VLBA TEST MEMO NO. 31

13 JAN 1992 VLBA GEODESY EXPERIMENT

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20 Mar. 1992

On 13 Jan. 1992, all 7 operational VLBA antennas were used in a bandwidth synthesis, dual frequency geodesy observation. At the time, Owens Valley and Brewster had only 4 cm while the other 5 antennas were equipped with dual frequency 4/13 cm systems. Between Feb 26 and March 4, Ed Fomalont and I traveled to Haystack to process the observations and to Goddard to reduce them using the CDP software. The processing was already well under way at Haystack when we arrived thanks to Bob Phillips and Mike Titus and was easily completed while we were there. At Goddard we received considerable help from Dave Gordon, Bob Potash and Chopo Ma and were able do reduce the observations as far as seemed worthwhile in under 3 days. An experienced person could probably have done it in 1 day. Many lessons were learned and the purpose of this memo is to record some of them.

RESULTS:

Once all data bases were made and after individual solutions derived, Chopo Ma added our data to their grand all-geodesy data set of over 800,000 scans and did a global fit. The positions from that fit are what we have distributed to the correlators. The new VLBA positions, plus a few others are given in the following table along with the formal residuals of the fit. The positions of many other antennas were included in the fit and can be obtained from me if desired. Units are millimeters and the epoch is 1 Jan. 92. Note that the epoch matters since some stations are moving at several centimeters per year with respect to each other. I have truncated, rather than rounded, the numbers at 0.1 mm. As described later, the KP position is based on 13 cm only and the NL and BR positions are based on 4 cm only. No ionosphere corrections could be made in either case. The formal fit errors don't take into account all systematics. The KP, NL and BR positions probably should not be considered to be better than about 10 cm. Note that these are the station positions in a model that includes many other effects. They cannot be used for accurate comparisons with other numbers without full knowledge of that model.

Station	X (mm)	dX (mm)	Y (mm)	dY (mm)	Z (mm)	dZ (mm)
VLBA_PT	-1640951845.3	1.0	-5014816771.8	2.9	3575412296.4	2.5
VLBA_FD	-1324007278.5	1.0	-5332182742.7	3.0	3231962879.4	2.4
VLBA_LA	-1449750500.9	1.1	-4975299368.5	3.0	3709124353.5	2.6
VLBA_KP	-1995676777.8	13.1	-5037318353.4	27.3	3357328425.2	19.8
VLBA_NL	-130870357.0	4.0	-4762317960.6	11.6	4226851521.2	10.3
VLBA_BR	-2112063099.0	5.0	-3705357241.7	8.6	4726814293.3	10.1
HAYSTACK	1492406628.1	.5	-4457267336.0	1.1	4296882121.5	1.1
NRAO 140	882881756.7	2.1	-4924483109.7	6.9	3944131035.6	5.8
OVRO 130	-2409598945.2	2.4	-4478350279.0	5.1	3838603619.6	4.8
EFLSBERG	4033949443.4	48.1	486989570.3	22.4	4900431148.5	63.6
ONSALA60	3370608004.6	3.3	711916569.7	1.9	5349831076.9	5.9
WESTFORD	1492208486.4	.0	-4458131334.5	.0	4296015894.7	.0
GILCREEK	-2281545326.5	1.9	-1453645826.3	2.6	5756993628.3	4.6
MEDICINA	4461371968.7	4.6	919595877.5	2.3	4449559516.9	6.9
NOTO	4934565102.1	6.4	1321200315.4	3.3	3806484779.4	8.0

SCHEDULING:

Scan length: 86 seconds.
Time between scans: 6 Minutes.
Source List from CDP proposals for 1992.
Scheduled with SCHED and PC-SCHED plus special programs to display source positions.
Minimum elevation: Tried for 10 deg. Some scans lower.
Very little subnetting.
No frequency switching.
Frequencies (LO sums): 8150.99, 8230.99, 8410.99, 8550.99
2220.99, 2230.99, 2290.99, 2320.99
Apriori positions: Range from PT good to ~1cm to KP which was off by about 20m!
Phase cal: 10 kHz was used. I intended to use 20 kHz but forgot. Spurious signals may be less of a problem at 20 kHz.

PROBLEMS and NOTES:

Weather was poor at most sites before the run. Improving during the observation.

FREQUENCIES etc.:

Four frequencies would normally be considered too few. The sidelobes in the delay function, especially at 4cm, were not much less than 90 percent of the main peak. However, the SNR was usually quite high. As long as all channels were there, very few, if any, errors were made in choosing the right peak of the delay function. Comparison of the single band delay with the multi-band delay showed that they differed by a constant plus noise of less than 10 ns. It should be possible to use the single band delays to constrain the multi-band delays and allow close ambiguity spacings. However this was not done for this experiment and the software is not able to do it.

All Stations:

There was an occasional bad weather point (eg. Temperature) at many stations. The program writing the exported monitor files may not be paying attention to status bits from the weather instruments. Ron Heald has modified TSM (which writes out the monitor data) to flag bad data.

There was considerable uncertainty in how to use the cable cal measurements and so they were not used in the solution. This needs investigation. The cable cal numbers should be written in a more convenient format for processing.

The setup scans (no data being written) should be ignored in the Mark III summary file. Ron has made this change.

It would be good to have accurate horizons for scheduling. Tony Beasley and the operations group are gathering these data.

The one second time glitches, that have been seen in several experiments recently, were not seen. They have recently been traced to a problem in the formatter that occurs during heavy monitor requests.

Pie Town:

The playback error rates were high. The head at Pie Town has been replaced since.

For one pass through the tape, a head must have been clogged causing the channel to be rejected. This in turn caused 2 hours of data to be rejected. This problem was fixed when the tape reversed.

There is a fairly strong phase cal amplitude vs phase dependence at 4 cm, especially in BBC 3. This suggests the presence of spurious signals. At 13 cm, there is insufficient phase range to make this test. We need a careful round of spurious signal checks.

Kitt Peak:

There were no fringes at 4 cm. This has since been traced to a serious slippage in the position of the ellipsoid.

The tape footages in the log files were off by 300'. Mount proceedures have been reviewed to try to avoid this.

The cable cal measuring system is broken.

The antenna could not be pointed for some time because the wind guage was frozen.

There was considerable RFI at 13 cm noticed at observe time.

Los Alamos:

The sensitivity at 4 cm was lower than normal (and than other stations) by a factor of 3 to 4. The system temperatures were not abnormally high. Recent pointing data has shown a pointing change of about 2.5 arcminutes which probably accounts for the sensitivity loss. This change occured at 4cm with the ellipsoid only. No change was seen at other frequencies. This suggests that the ellipsoid position has changed.

The 13 cm system temperatures were high. The third channel (2293 MHz) was especially bad and probably had RFI.

The cable measureing system was not working.

The phase cal seemed more variable at LA than other stations. The effect was larger at 4 cm than at 13 cm so it scales with frequency. Could it be something in the cable carrying the 5 MHz reference to the injectors? Variable phase cal has been an on-going problem at LA when measured with the PCAL screen.

