (afternoon of March 14) with magnitudes typically in the 20^{o} to 180^{0} range. It appears that the largest phase variations occur in the CC correlator.

Antenna 11 exhibited large (40° or more) and numerous AA-CC phase variations which appear correlated with large fluctuations in the phase of the 5 MHz L.O. signal at the antenna. The L14 module was known to have lock problems at this time. It is probably significant that the poor behavior of antenna 11 occurred after the power failure.

At approximately 2:30 on March 15 all baselines involving antenna 3 exhibited a change in the AA-CC phase of approximately 10° and at approximately 3:15 all baselines involving antenna 1 show a jump of about 10°. Although the 5 MHz phase on antenna 3 shows a glitch at the time of the AA-CC phase jump, there appears no similar correlation for antenna 1. There was a glitch in the 600 MHz round-trip phase at the time of the phase jump in antenna 1.

Again it appears that the CC correlator phases changes by a larger amount than the AA phase.

4.0 BASELINE POLARIZATIONS

The most convenient means of examining the correlator instrumental polarization is to observe 3C84. This source is a very strong (about 50 Jy at 6 cm) unresolved source (to the 1 or 2 percent level) whose intrinsic integrated polarization is approximately 0.1 percent. We tracked this source continuously for about 2 hours through the meridian. These observations indicate that (a) the typical correlator polarizations are in the 1 to 3 percent range and (b) the instrumental polarizations exhibit temporal variations ranging from several tenths to over 1 percent. Figure 2 shows the temporal variations of four correlators involving antenna 3C. This particular IF showed the largest time variations (of about 1 percent) for our particular run. The 7C and 10C IFs appeared to exhibit variations in the neighborhood of about 0.5 percent. Most correlators show a variation greater than .2 percent (source polarization is 0.1 percent) suggesting that most instrumental polarizations may all vary in time. The weak strength and strong polarization of the other calibrators precludes any conclusive statements about the temporal behavior of the instrumental polarization from the observations of these sources.

There were no conclusive correlations of the polarization variations with system temperature, dewar temperature, paramp bias voltage, B-rack temperature, 600 MHz round-trip phase, or the 5 MHz phase at the antenna. John Archer has recently discovered from data with a much larger time base than ours a correlation between the vertex room temperature and the polarization changes associated with antenna 3. His observations do not contradict ours since our time base was too short to draw any firm conclusions.

Observations from our September 1977 run indicated that the 1 percent variations seen in 3C84 occurred within or in front of the transfer switch. Recent observations of 3C84 during test runs on February 25 and April 13 of this year show that the large variations do not always occur in antenna 3.

Figure 3 exhibits the temporal variation of the correlator polarization phase for 3C84 of some correlators involving antenna 3. For antenna 3 the variations over a two-hour time scale can be as large as 60°. Some correlations show changes larger than this with 7A11C exhibiting the largest of 100° over two hours.

5.0 ANTENNA POLARIZATIONS

The antenna polarizations were calculated from our calibrator observations using the Earth's rotation to beat the source polarization with the antenna polarizations. This method yields both the antenna and source polarizations. Table 1 lists the average IF polarizations referenced to 1A obtained from the observations of our few calibrators. The errors quoted are strictly the rms of the amplitudes and phases (phases and not position angles are quoted). The rms scatters quoted in the table are consistent with the peak-to-peak variation in the correlator polarizations of 3C84 and the assumption that most antenna polarization probably vary. These observations suggest that the instrumental variations over a day are no worse than (and perhaps limited by) the short 1 to 2 hour variations.

6.0 ANTENNA POLARIZATION ON DIFFERENT PADS

Shortly after our run antenna 3 was moved to a different pad and its polarization was remeasured on two different dates. The results are listed in Table 2. It can be seen that the difference in polarizations of this antenna at the two pads is less than 0.4 percent and certainly within the temporal variations seen within our observing run.

7.0 INSTRUMENTAL POLARIZATION DEPENDENCE ON ELEVATION

Figure 4 shows the dependence of the polarization of 3C286 on elevation for the baseline 1-3. There is a change of 1 percent and 20 degrees at the low elevation of 20°. As expected the largest changes in the intrinsic source polarization are associated with antenna 3; this same antenna exhibited the largest instrumental time variations with about the same magnitude. From our present data it does not appear possible to distinguish temporal variations from any elevation dependence. There appears to be no variation of instrumental polarization with elevation that is much greater than 1 percent and 20 degrees.

