# Operational VLBI Clock Synchronization and Platform Parameter Determination

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*The operation and results of the Block I VLBI system for clock synchronization and platform parameter determination are described. The history of system performance from July 1980 to August 1981 is given. The steps in producing clock sync and platform parameters are outlined. It is shown that the VLBI data provide useful monitoring of the Deep Space Network Frequency and Timing System performance and earth orientation.*

## I. Introduction

The Block I VLBI (Very Long Baseline Interferometry) system (Ref. 1) has been developed at JPL to provide near-real-time Deep Space Station (DSS) clock synchronization (clock sync), platform parameter determination (UT1 and polar motion – UTPM), and spacecraft navigation. From July 1980 to August 1981 system development was carried out concurrently with observations designed to measure clock sync and UTPM. This report describes the steps involved (see Fig. 1) in conducting and processing the observations. The history of system development and performance during this period is discussed. The disposition of 101 passes scheduled from July 14, 1980, to August 29, 1981, is given in Table 1. Clock sync results for December 1980 to August 1981 are given in Table 2 and Figs. 2 and 3.

## II. Observation Scheduling

Beginning in 1980, weekly VLBI observing sessions were scheduled on both the California-Spain and California-Australia baselines for the purpose of making clock sync and UTPM measurements and for Block I (Ref. 1) system development and checkout. The 64-m DSS was used because Block I equipment is available there, and the recording bandwidth (250 kHz) of the Block I system requires the sensitivity of the large antennas. In most cases both baselines were observed in the same 24-hour period. Estimation of clock parameters requires only single baseline observations, but UTPM estimates require two baselines to separate all three parameters.

For each baseline, 7 to 13 extragalactic radio sources (EGRS) from the radio source catalog were observed for

200 seconds each. Source selection and pointing predicts were generated in special purpose software. A tape of pointing predicts was given to Operations for reformatting and transmission by high speed data line (HSDL) to the DSS. For most of the 1981 observations, the scheduling of sessions was governed mainly by DSS availability. However, during the period from DOY 136 through 200, a sidereal schedule was employed, which permitted the same sources to be observed each week for 10 consecutive weeks. The sidereal schedule consisted of a set of 12 observations which were done in the same sequence each time. The observing time shifted at the sidereal rate (approximately 4 min/day) so the same sources could be used. The sidereal schedule proved to be very helpful in the identification of systematic problems.

Standard DSS configuration and observing procedures were developed. These procedures were the Deep Space Network Operations Plan for the Block I VLBI System written by the Mission Coordination Group of the Control Center Operations Section and the Deep Space Station Standard Operating Procedure Very Long Baseline Interferometry (VLBI) System Block I written by the System Support Group of the Deep Space Network System Support Section. These procedures and the automated pointing predicts resulted in relatively smooth operations. Initially data were acquired in four S-band and four X-band bandwidth synthesis (BWS) channels with a maximum spanned bandwidth of 30 MHz in each band. To improve signal-to-noise ratios, the configuration was changed to three BWS channels per band with a maximum span of 40 MHz on 1981 DOY 107. The BWS technique provides the accuracy of a large spanned bandwidth (30-40 MHz) while recording only a small bandwidth (250 kHz). This is accomplished by sequentially sampling 250-kHz channels spaced across the desired spanned bandwidth. The channels are processed separately and the results combined to produce an effective bandwidth comparable to the spanned bandwidth. Occasional mistuning of the S-band travelling wave maser resulted in loss of one of the outer channels, but this did not greatly affect the overall quality of the results since X-band data were used for all solutions to date.

A total of 101 passes (Table 1) were scheduled from July 14, 1980, through August 29, 1981. Of these passes 72 were conducted, 41 produced clock sync results, and 32 produced useable data for UTPM solutions. Table 1 indicates at what point a pass failed from schedule to solution. A more important statistic is the success rate of passes after data processing was moved to the Block I VLBI Processing System (VPS) on March 28, 1981 (DOY 087). Since then, 44 passes were scheduled. Of these 11 were cancelled, 2 had data lost, and 24 produced cross correlation fringes (24 of 31). Of the 24 sessions which gave fringes, 22 produced clock sync results and 17 were useable for UTPM solutions. This improvement in overall system performance is very encouraging.

During 1981, passes were scheduled by the Voyager Project to minimize conflicts. A total of 46 sessions were conducted through August 2, 1981, at which time the Voyager 2 Saturn encounter and the DSS 14 bearing problems terminated activities. Observing sessions will begin again after DSS 14 scheduled downtime in 1981 October.