Fort Davis:

There was a 0.5 microsecond time jump on about 5 percent of the scans. This showed up only in the single band delays which depend on the sample times. When corrected by the detected phase cal phases, the jumps were removed indicating that the problem is not in the maser or any part of the system that feeds the phase cal injectors. It was seen at both 4 cm and 13 cm and so is not a failure of one of the samplers. My best guess is that something went wrong with the time in the formatter. At the sample rate in use, 0.5 microseconds is 2 bits. The problem is seen in scan average data so it is likely that it resets only between scans. The is a serious problem that needs to be investigated. The logs note a formatter header control module and FIFO error, but not at the time of the offset delays. George Peck suggests that the 32MHz synthesizer should also be suspect.

During the Fort Davis Ties experiments, a 10 mbar pressure offset was noticed in the measurements taken at the old Fort Davis site and at the VLBA site. The elevation difference could only account for about 1 mbar. Since the old Fort Davis barometer had been included in several Bendix calibration rounds, it was assumed to be the accurate one. A 10 mbar pressure error is gross compared to the presumed accuracy of our barometers. This points out the need to begin our own calibration checks and that has happened during the last week.

The residual phases after removal of the multi-band delay and the phase cal phases still shows some curvature between channels. This indicates some problem with the phase cal measurements, perhaps the presence of spurious signals.

The antenna had to be standby'd several times to clear overcurrent faults.

North Liberty:

There were no fringes at 13 cm. This was the result of a wiring problem that has been corrected.

There were high error rates on playback, especially on track 1 (Mark III labeling - track 4 by VLBA labeling). The head has recently been replaced (since these observations).

There were no fringes to BBC 2 lower sideband. I do not know the reason but the system had been checked over carefully since then.

There was no data recorded in the reverse direction anywhere on the tape. Therefore half the data were lost. The reason is not known.

Owens Valley:

The FRM was not at the correct position so no fringes were found.

The cable cal (round trip) measurements covered a much wider range than at the other sites and show the opposite dependence on temperature as seen at other sites.

Brewster:

The cable cal seems to have higher scan to scan noise variation than at other sites. This may be the result of the fact that 2 different types of modules are in the field and they require calibration constants that differ by a factor of 3. The monitor extraction software does not know this yet.

CABLE CAL DATA:

Figures 1 to 4 show cable cal measurements and ambient temperatures at each site. The dependence of cable cal delay on temperature of about 13ps/C is clear at several sites. KP and LA cable cal data clearly indicate a failure of some sort. OV has a high temperature dependence and high total range. Is this an antenna problem or a decoding problem? There are two types of modules in use and they require different calibration. This is not accounted for in the monitor software yet. We will be investigating this.

PHASE CAL DATA:

Figure 5 shows the phase cal amplitudes vs phase for LA and PT at 4 cm. There seems to be very little dependence of amplitude on phase at LA which is as it should be. At PT, there is clearly a dependence even though the total range of phases is small. This indicates that spurious signals at 10 kHz are present.

Figure 6 is like Figure 5 but for 13 cm. It is clear that the range of phases is too small to allow anything to be said about spurious signals. Note that the frequency dependence of the phase cal phase range demonstrates the the larger variations in phase cal phase are the result of variations in the receivers or more likely in the cable that carries the phase cal reference signal (5 MHz) up the antenna.

BASELINE SOLUTIONS:

Figures 7-9 show sample output from the program SOLVE for a solution for the baselines between PT, LA, and FD. This was an isolated solution using an apriori PT position as the reference rather than the global solution using Westford as the reference from which the station positions presented earlier were derived. The numbers will differ both because different full data sets were involved and because of the different reference positions. In this solution, the parameters solved for were the positions and clocks of PT and FD (LA was treated as a reference), and the atmospheres at all three sites. Other solutions were made with 2 nutation terms turned on. The clocks and atmospheres were treated as piecewise continuous parameters with solution intervals of 1.5 hours. SOLVE has the ability to fit for many other paramters, but we did not try very many.

Figure 7 gives the numerical results of the fit. Figure 8 shows the residuals from the fit. The data are multiband delays at 4 cm corrected for the ionosphere. Figure 9 is a display of the fitted clocks and atmospheres. The atmosphere plot is superimposed on a display of the elevations of the observations in units of atmospheres (close to sec(za)). The horizontal lines represent 5, 10 and 15 atmospheres. The values of the atmospheres and clocks are residuals after subtraction of an apriori model. There appears to be a correlation between stations in the atmospheres as seen in the peak in the first few hours. I worry that this is evidence of some other problem.

Note that, when the station coordinates are expressed in terms of horizontal and vertical terms, the formal errors are much greater in the vertical. This is mainly because problems with determining the atmosphere map into uncertainty in the vertical position.

The residuals shown in Figure 8 are all less than 0.3 ns. The delay function that was used (determined by the frequency sequence) has low sidelobes this close to the main peak. The possible confusion resulting from picking the wrong peak of the delay function would be of order 10 ns or more from the correct delay. The fact that all residuals are much smaller than this is the evidence that the frequency sequence did not give us problems.