8.0 CALIBRATION

We have determined the instrumental polarization of the antennas to approximately 1 percent. Next we wish to demonstrate, albeit in a simple minded manner, that the correction of raw data for this instrumental polarization does improve our measurement of source polarizations. Table 3 lists the apparent source polarization uncorrected and corrected for the instrumental parameters listed in Table 2. In addition, the range of published polarization measurements by other observers prior to 1972 are given.

There are several points of interest. First, the rms of the degree of polarization of the calibrated data is approximately a factor of three smaller than the rms of the uncalibrated data. This is a reflection of the improved "coherency" between different correlators of the measured source polarizations after it has been corrected for the measured instrumental polarization. Secondly, a comparison of the published and calibrated values shows quite good agreement. It should be remembered that all sources but 3C286 and 3C287 are known to be variable in flux density and polarization.

Finally, the uncertainty in the calibration of the instrumental is noticeable in the weakly polarized sources. For example, not only is the rms of the calibrated degree of polarization of 3C84 a factor of ten larger than one expects from the noise, but the calibrated degree of polarization (0.7 percent) is much larger than that calculated (0.1 percent) from the calibration technique of tracking 3C84 through the meridian. This latter method uses much more data and therefore yields a better estimate to the source polarization. The rms of the position angle of the weakly polarized sources (e.g., P1127-14) is a factor 6 or more larger than one expects from noise alone. These data indicate that the real limitation in calibrating weakly polarized sources at the moment is the calibration of the instrumental polarization and not system noise.

Table 1

Average Antenna IF Polarizations for April 14, 1978

Antenna	IF A amp [%]	IF A phase [°]	IF C amp [%]	IF C phase [°]	# pts
1			0·65(·11)	-85·9(34·5)	4
3	2·02(·15)	-59·3(16·9)	3·14(·25)	- 4·8(18)	4
7	0·74(·15	-132·8(11·7)	2·99(·32)	9·0(11·9)	4
8	0·98(·07)	-109·0(13·0)	1·20(·61)	-27·8(4·6)	4
9	1·20	-140	2·68	-38·4	1
10	0·30(·18)	+164·0(51)	2·02(·71)	-17·6(21·2)	4
11	1·90(·27)	-83·1(6·9)	1·59(·17)	-90·2(5·6)	4

rms is given in brackets

Antenna 1A is used as reference

Table 2

Antenna 3 Polarizations on Different Stations

Date	IF A amp [%]	IF A phase [°]	IF C amp [%]	IF C phase [°]	Station	Sources
March 15, 1978	1·85	-59·2	3·06	-13·6	DW3	3C286
April 1, 1978	1·96	-42·3	3·16	-14·8	DE1	3C286
April 13, 1978	1·61	-65·3	2·81	-17·1	DE1	3C84

Formal errors are 0·04 percent in amplitude and 1 degree in phase

Table 3

Source	Uncalibrated amp [%]	Uncalibrated p.a. [degrees]	Calibrated amp [%]	Calibrated p.a. [degrees]	Integr. time [min]	Published Ranges amp [%]/p.a. [degrees]
3C84	2.1 (1.3)	104 (17)	0.7 (0.4)	63 (25)	3.5	0.2 to 0.6/ 96 to 116
DA267	2.1 (1.1)	115 (23)	0.6 (0.3)	152 (23)	3.5	0.3 to 1.0/ 58 to 67
P1127-14	4.3 (1.4)	158 (26)	3.1 (0.5)	149 (27)	8.6	2.7 to 3.5/125 to 136
3C273	4.2 (1.4)	156 (19)	2.4 (0.5)	157 (17)	9.0	2.0 to 3.2/140 to 150
3C286	9.6 (1.2)	145 (8)	10.9 (0.6)	33 (4)	3.0	11.0/33.0 *
3C287	6.3 (1.4)	148 (17)	5.2 (1.0)	155 (12)	1.0	4.7 to 6.4/152 to 157
3C345	4.8 (1.5)	37 (26)	3.7 (0.5)	32 (24)	4.5	2.4 to 3.2/ 36 to 53

* The published position angle of 3C286 has been used to set the absolute phase of the cross correlation.