## III. Data Acquisition

Data are recorded on tape at each station by the Occultation Data Assembly (ODA) which is shared by the VLBI and Radio Science Subsystems. The recording rate is 500 kbits/sec. Currently, data are replayed over wide-band data lines (WBDL) at 56 kbits/sec directly onto the discs of the Network Operations Control Center (NOCC) VLBI Processing Subsystem (VPS) (see Fig. 1). Before 1981 DOY 086, data were obtained from intermediate data record (IDR) tapes, which resulted in some of the problems discussed below. Since the playback rate is 1/9 of the record rate, it takes approximately 6 hours to play back the 40 minutes of data from each pass.

In the process of implementing the first operational VLBI system, numerous problems in data acquisition and playback were solved in the past year. Two operational difficulties were resolved. First, during acquisition the NOCC had little visibility into DSS activities. Use of the Network Radio Science realtime monitor (RTM) partially solved this problem. Second, there were no personnel to support VLBI acquisitions and playbacks in real-time. NOCC controllers were trained and given detailed procedures (as discussed above) to cover these activities.

A number of problems in data acquisition were difficult to detect at first because of the very long turnaround time caused by doing all the processing at Caltech from IDRs. The slow detection of problems and lack of feedback to the stations resulted in additional bad data. Now, rapid turnaround with the VPS gives better DSS awareness and NOCC control of VLBI passes. Weak and poor fringe results were traced in part to antenna pointing errors. This was largely corrected by implementing an antenna pointing program developed by R. Livermore of Tidbinbilla Deep Space Communication Complex, Australia. This program allows for entering pointing offsets automatically during tracking to significantly reduce errors due to antenna distortion and axis pointing errors. Recently, slew restrictions at DSS 14 due to its azimuth bearing problem have resulted in occasional loss of one or two sources per pass and the cancellation of several clock sync passes during Voyager 2 Saturn encounter. A temporary solution currently being tested is to transmit the VLBI baseband signal from DSS 13 to DSS 14 by the microwave link in order to use the ODA at DSS 14. Other hardware has also caused some difficulties. In the initial implementation of the DSS Block I system, ODA tapes consistently failed to start on time. This has been largely solved by operational workarounds and program modifications. There also have been a small number of VPS and peripheral failures which have all been fixed.

An overall real-time verification of the VLBI observation is desirable. An important step in this direction is a real-time capability to validate the performance of the microwave and VLBI hardware. This capability is being developed by monitoring the phase calibration tones (phase cal) at the ODA. Phase cal tones are injected into the front end of the maser amplifier and can be detected in real-time at the ODA for system validation or later when the data are correlated. Phase cal can then be used to correct the VLBI data for dispersive effects in the instrumentation.

UTPM solutions require data from a number of EGRS distributed about the sky. Several problems have been associated with the source schedules. First, the slews between sources did not adequately take into account antenna prelimits, cable wrap, or keyholes. This problem was handled by manually plotting each acquisition on a stereo plot for each station involved and providing warning notes to the controller. Another problem, still being worked, is not having enough sources in the source catalog to provide the desired number of observations on the DSS 14/DSS 63 baseline within scheduling constraints.

In the playback area there were two major problems, both of which now appear to be solved. The first involved the lack of monitoring of the playback data when the normal Ground Communications Facility (GCF) system was used. This difficulty was solved by direct playbacks to the VPS discs. The VPS software provides playback monitor capability and maintains a log of the data received and of the numbers and types of errors. This also permits immediate validation of the GCF lines from the DSS to the VPS. The GCF IDR capability is used as a backup. A temporary problem of a significant percentage of IDR tapes being unreadable on the VPS was also solved by direct playbacks to the VPS, eliminating the additional processing step of reading IDRs onto disc. The cause of the bad IDRs was apparently physically bad tapes. Before direct replays to the VPS began, the problem could sometimes be overcome by regenerating the data onto good tapes.

Operational experience has shown that the inability of the ODA to do selective recalls makes playbacks clumsy if any significant line outages occur. When outages occur, replay has to begin at the beginning of the ODA tape being played. Each ODA tape takes about 90 minutes to play back. A future ODA implementation will provide disc instead of tape data recording at the DSS, and include a selective recall capability.

## IV. Correlation

The activities involved in correlation, from an operations viewpoint, are: data verification, correlation control record generation, fringe search, and postcorrelation record (PCR) generation. During correlation there is some indication of whether there are fringes and phase cal tones, and the fringe quality for the pass can be estimated. Detailed results (fringe and phase cal amplitudes) on a channel-by-channel basis are best obtained from postcorrelation analysis.