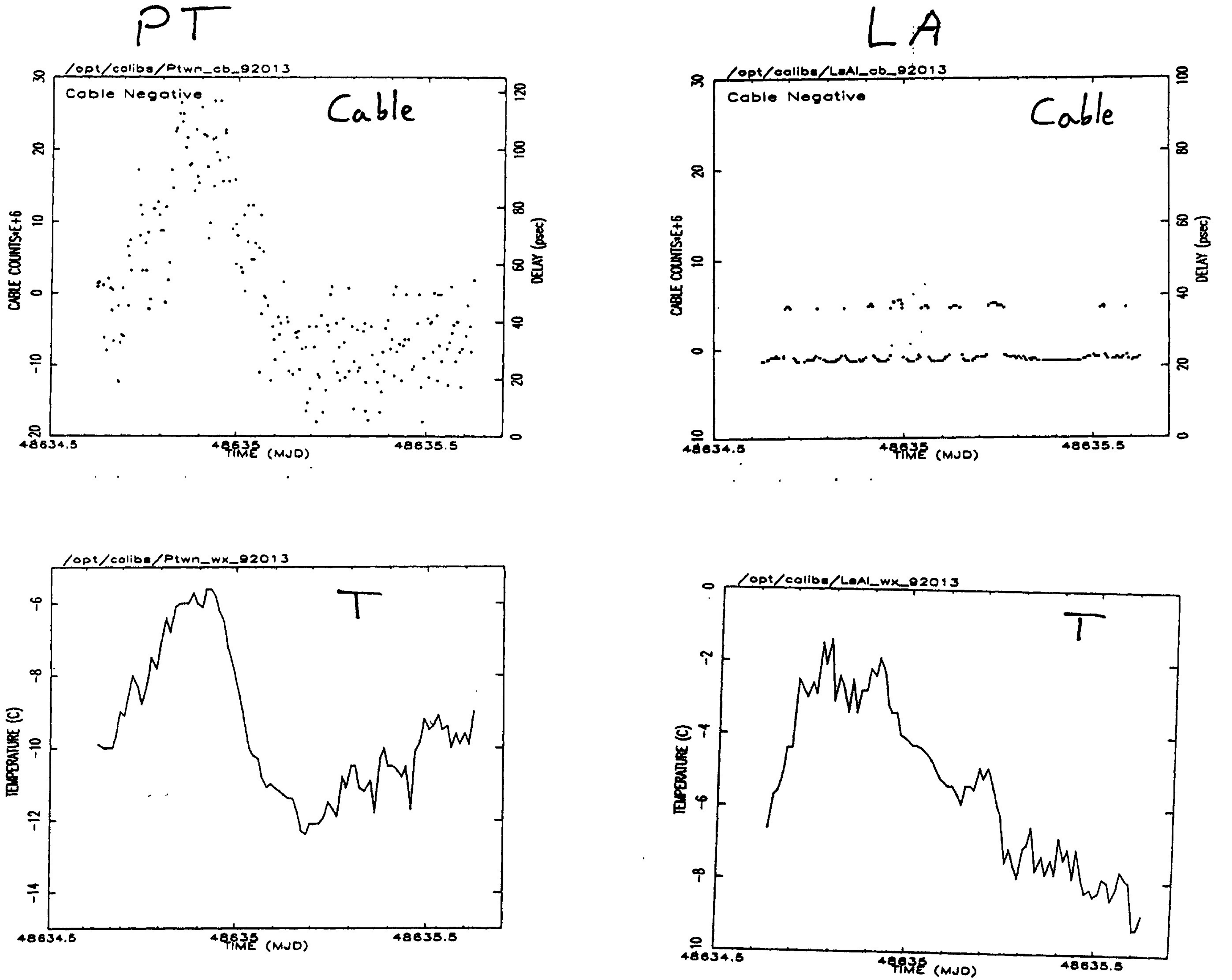

PT
LA
/opt/calibs/Ptwn_cb_92013
Cable Negative
Cable
CABLE COUNTS*E+6
DELAY (psec)
TIME (MJD)
48634.5
48635
48635.5
/opt/calibs/LeAl_cb_92013
/opt/calibs/Ptwn_wx_92013
T
TEMPERATURE (C)
/opt/calibs/LeAl_wx_92013