These calibrated and uncalibrated data represent averages of all correlators involving antennas 1, 3, 7, 8, 9, 10 over the integration time specified. The numbers quoted in brackets represent the rms of the data across different correlators.

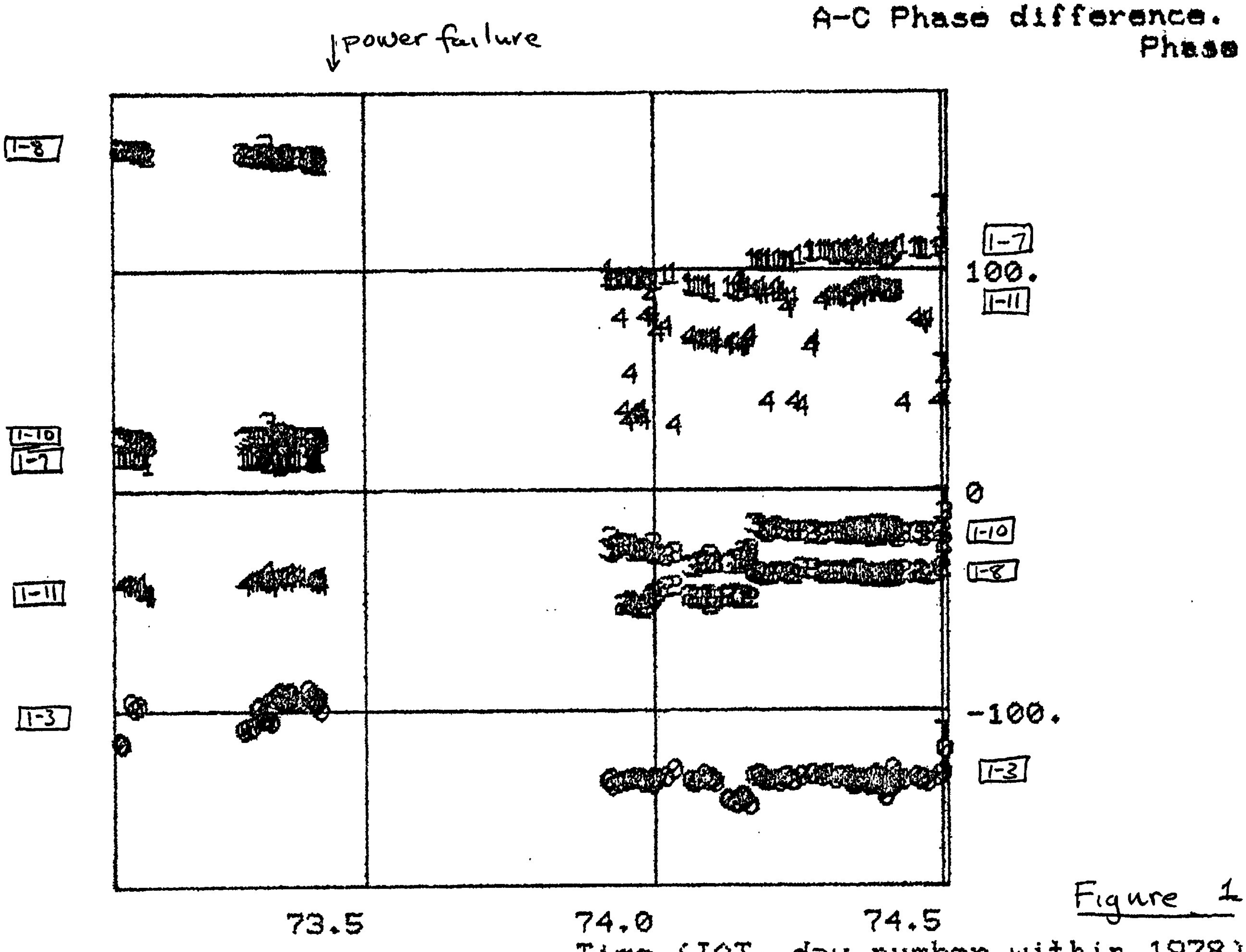


Figure 1

MAR14[14,]
1 Phase *:* * 6.0cm 1-? AA/CC Cal:N
TAve:Scan V BAve:N PFlg:2 Mode: Bar:RMS
Distinguished Antennas: 0 1-3; 1 1-7; 2 1-8; 3 1-10; 4 1-11