Data verification simply involves verifying that data from both stations are on the VPS discs, and that enough ancillary data are available to create a correlation control record.

The control record generation step includes running "ANCEDIT," which generates a correlation control record (CCR) automatically from the ancillary data and other stored information. This CCR was manually examined and edited as necessary. If peculiarities were noted in the CCR, information on the pass was reviewed and correlation would be attempted with the unedited results. For example, if it appeared that both DSSs used a nonstandard setup, the reported frequencies rather than the requested values were used. Usually the information that needed to be edited was source locations or source names.

After the CCR was examined, the "PROCESS" mode of the correlation program was loaded, and a run on the data was made looking for fringes. If no fringes were found, the CCR was checked again, and the time offsets between the DSSs were verified. If this was all correct, a single channel on a strong source was correlated. If no fringes were found again, a complete PCR was run and passed on to the TEMPO (Time and Earth Motion Precision Observations) Team for further processing.

If fringes are found, the "FSEARCH" mode of the program was run to get the approximate relative DSS clock offset. All of the offset was assigned to DSS 14 in the CCR (this makes postcorrelation processing easier), and a continuous PCR of the pass was generated. A backup copy of the PCR was written to tape for archival purposes. The TEMPO Team was then informed of the availability of the PCR.

A small number of passes result in no fringes or very few fringes with no obvious reason for the poor results. Improved phase cal tone monitoring with the next ODA software revision should help in identifying this problem. Possible reasons for no fringes include: (1) weak sources; (2) hardware failure; (3) an undetected error in setup (most likely incorrect frequency settings); (4) something as yet unsuspected. Passes where there have been poor results for unknown reasons are being investigated. It was generally found that a pass is either very bad or very good, i.e., no fringes or 80-100% fringes.

## V. Postcorrelation Processing

### A. Software Development

Beginning with 1981 DOY 086 all postcorrelation processing was done on the Block I VAX (Digital Equipment Corp. Virtual Address Extension, hereafter simply VAX) computer. The four major steps in postcorrelation processing and the software modules involved are: (1) fringe phase tracking (PHASOR); (2) phase calibration tone tracking (PCAL); (3) bandwidth synthesis ambiguity resolution (FITDELAY); and (4) clock and UTPM estimation (MASTERFIT). These modules were transferred to the Block I VAX from the Caltech IBM 3032. Extensive tests and comparisons with the modules still running on the IBM 3032 disclosed several software errors. These errors were corrected and the VAX and IBM versions brought into agreement before processing was shifted to the VAX.

A significant software development effort was carried out on the VAX to provide the interface between the VPS and PHASOR/PCAL. Several utility routines were created for transferring PHASOR/PCAL output from the VAX to the IBM for testing and for estimation as MASTERFIT was the last module transferred. The modules PHASOR and PCAL are also used in processing spacecraft VLBI data (Differenced Downlink Only Range, DOR).

### B. Clock Synchronization Results

Of the 46 observing sessions conducted in 1981, 30 produced useful data for clock synchronization. As shown in Table 2 the clock offset uncertainties ranged from 35 to about 200 nsec. These data were processed without phase calibration for instrumental delays. Therefore, a bias is expected in the reported clock offset values. Comparisons with the offsets measured by a travelling clock indicate that the bias is smaller than 1 $\mu$sec on both baselines (Figs. 2 and 3). Data from DOR passes are also included in the figures since observation of only one EGRS is needed to establish the clock offset. All VLBI-derived clock offsets are in good agreement. Comparisons of the VLBI data with the FTS records of clock behavior by S. C. Ward, Frequency and Timing System (FTS) System Cognizant Operation Engineer, gave independent confirmation of a number of known clock anomalies. Figures 2 and 3 show the VLBI data with rates fitted (see below) and discrepant points indicated. The main causes of disagreement were (1) a loss of synchronization between the VLBI subsystem and the FTS epoch which gives an error of $N \times 200$ nsec ($N$ an integer), and (2) a 1-$\mu$sec retardation of the DSS 14 epoch measured by the FTS standards laboratory. The cause of the erratic behavior labelled 3 in Fig. 3 is not yet known. The steep slope at the beginning of Fig. 3 is due to the use of a Cs standard at DSS 63 from November 11, 1980, to January 14, 1981.

The long-term clock rate calculated from the slope of the offset data was found to be $0.51 \pm 0.009 \times 10^{-12}$ s/s on the DSS 14/43 baseline and $0.05 \pm 0.02 \times 10^{-12}$ s/s on the DSS 14/63 baseline. These values agree with the LORAN determinations of clock rate and are about 10 times more accurate. The clock rates from individual sessions have uncertainties ranging from 0.13 to $1.5 \times 10^{-12}$ s/s. The averages over the clock rates for each baseline agree very closely with the long-term rates.