Figure 1

KP—VLBA T

FD—VLBA

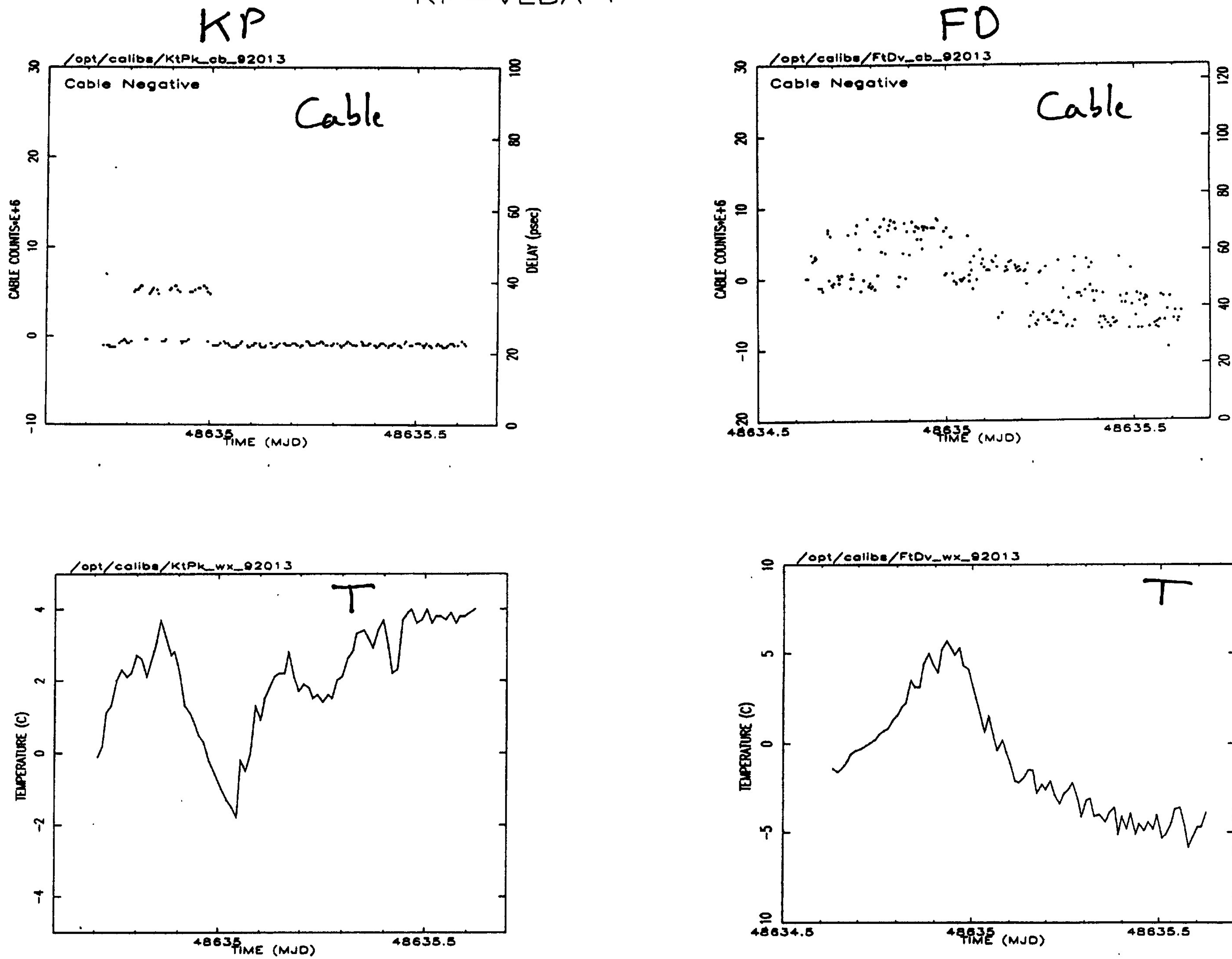


Figure 2

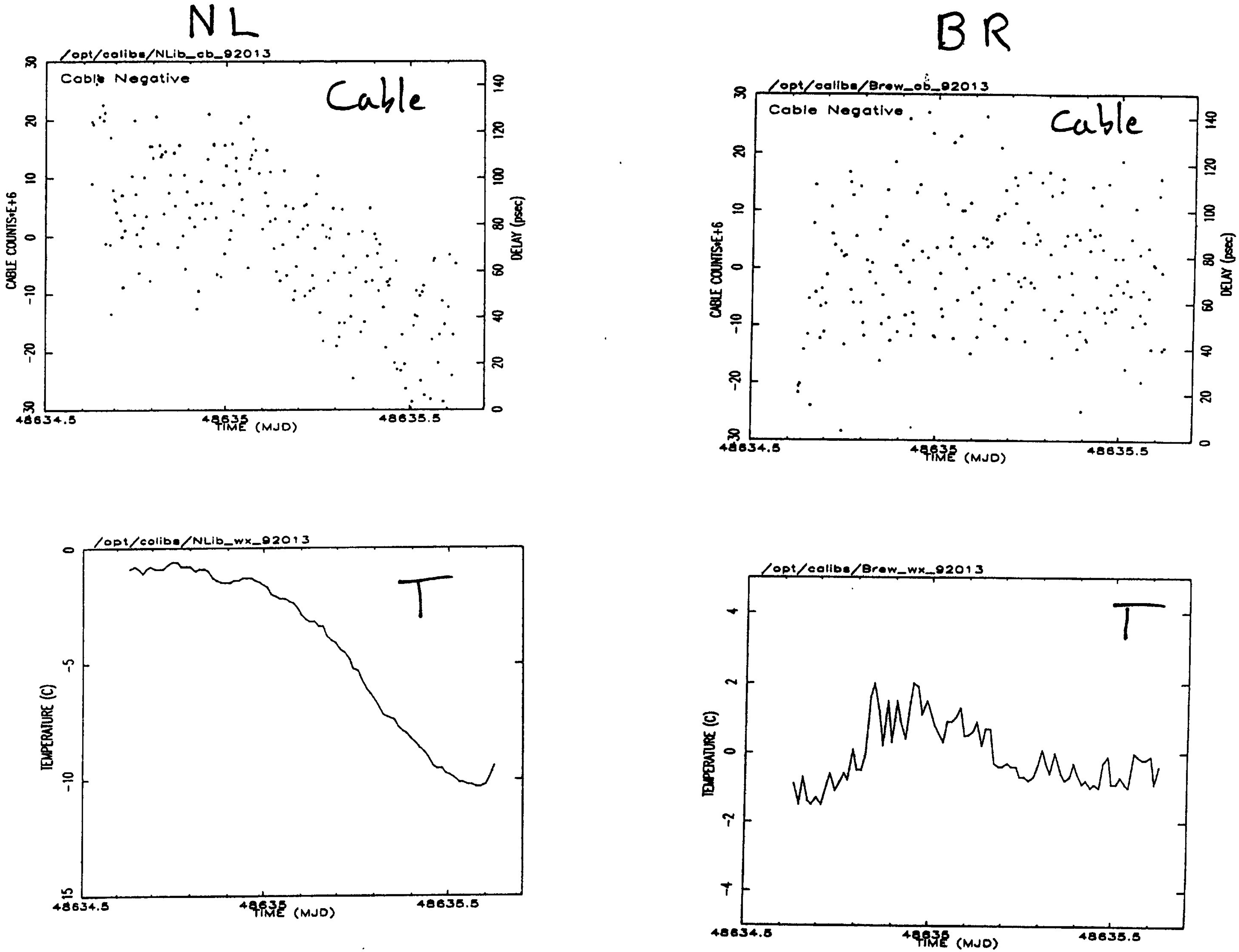

NL
BR
/opt/calibs/NLib_cb_92013
Cable Negative
Cable
CABLE COUNTS*E+6
DELAY (psec)
TIME (MJD)
/opt/calibs/Brew_cb_92013
Cable Negative
Cable
CABLE COUNTS*E+6
DELAY (psec)
TIME (MJD)
/opt/calibs/NLib_wx_92013
T
TEMPERATURE (C)
TIME (MJD)
/opt/calibs/Brew_wx_92013
T
TEMPERATURE (C)
TIME (MJD)