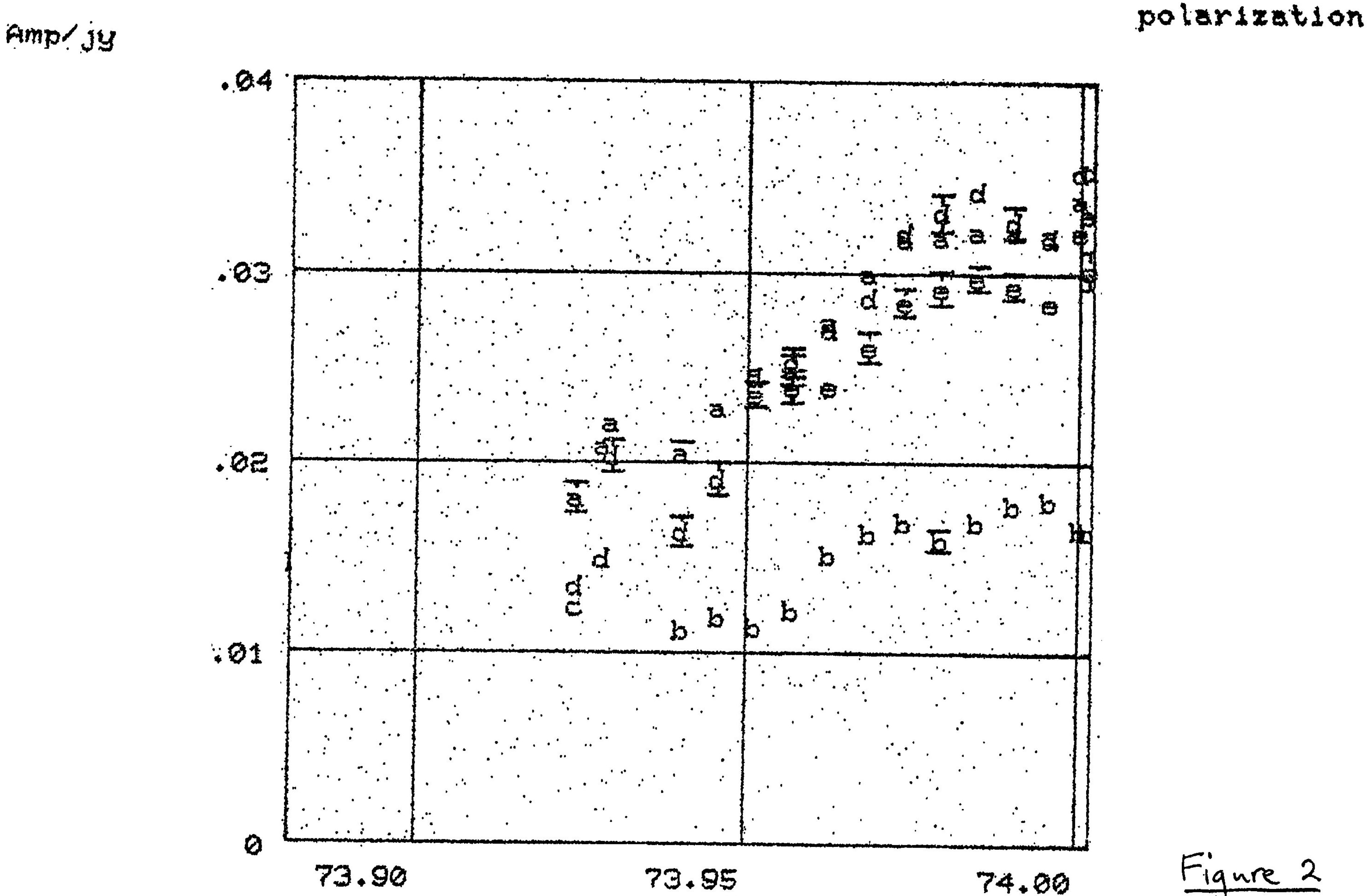


Figure 2

MAR14[14,]
1 Amp/jy 3C84:* * 6.0cm 3-? CA Cal:A
Fl:49.90 TAve:Scan V BAve:N PFlg:2 Mode: Bar:RMS
Distinguished Antennas: b 3-4; c 3-6; d 3-7; e 3-8
2a Amp/.iu 3C84:* * 6.0cm 1-3 AC Cal:A