### C. UTPM Estimation

Of the 46 observing sessions conducted in 1981, 21 produced useful data for UTPM estimation. This success rate can be contrasted with the 1980 performance, when only 11 of 38 passes produced UTPM solutions.

After fringe fitting, delay observables were constructed by bandwidth synthesis, while the delay rate was derived from a single channel fringe frequency. Solutions using the delay and delay rate data are obtained with the program MASTERFIT. Due to the limited number of sources observed during each session, the solve-for parameters were restricted to earth orientation parameters plus a first-degree-polynomial clock model and a term allowing for systematic errors between the delay and delay rate data. The solutions rely upon a priori knowledge of the baseline vectors and source positions. The tropospheric and ionospheric delays were modeled by tables of average zenith delays and elevation angle mapping functions. Since dual-frequency (S and X bands) data were recorded, it was possible to estimate the ionospheric delay from the data, but solutions done using SX data had, in general, larger root mean square (rms) residuals than corresponding X-band solutions.

The original TEMPO solution strategy was, when possible, to combine data from paired observing sessions and to solve for all three UTPM parameters. If data from only one session were available, solutions were done for two of the three standard UTPM components. Such single baseline solutions rely upon outside information (the Bureau Internationale de l'Heure (BIH) Circular-D) for the unadjusted component.

Errors or biases in the unadjusted component will map into the adjusted parameters, and the results may be corrupted. Since one purpose of these experiments was to provide results independent of the BIH, this was not a satisfactory method of solution. Even if data were available from both observing sessions, any changes in the earth orientation between the two sessions would corrupt the joint solution. In addition, any solution involving combined data obscures the contribution from the individual observing sessions and makes it hard to evaluate session performance.

Single baseline VLBI observations are insensitive to rotations about the baseline and thus cannot provide all three UTPM components without further constraints. Rotations of the earth about the baseline vector are equivalent to motions along a line parallel to the degenerate direction in the UTPM parameter space. If the UTPM parameter adjustments are constrained to lie in a plane normal to the degenerate direction, errors in the a priori value for the UTPM in the constrained direction will not affect the residuals or postfit parameter adjusts in the constraint plane. Solutions with such constraints are called normal plane solutions.

A program (Earth Rotation Analysis Of Variance (ERANOV)) was written to process normal plane solutions. ERANOV accepts as inputs the parameter adjusts, formal parameter errors, and correlation matrix resulting from a MASTERFIT normal plane solution and implements the solution analysis described above. The results obtained from the analysis of normal plane solutions consist of parameter adjusts describing a point in the constraint plane, together with the error ellipse associated with the point. A complete derivation of normal plane solutions will be published.

The overall results of carrying out the UTPM analysis on the data listed in Table 1 (X-band data only) are summarized below.

(1) Sent to the BIH – data from July 14, 1980, through March 1, 1981:

15 observing sessions had usable results out of 53 scheduled and 39 conducted

154 delay and 153 delay rate observations in the 15 usable passes

RMS delay residual = 0.631 nanosec

RMS delay rate residual = 0.338 picosec/sec

(2) In analysis – data from March 9, 1981, through August 29, 1981:

17 observing sessions had usable results out of 48 scheduled and 33 conducted

142 delay and 146 delay rate observations in the 17 usable passes

RMS delay residual = 0.985 nanosec[1]

RMS delay rate residual = 0.748 picosec/sec[1]

## VI. Summary and Conclusions

The operation and results of the Block I Operational VLBI time synchronization and platform parameter determination system were outlined. Problems which arose during system startup were described. Most of the problems were overcome as operational equipment and software, in particular the VLBI Processing System on the Block I VAX, were implemented. Better operational procedures also contributed to improved data quality.

Useful clock sync and UTPM data were obtained for the period July 14, 1980, to August 2, 1981. The clock data were a factor 10 more accurate than other available data and clearly show known clock anomalies. UTPM data were sent to the BIH to aid in understanding the earth's orientation.

Thanks to the efforts of a large number of people at JPL, especially in the operations area and at the Deep Space Stations, the Block I VLBI system has developed into a powerful and well-functioning tool for the DSN to use in monitoring FTS performance and earth orientation.

[1]These rms residuals should be regarded as preliminary. The cause of the increase in the rms residuals between the two data sets is being investigated.