Figure 3

OV—VLBA TJA13

OV

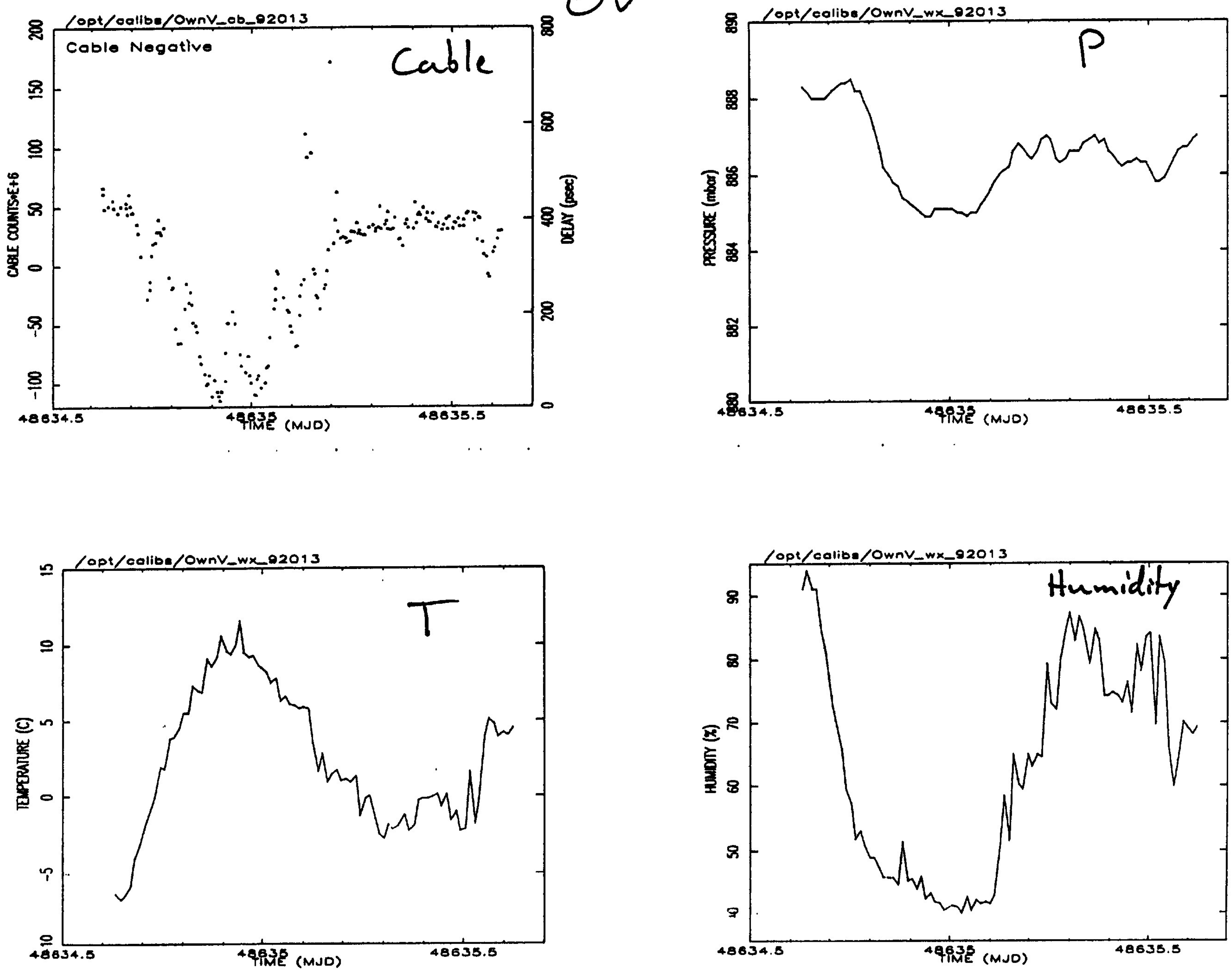
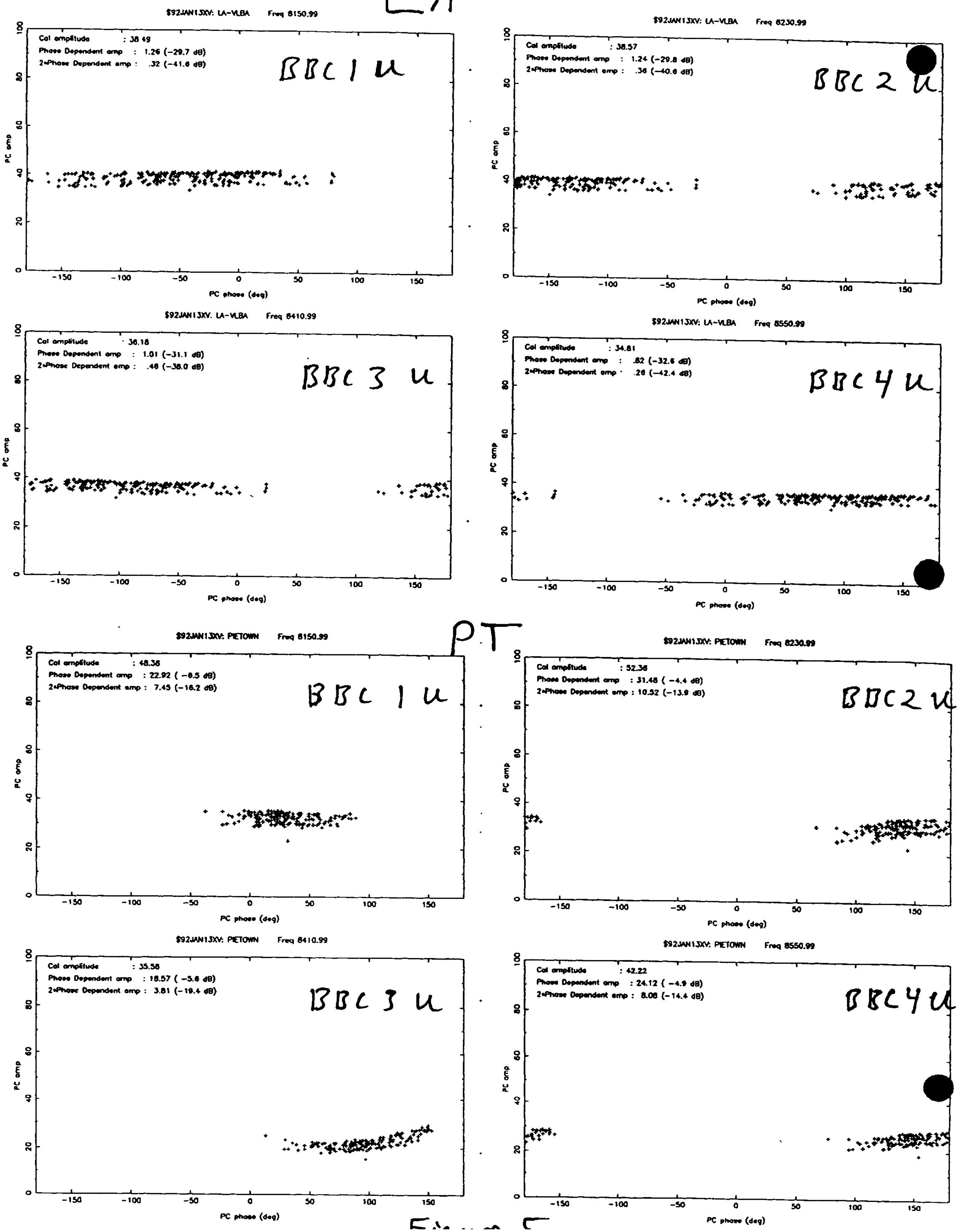