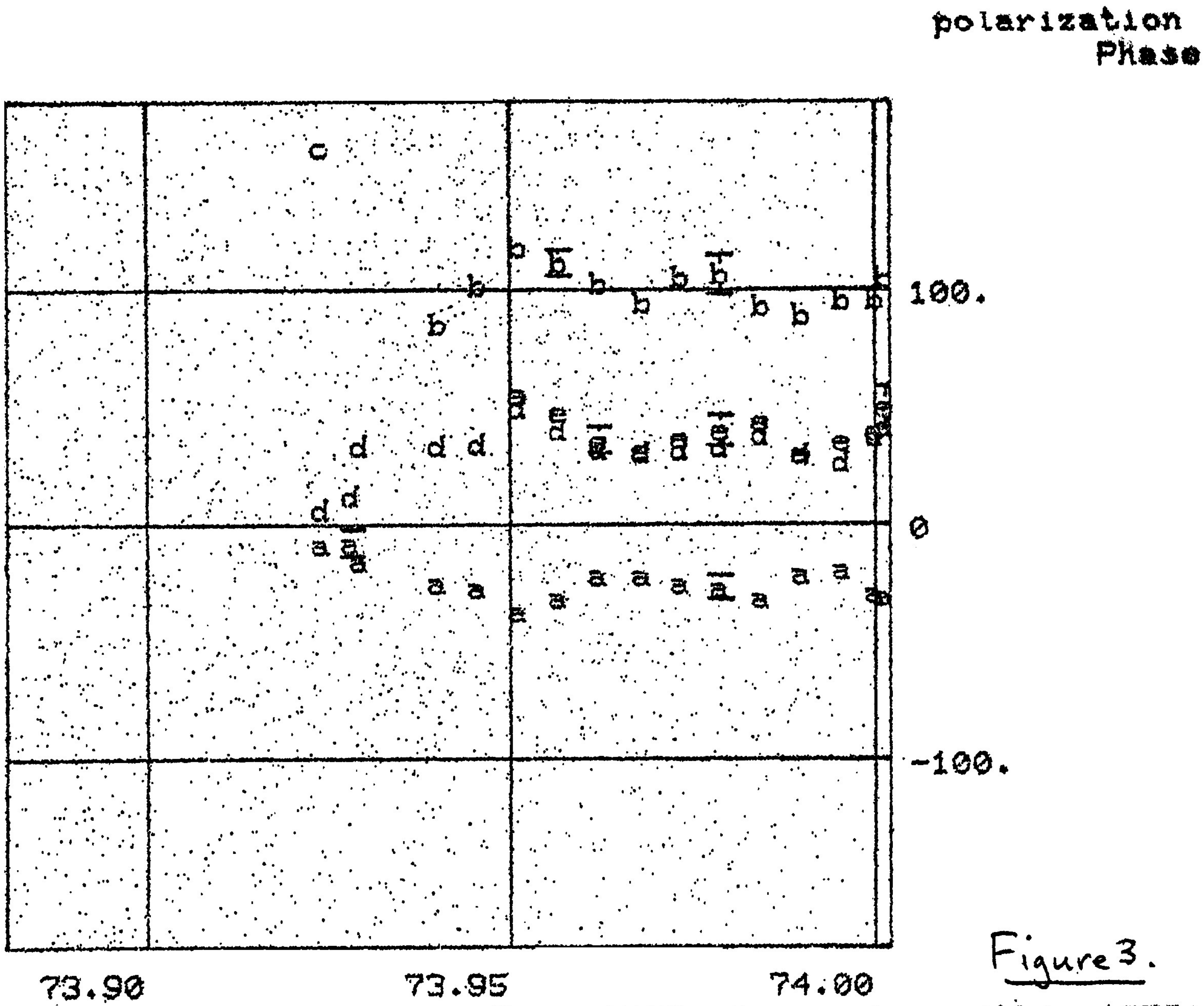