# Reference

1. Chaney, W. D., "The DSN VLBI System Mark IV-85," *TDA Progress Report 42-64*, pp. 61-76, Jet Propulsion Laboratory, Pasadena, Calif., Aug 15, 1981.

**Table 1. Status of JPL Tempo Block I VLBI experiments**

Explanation of the steps:

Pass = observations conducted
Corr = correlated successful
PHASOR = fringe fitting
FITDELAY = ambiguity resolution
MASTERFIT = least squares solution to data

MASTERFIT solutions require at least 6 data points for good results. Experiments without at least 6 X-band delay observations were cancelled. Experiments with more S-band data may be used in the future.

X = step successfully completed
C = processing cancelled at this step

Baseline ID:

A = 14/43 experiment
B = 14/63 experiment

| Date | ID/DOY | Pass | Corr | PHASOR | FITDELAY | MASTERFIT | Notes |
|---|---|---|---|---|---|---|---|
| 07/14/80 | B 196 | X | X | X | X | X | Data sent to BIH |
| 07/15/80 | A 197 | X | X | X | X | X | Data sent to BIH |
| 07/19/80 | B 201 | X | X | X | X | X | Data sent to BIH |
| 07/21/80 | A 203 | X | C | | | | No fringes |
| 07/25/80 | B 207 | X | X | X | X | X | Data sent to BIH |
| 07/31/80 | A 213 | X | X | X | X | C | Not enough data |
| 08/02/80 | B 215 | X | C | | | | No fringes |
| 08/05/80 | A 218 | X | X | C | | | No convergence |
| 08/24/80 | A 237 | X | X | X | X | X | Data sent to BIH |
| 08/24/80 | B 237 | X | X | X | X | X | Data sent to BIH |
| 08/11/80 | A 224 | X | C | | | | No fringes |
| 08/11/80 | B 224 | X | C | | | | No fringes |
| 08/18/80 | A 231 | X | C | | | | No fringes |
| 08/30/80 | A 243 | C | | | | | Station problems |
| 09/15/80 | B 259 | X | X | X | X | X | Data sent to BIH |
| 09/23/80 | A 267 | X | X | X | X | X | Data sent to BIH |
| 09/24/80 | B 268 | X | X | X | X | X | Data sent to BIH |
| 09/30/80 | A 274 | X | X | X | X | X | Data sent to BIH |
| 10/01/80 | B 275 | C | | | | | Pass cancelled |
| 10/09/80 | A 283 | X | C | | | | No fringes |
| 10/10/80 | B 284 | X | X | X | X | C | Bad IDR data |
| 10/16/80 | A 290 | X | X | X | X | X | Data sent to BIH |
| 10/17/80 | B 291 | X | X | X | X | X | Data sent to BIH |
| 10/23/80 | A 297 | X | C | | | | Station problems |
| 10/24/80 | B 298 | X | C | | | | Playback problems |
| 10/31/80 | A 305 | C | | | | | Pass cancelled |
| 10/31/80 | B 305 | C | | | | | Pass cancelled |
| 11/06/80 | A 311 | X | C | | | | Playback cancelled |
| 11/06/80 | B 311 | X | C | | | | Playback cancelled |
| 11/22/80 | B 326 | X | C | | | | No fringes |
| 11/22/80 | A 327 | X | X | X | X | X | Data sent to BIH |
| 12/01/80 | B 336 | X | C | | | | Unreadable IDRS |
| 12/02/80 | A 337 | C | | | | | Pass cancelled |
| 12/07/80 | B 342 | X | X | X | X | C | Not enough data |
| 12/08/80 | A 343 | X | X | X | X | X | Data sent to BIH |
| 12/13/80 | B 348 | X | X | X | X | X | Data sent to BIH |
| 12/14/80 | A 349 | X | X | X | X | X | Data sent to BIH |

Table 1 (contd)