Figure 4

4 cm LA Phase cal amp vs phase



13 cm PT Phase cal amp vs phase

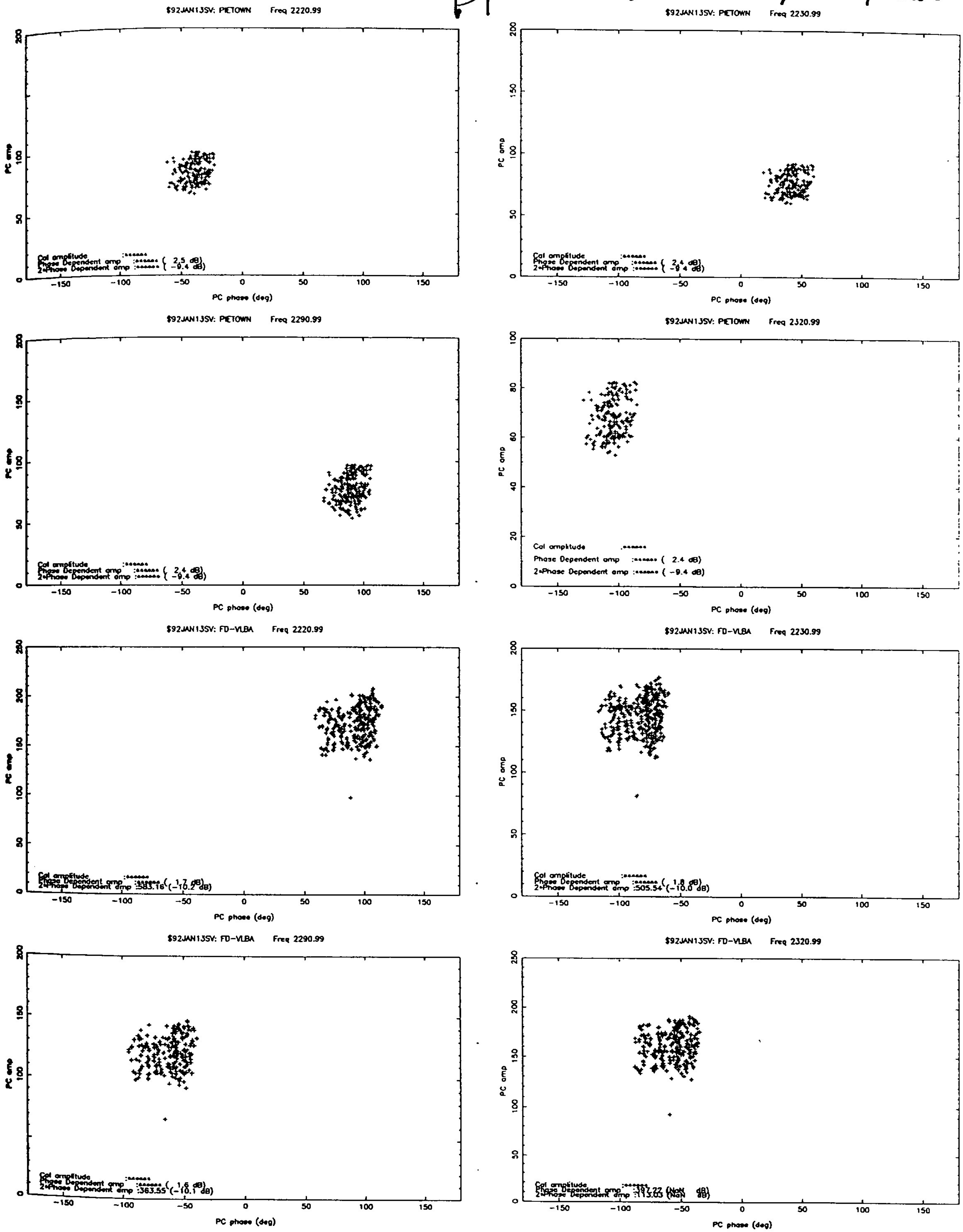


Figure 6

Solve Solution for PT, LA, FD

Run 22063-2115 499 Observation Pairs Available
Group delay only

Data Type	Number of Observations Used	Weighted RMS Residual	Normalized RMS Residual	Chi Square
Delay	483	41 ps	.90	1.02
Rate	0	128 fs/s	.97	1.05
Combined	483		.90	1.02

Baseline Statistics

Baseline	# W.Obs used/total	W.RMS Del ps	N.R.D. standard	N.R.D. (15ps+i)	W.RMS Rate fs/s	N.R.R.
LA-VLBA -FD-VLBA	190/ 197	47	.90	1.57	207	.95
PIETOWN -LA-VLBA	151/ 156	45	.96	1.17	87	1.00
PIETOWN -FD-VLBA	142/ 146	32	.85	1.42	179	.97

Source Statistics *Source positions held fixed*

Source		# W.Obs	W.RMS Del ps	N.R.D. standard	N.R.D. (15ps)	W.RMS Rate fs/s	N.R.R.
2121+053	A	17/ 18	56	1.05	1.35	86	.55
1622-297	B	11/ 11	42	.73	.94	98	.56
1921-293	C	11/ 11	36	1.01	2.46	69	.60
4C39.25	D	33/ 33	30	.86	1.79	168	1.57
1156+295	E	26/ 28	50	.96	1.19	66	.48
2234+282	F	19/ 19	50	.91	1.24	293	1.66
1611+343	G	19/ 20	38	.93	1.58	51	.42
1739+522	H	22/ 24	39	.90	1.45	101	.84
1803+784	I	22/ 22	27	.60	.94	78	.60
NRAO530	J	18/ 18	36	.93	1.55	49	.42
OQ208	K	15/ 16	34	.67	.91	121	.84
2216-038	L	12/ 12	39	.81	1.27	97	.66
1502+106	M	21/ 22	43	.71	.82	106	.68
0212+735	N	17/ 17	58	1.35	2.17	73	.57
1741-038	O	11/ 11	47	1.04	1.39	43	.32
0300+470	P	19/ 20	54	.90	1.11	106	.69
2255-282	Q	16/ 16	57	1.07	1.40	186	1.19
0119+041	R	18/ 20	62	1.10	1.40	123	.73
0234+285	S	23/ 23	39	.96	1.66	51	.44
0552+398	T	25/ 26	24	.68	1.50	44	.40
0420-014	U	20/ 20	32	.80	1.43	64	.51
0528+134	V	16/ 18	43	.80	.99	69	.49
0454-234	W	13/ 13	55	.97	1.13	110	.69
0742+103	X	20/ 20	43	.97	1.39	325	2.54
0727-115	Y	15/ 15	24	.64	1.28	106	.95
0919-260	Z	12/ 12	49	.98	1.25	226	1.57
1034-293	A	12/ 14	51	.91	1.08	97	.61

ADJST Control: F for full printout, Return for brief

Figure 7

```
                    *** FLYBY STATUS ***

                 directory: /solve/save_files/

Station    Source     Nutation   Nutation   Earth      Station
Positions  Positions  Model      Time       Rotation   Velocity
                                 Series     Series     Model
---------- ---------- ---------- ---------- ---------- ----------
g91sites   g91stars   NONE       NONE       NONE       NONE

Parameter adjustments for run 22063-2115 User=JR    ADJST Ver. 91.07.01
                                     Parameter    Adjustment     Scaled Sigma
    LA-VLBA  CLCK              Batch Mode Reference
  1. LA-VLBA  AT 0 92/ 1/13 15:27                    -130.38 ps      15.27 ps

 18. FD-VLBA  7613        X Comp  -1324007376.84 mm      -43.84 mm      1.88mm
 19. FD-VLBA  7613        Y Comp  -5332182858.13 mm      -66.83 mm      5.20mm
 20. FD-VLBA  7613        Z Comp   3231962933.59 mm       28.89 mm      4.04mm
     FD-VLBA  7613        U Comp (Vert)    79.62 mm       79.62 mm      6.32mm
     FD-VLBA  7613        E Comp (        -26.44 mm      -26.44 mm      1.56mm
     FD-VLBA  7613        N Comp  Horiz.) -13.58 mm      -13.58 mm      2.11mm
 21. FD-VLBA  CL 0 92/ 1/13 15:22                  -1164.21 ns        .06 ns
 22. FD-VLBA  CL 1 92/ 1/13 15:22                    -16.90 D-14    2.26 D-14
 23. FD-VLBA  CL 2 92/ 1/13 15:22                    -1.08-14/d     1.96-14/d
 40. FD-VLBA  AT 0 92/ 1/13 15:27                   -146.02 ps     13.48 ps

 57. PIETOWN  7234        X Comp  -1640951947.61 mm     1627.39 mm      2.21mm
 58. PIETOWN  7234        Y Comp  -5014816906.96 mm     -967.96 mm      5.38mm
 59. PIETOWN  7234        Z Comp   3575412349.26 mm      557.26 mm      4.04mm
     PIETOWN  7234        U Comp          655.92 mm      655.92 mm      6.64mm
     PIETOWN  7234        E Comp         1847.72 mm     1847.72 mm      1.64mm
     PIETOWN  7234        N Comp          227.13 mm      227.13 mm      1.85mm
 60. PIETOWN  CL 0 92/ 1/13 15:22                   -519.14 ns        .06 ns
 61. PIETOWN  CL 1 92/ 1/13 15:22                     -9.33 D-14    2.27 D-14
 62. PIETOWN  CL 2 92/ 1/13 15:22                     1.70-14/d     1.97-14/d
 79. PIETOWN  AT 0 92/ 1/13 15:27                   -133.19 ps     14.30 ps

Atmosphere Constraint Statistics
 1.LA-VLBA  Input  50.00 ps/h RMS  20.16 ps/h NRMS   .40 share  .1 count  17
 2.FD-VLBA  Input  50.00 ps/h RMS  37.32 ps/h NRMS   .75 share  .1 count  17
 3.PIETOWN  Input  50.00 ps/h RMS  27.78 ps/h NRMS   .56 share  .2 count  17
   Overall                    RMS  29.27 ps/h NRMS   .59 share  .1 count  51

Clock Constraint Statistics
 2.FD-VLBA  Input   5.00 D-14 RMS   1.50 D-14 NRMS   .30 share  .2 count  17
 3.PIETOWN  Input   5.00 D-14 RMS   1.82 D-14 NRMS   .36 share  .2 count  17
   Overall                    RMS   1.67 D-14 NRMS   .33 share  .2 count  34
```