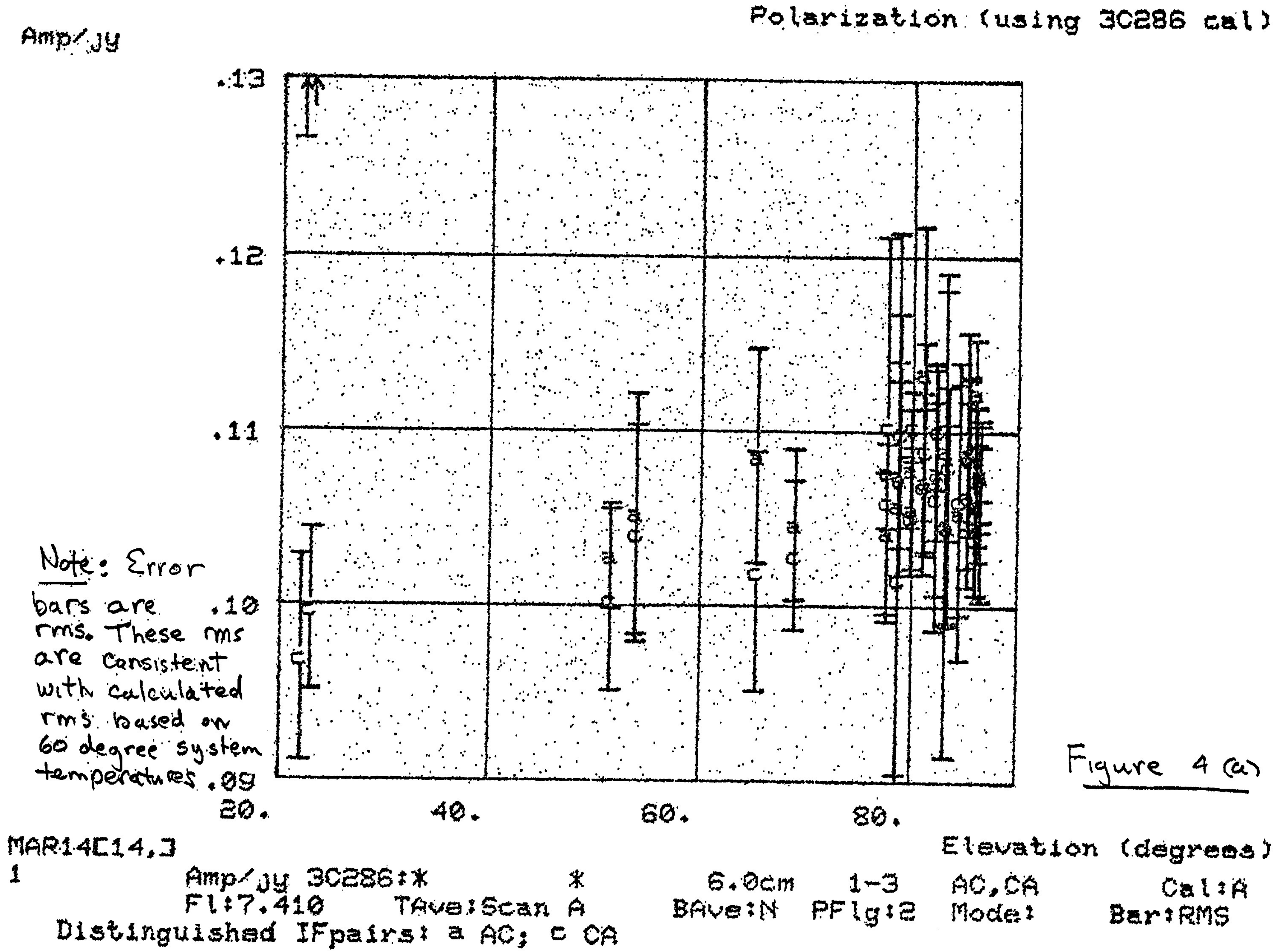