| Date | ID/DOY | Pass | Corr | PHASOR | FITDELAY | MASTERFIT | Notes |
|---|---|---|---|---|---|---|---|
| 12/23/80 | A 358 | X | X | X | X | X | Data sent to BIH |
| 12/23/80 | B 358 | C | | | | | Station problems |
| 12/30/80 | A 365 | X | X | X | X | | Ready to MFIT |
| 12/31/80 | B 366 | X | X | X | X | C | Not enough data |
| 01/22/81 | A 022 | X | C | | | | No fringes found |
| 01/22/81 | B 022 | X | C | | | | Unreadable IDRS |
| 01/29/81 | B 029 | X | C | | | | Station problems |
| 01/31/81 | A 031 | X | C | | | | Missing IDRS |
| 02/04/81 | A 035 | X | X | X | X | X | Data sent to BIH |
| 02/04/81 | B 035 | X | C | | | | Missing IDRS |
| 02/11/81 | A 042 | X | X | X | X | X | Data sent to BIH |
| 02/11/81 | B 042 | X | X | X | X | C | Not enough data |
| 02/19/81 | A 050 | X | X | X | X | C | Not enough data |
| 02/19/81 | B 050 | X | X | X | X | X | Data sent to BIH |
| 03/01/81 | A 060 | X | C | | | | No fringes found |
| 03/01/81 | B 060 | X | X | X | X | X | Data sent to BIH |
| 03/09/81 | A 068 | X | C | | | | Station problems |
| 03/09/81 | B 068 | X | X | X | X | C | Not enough data |
| 03/16/81 | B 075 | X | C | | | | No fringes found |
| 03/17/81 | A 076 | X | C | | | | Station problems |
| 03/27/81 | A 086 | X | C | | | | No fringes found |
| 03/28/81 | B 087 | X | C | | | | No fringes found |
| 04/04/81 | A 094 | X | X | X | X | | MFIT solutions |
| 04/05/81 | B 095 | X | C | | | | No fringes found |
| 04/12/81 | A 102 | X | X | X | X | | MFIT solutions |
| 04/12/81 | B 102 | X | X | X | X | | MFIT solutions |
| 04/17/81 | B 107 | X | X | | | | In backlog |
| 04/18/81 | A 108 | X | C | | | | No fringes found |
| 04/26/81 | A 116 | X | X | | | | In backlog |
| 04/26/81 | B 116 | C | | | | | Antenna failure |
| 05/03/81 | A 123 | X | C | | | | Playback cancelled |
| 05/03/81 | B 123 | X | X | X | X | | S-band only |
| 05/10/81 | A 130 | X | X | X | X | | MFIT solutions |
| 05/10/81 | B 130 | X | X | X | X | | MFIT solutions |
| 05/16/81 | A 136 | X | X | X | X | | MFIT solutions |
| 05/16/81 | B 136 | C | | | | | Station problems |
| 05/24/81 | A 144 | C | | | | | Antenna failure |
| 05/24/81 | B 144 | C | | | | | Antenna failure |
| 05/31/81 | A 151 | X | X | X | X | | MFIT solutions |
| 05/31/81 | B 151 | X | X | X | X | | MFIT solutions |
| 06/08/81 | A 159 | X | C | | | | IDRS bad |
| 06/08/81 | B 159 | X | C | | | | No fringes found |
| 06/14/81 | A 165 | X | X | X | X | | MFIT solutions |
| 06/14/81 | B 165 | X | X | X | X | | MFIT solutions |
| 06/21/81 | A 172 | C | | | | | Pass cancelled |
| 06/21/81 | B 172 | C | | | | | Pass cancelled |
| 06/28/81 | A 179 | X | X | X | C | | No delay data |
| 06/28/81 | B 179 | X | X | X | | | Ready to MFIT |
| 07/05/81 | A 186 | X | C | | | | No fringes found |
| 07/05/81 | B 186 | X | C | | | | No fringes found |
| 07/12/81 | A 193 | X | X | X | X | | MFIT solutions |
| 07/12/81 | B 193 | X | X | X | X | | MFIT solutions |
| 07/19/81 | A 200 | X | X | X | X | | MFIT solutions |
| 07/19/81 | B 200 | X | X | X | X | | MFIT solutions |
| 07/26/81 | A 207 | X | X | X | X | | MFIT solutions |
| 07/26/81 | B 207 | X | X | X | X | | S-band only |
| 08/01/81 | A 213 | X | X | X | X | | MFIT solutions |
| 08/02/81 | B 214 | X | X | X | X | | MFIT solutions |

**Table 1 (contd)**

| Date | ID/DOY | Pass | Corr | PHASOR | FITDELAY | MASTERFIT | Notes |
|---|---|---|---|---|---|---|---|
| 08/11/81 | A 223 | C | | | | | Pass cancelled[a] |
| 08/12/81 | B 224 | C | | | | | Pass cancelled[a] |
| 08/23/81 | A 235 | C | | | | | Pass cancelled[a] |
| 08/23/81 | B 235 | C | | | | | Pass cancelled[a] |
| 08/29/81 | A 241 | C | | | | | Pass cancelled[a] |
| 08/29/81 | B 241 | C | | | | | Pass cancelled[a] |

[a]These passes were cancelled to protect the DSS 14 antenna from further injury from the azimuth bearing problem.