1.5 hour piecewise continuous clocks and atmospheres.
LA is reference station.
PT apriori was in different reference frame.

```
Corrected Reduced Chi-Square     .99 Re-scale the scaled errors by   1.10
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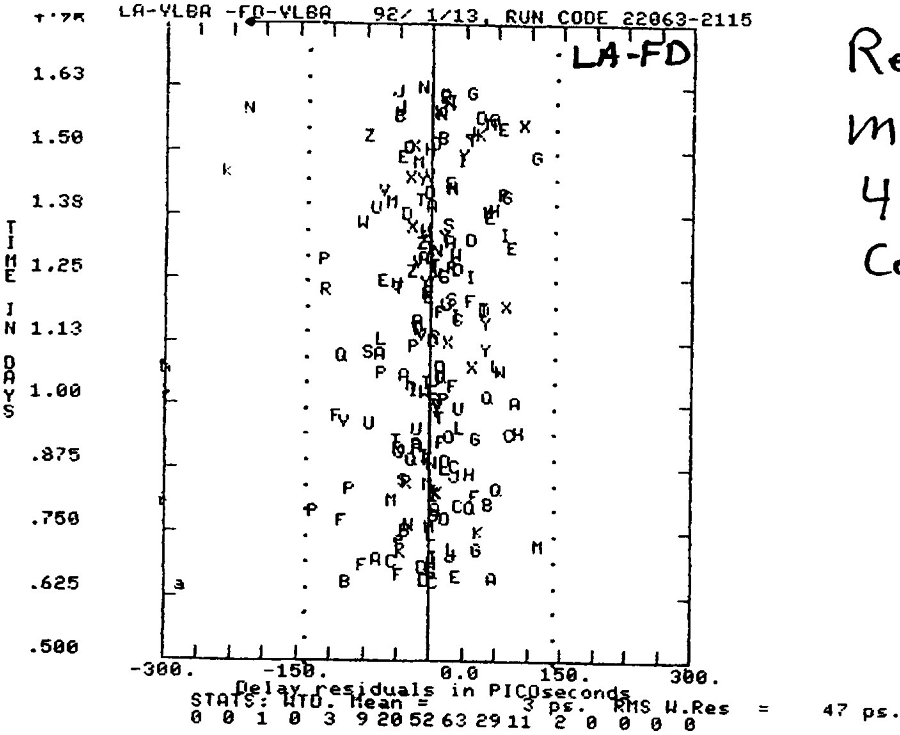
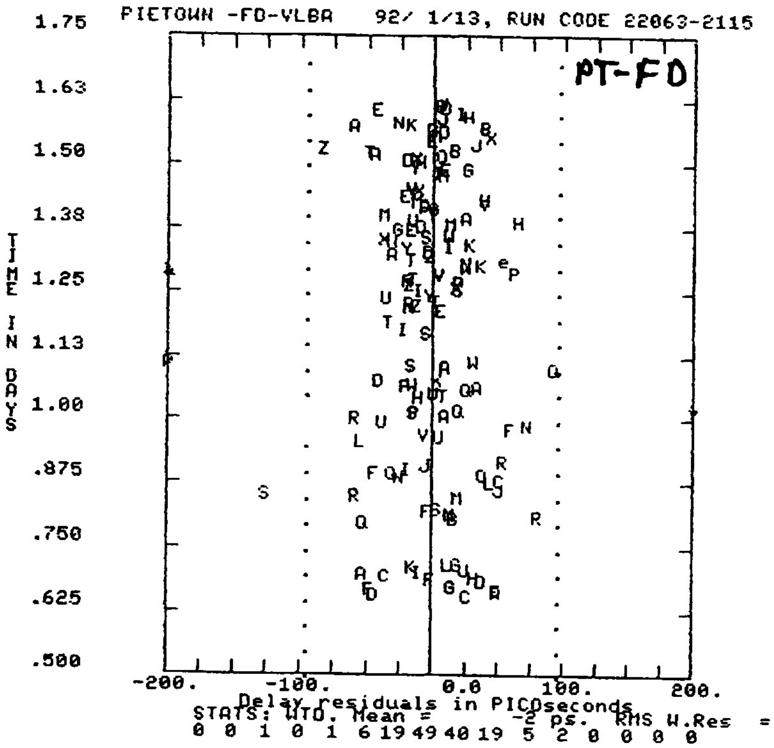
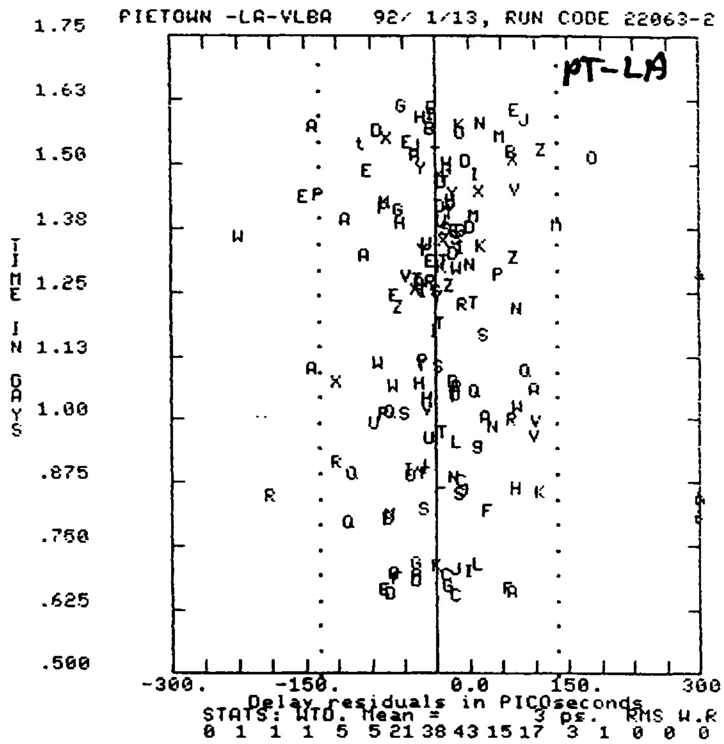