Figure 3.

MAR14[14,]
1 Phase 3C84:* * 6.0cm 3-7 CA Cal:A
TAve:Scan V BAve:N PFlg:2 Mode: Bar:RMS
Distinguished Antennas: b 3-4; c 3-6; d 3-7; e 3-8
2a Phase 3C84:* * 6.0cm 1-3 AC Cal:A



Polarization (using 3C286 cal)
Amp/Jy
.13
.12
.11
.10
.09
20.
40.
60.
80.
Elevation (degrees)
Note: Error bars are rms. These rms are consistent with calculated rms based on 60 degree system temperatures
MAR14[14,]
1
Amp/Jy 3C286:* * 6.0cm 1-3 AC,CA Cal:A
Fl:7.410 TAve:Scan A BAve:N PFlg:2 Mode: Bar:RMS
Distinguished IFpairs: a AC; c CA

Figure 4 (a)

[redacted]ol[redacted]iz[redacted]o[redacted]us[redacted]g [redacted]28[redacted]c[redacted]
Phase

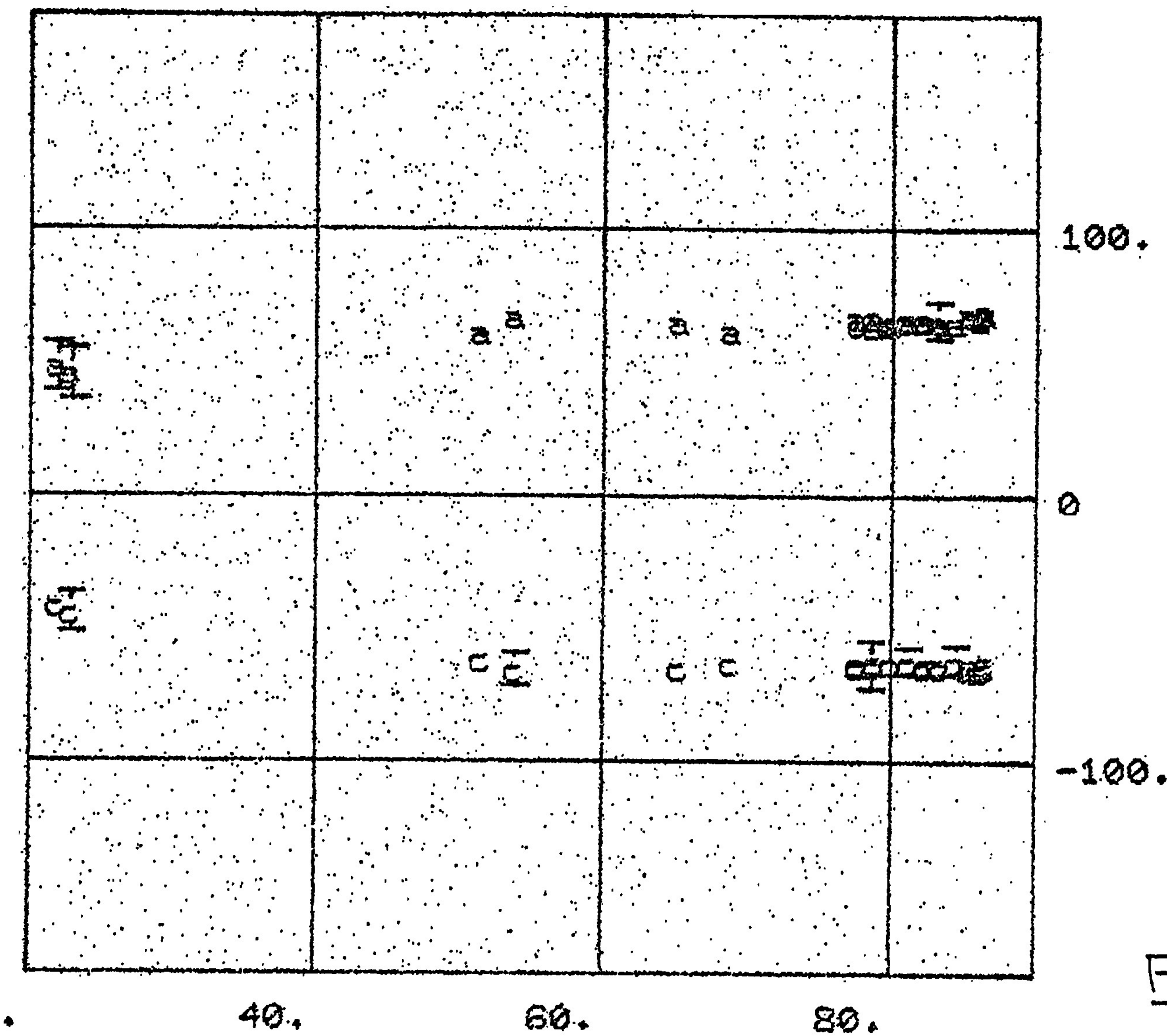


Figure 4 (b)

MAR14[14,]   Elevation (degrees)
1   Phase   3C286:*   *   6.0cm   1-3   AC,CA   Cal:A
TAve:Scan A   BAve:N   PFlg:2   Mode: Bar:RMS
Distinguished IFpairs: a AC; c CA