## Table 2. Validated results for clock synchronization, Block I system

VALIDATED RESULTS FOR CLOCK SYNCHRONIZATION

BLOCK 1 SYSTEM

REPORT DATE:11/09/81 COVERING DEC THRU MAY 1981

COMMENTS,NOTES,OR SIGNIFICANT EVENTS:
NS=NOT SCHEDULED
NG=NO BLK1 DATA
*=BLK 1 BACKLOG
%=UT1-PM PAIR
¬=CLOCK RESETS

| ----> | | RELATIVE CLOCK PARAMETERS:DSS43-DSS14 | | | | | | COMMENTS,NOTES,OR SIGNIFICANT EVENTS | | RELATIVE CLOCK PARAMETERS:DSS63-DSS14 | | | | | | <----- | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SET ID | NO. OBS. USED | REFERENCE TIME | | CLOCK OFFSET | | RATE X E-12 | | | | REFERENCE TIME | | CLOCK OFFSET | | RATE X E-12 | | NO. OBS. USED | SET ID |
| | | DOY | HH:MM:SS | VALUE | ERR | VALUE | ERR | | | DOY | HH:MM:SS | VALUE | ERR | VALUE | ERR | | |
| AC02 | NS | 337 | **********PASS CANCELLED*********** | | | | | | | 336 | *********BAD IDRS DSS 14*********** | | | | | NG | BC01 |
| AC08 | 8 | 343 | 05:25:41 | -3.803 | .016 | - .08 | .31 | % | % | 342 | 22:59:40 | -1.976 | .051 | - .09 | 5.32 | 9 | BC07 |
| AC14 | 10 | 349 | 04:54:38 | -3.529 | .048 | - .76 | .18 | % | % | 348 | 23:49:40 | -1.463 | .048 | - .55 | .66 | 8 | BC13 |
| AC23 | 9 | 358 | 08:34:43 | -3.184 | .061 | .23 | .20 | | | 358 | *********STATION PROBLEMS*********** | | | | | NG | BC23 |
| AC30 | NG | 365 | *********STATION PROBLEMS*********** | | | | | | | 366 | 05:42:40 | -1.113 | .133 | .29 | .26 | 9 | BC31 |
| A122 | NG | 022 | ***********NO FRINGES************* | | | | | | | 022 | *****NO FRINGES, NO TONES DSS14***** | | | | | NG | B122 |
| A130 | 11 | 030 | 07:04:59 | -1.946 | .062 | - .08 | .18 | | | 029 | **********PASS CANCELLED*********** | | | | | NS | B129 |
| A204 | 12 | 035 | 09:02:42 | -1.809 | .060 | 1.12 | .53 | | | 035 | *********INCOMPLETE IDRS*********** | | | | | NG | B204 |
| A211 | 12 | 042 | 08:02:34 | -1.550 | .058 | .23 | .13 | % | % | 042 | 05:08:40 | .084 | .070 | .63 | .49 | 9 | B211 |
| A219 | 6 | 050 | 07:04:59 | -1.119 | .130 | - .08 | .18 | % | % | 050 | 00:08:41 | .098 | .205 | .83 | .28 | 8 | B219 |
| A301 | NG | 060 | ***********NO FRINGES************* | | | | | | | 060 | 18:42:40 | .203 | .073 | - .55 | .27 | 8 | B301 |
| A309 | NS | 068 | **********PASS CANCELLED*********** | | | | | | | 068 | 04:21:42 | .164 | .093 | .89 | .80 | 8 | B309 |
| A316 | NG | 075 | ***********NO FRINGES************* | | | | | | | 076 | **********PASS CANCELLED*********** | | | | | NS | B317 |
| A327 | NG | 086 | ****NO FRINGES DSS 14 TONES WEAK**** | | | | | | | 087 | *****NO FRINGES, NO TONES DSS63***** | | | | | NG | B328 |
| A404 | 11 | 094 | 13:19:40 | .781 | .071 | 2.83 | .44 | | | 095 | *****NO FRINGES, NO TONES DSS63***** | | | | | NG | B405 |
| A412 | 11 | 102 | 10:23:00 | .253 | .066 | 1.01 | .66 | % | % | 102 | 03:09:30 | - .842 | .130 | -1.22 | 1.52 | 7 | B412 |
| A413 | NG | 108 | ****NO FRINGES DSS 14 TONES WEAK**** | | | | | | | 107 | 06:44:36 | .488 | .188 | -2.26 | 0.55 | 7 | B417 |
| A426 | 9 | 116 | 12:08:34 | 1.545 | .102 | .84 | .65 | | | 116 | *******DSS 14 ANTENNA FAILURE****** | | | | | NS | B426 |
| A503 | NG | 123 | *********DSS 14 IDRS LOST*********** | | | | | | | 123 | 12:11:39 | .426 | .075 | .47 | .19 | 9 | B503 |
| A510 | 13 | 130 | 06:39:39 | 2.188 | .058 | .31 | .99 | % | % | 130 | 03:54:41 | .403 | .095 | .24 | .64 | 7 | B510 |
| A516 | 12 | 136 | 07:31:42 | 2.476 | .046 | .13 | .29 | | | 136 | *******BWS OSCILLATOR FAILURE****** | | | | | NG | B516 |
| A524 | NS | 144 | *******DSS 14 ANTENNA FAILURE****** | | | | | | | 144 | *******DSS 14 ANTENNA FAILURE****** | | | | | NS | B524 |
| A531 | 11 | 151 | 06:39:41 | 3.265 | .081 | - .19 | .32 | % | % | 151 | 03:48:39 | .628 | .153 | .06 | .22 | 7 | B531 |