Figure 7 (con't)

Residuals from Fit
Multiband delay
4 cm
Corrected for ionosphere





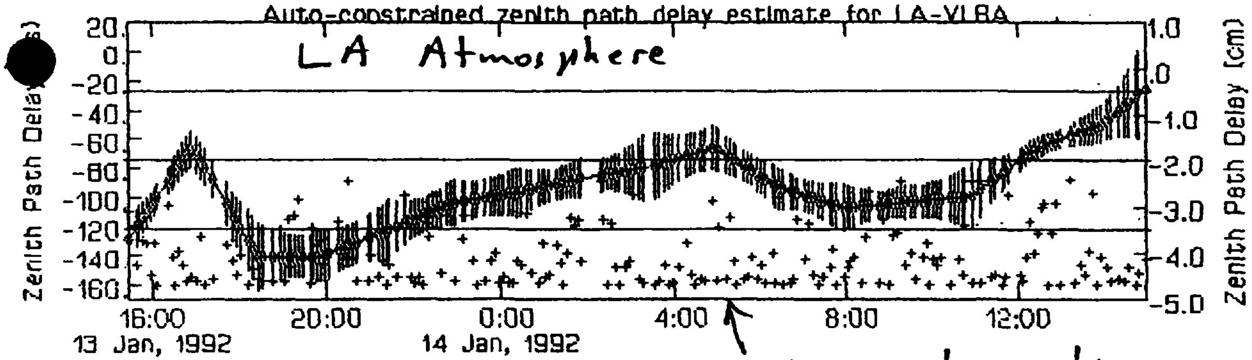
Rms W. Res = 32 ps



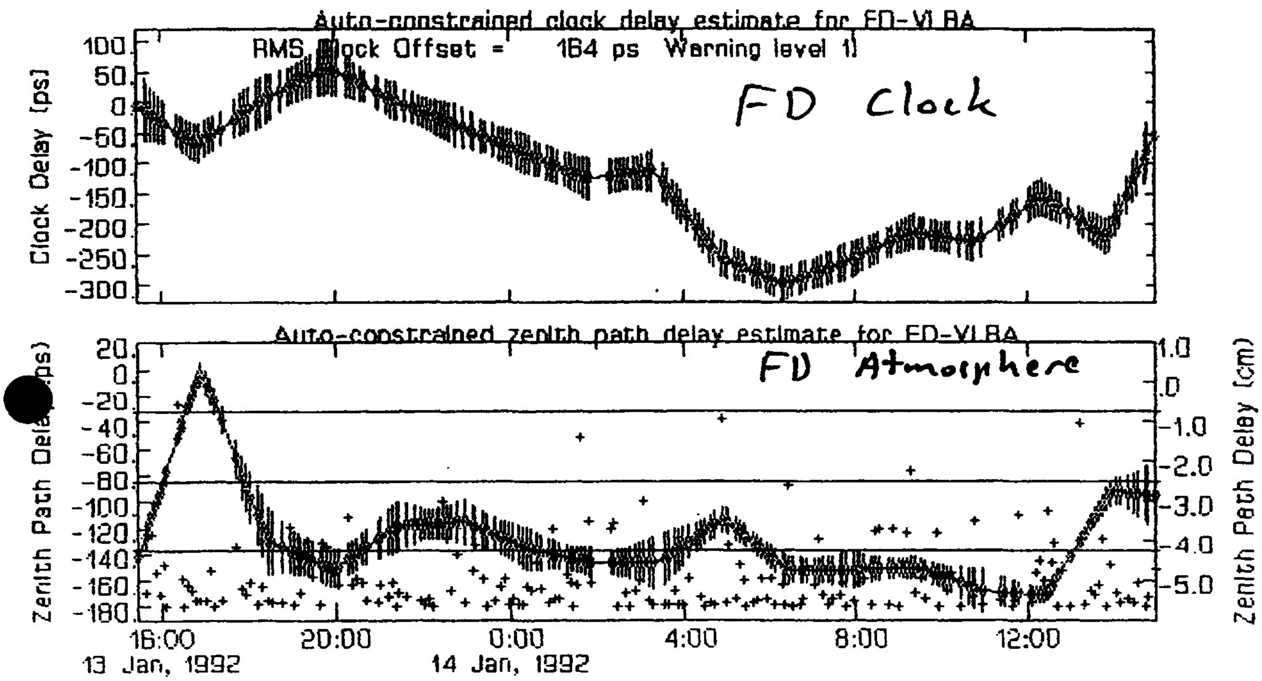
Rms W. Res = 45ps

Used Marini atmosphere

Figure 8



+ 's are observations - vert is ~~[struck out]~~ atmospheres. Lines are 5 atm.



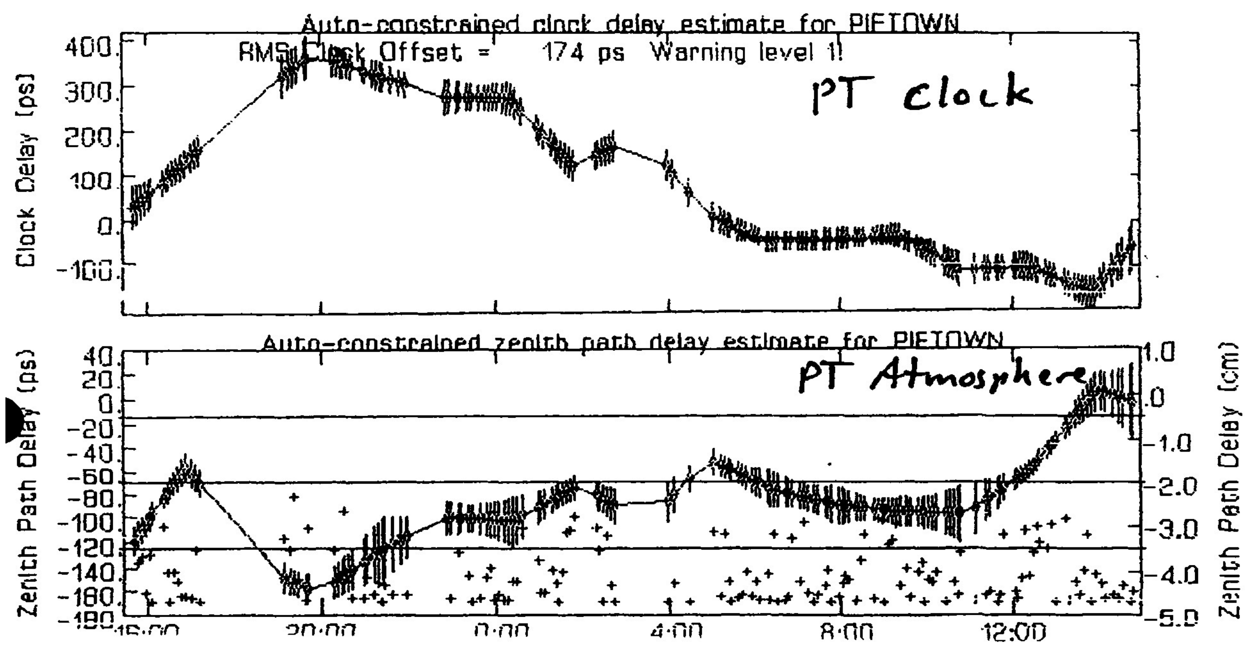


Figure 9