Table 2 (contd)

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VALIDATED RESULTS FOR CLOCK SYNCHRONIZATION

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BLOCK 1 SYSTEM

REPORT DATE:11/09/81 COVERING JUN THRU AUG 1981

COMMENTS,NOTES,OR SIGNIFICANT EVENTS

NS=NOT SCHEDULED
NG=NO BLK1 DATA
*=BLK 1 BACKLOG
%=UT1-PM PAIR
¬=CLOCK RESETS

| ----> | | RELATIVE CLOCK PARAMETERS:DSS43-DSS14 | | | | | | COMMENTS,NOTES,OR SIGNIFICANT EVENTS | RELATIVE CLOCK PARAMETERS:DSS63-DSS14 | | | | | | <----- | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SET ID | NO. OBS. USED | REFERENCE TIME | | CLOCK OFFSET | | RATE X E-12 | | | REFERENCE TIME | | CLOCK OFFSET | | RATE X E-12 | | NO. OBS. USED | SET ID |
| | | DOY | HH:MM:SS | VALUE | ERR | VALUE | ERR | | DOY | HH:MM:SS | VALUE | ERR | VALUE | ERR | | |
| A608 | * | 159 | ************IDRS LOST************* | | | | | | 159 | ****NO FRINGES DSS 14 TONES WEAK**** | | | | | NG | B608 |
| A614 | 9 | 165 | 05:37:43 | 3.786 | .056 | - .01 | .34 | % % | 165 | 02:59:03 | 0.456 | .112 | .07 | .26 | 7 | B614 |
| A621 | NS | 172 | **********PASS CANCELLED*********** | | | | | | 172 | **********PASS CANCELLED*********** | | | | | NS | B621 |
| A628 | NG | 179 | *****FRINGES CHANNELS 3 & 6 ONLY**** | | | | | | 179 | 01:57:39 | 0.179 | .097 | - .36 | .70 | 6 | B628 |
| A705 | NG | 186 | *****NO FRINGES, ABNORMAL TONES***** | | | | | | 186 | *****NO FRINGES, ABNORMAL TONES***** | | | | | NG | B705 |
| A712 | 12 | 193 | 03:47:44 | 6.079 | .101 | .12 | .18 | %<--X-BAND ONLY-->% | 193 | 01:16:57 | 1.026 | .193 | .21 | .13 | 7 | B712 |
| A719 | 12 | 200 | 03:20:36 | 6.356 | .065 | .25 | .21 | % | 200 | 00:22:47 | 1.265 | .086 | .34 | .21 | 8 | B719 |
| A726 | 9 | 207 | 13:55:40 | 6.684 | .035 | .81 | .22 | S-BAND ONLY--> | 207 | 00:00:39 | 1.275 | .062 | - .36 | .68 | 4 | B726 |
| A801 | 8 | 213 | 13:31:40 | 7.079 | .055 | .74 | .21 | % % | 214 | 06:06:43 | 1.619 | .136 | -1.05 | .32 | 6 | B802 |
| A811 | NS | 223 | **********PASS CANCELLED*********** | | | | | | 224 | **********PASS CANCELLED*********** | | | | | NS | B812 |
| A823 | NS | 235 | **********NOT SCHEDULED************ | | | | | | 235 | **********PASS CANCELLED*********** | | | | | NS | B823 |
| A829 | NS | 241 | **********NOT SCHEDULED************ | | | | | | 241 | **********PASS CANCELLED*********** | | | | | NS | B829 |

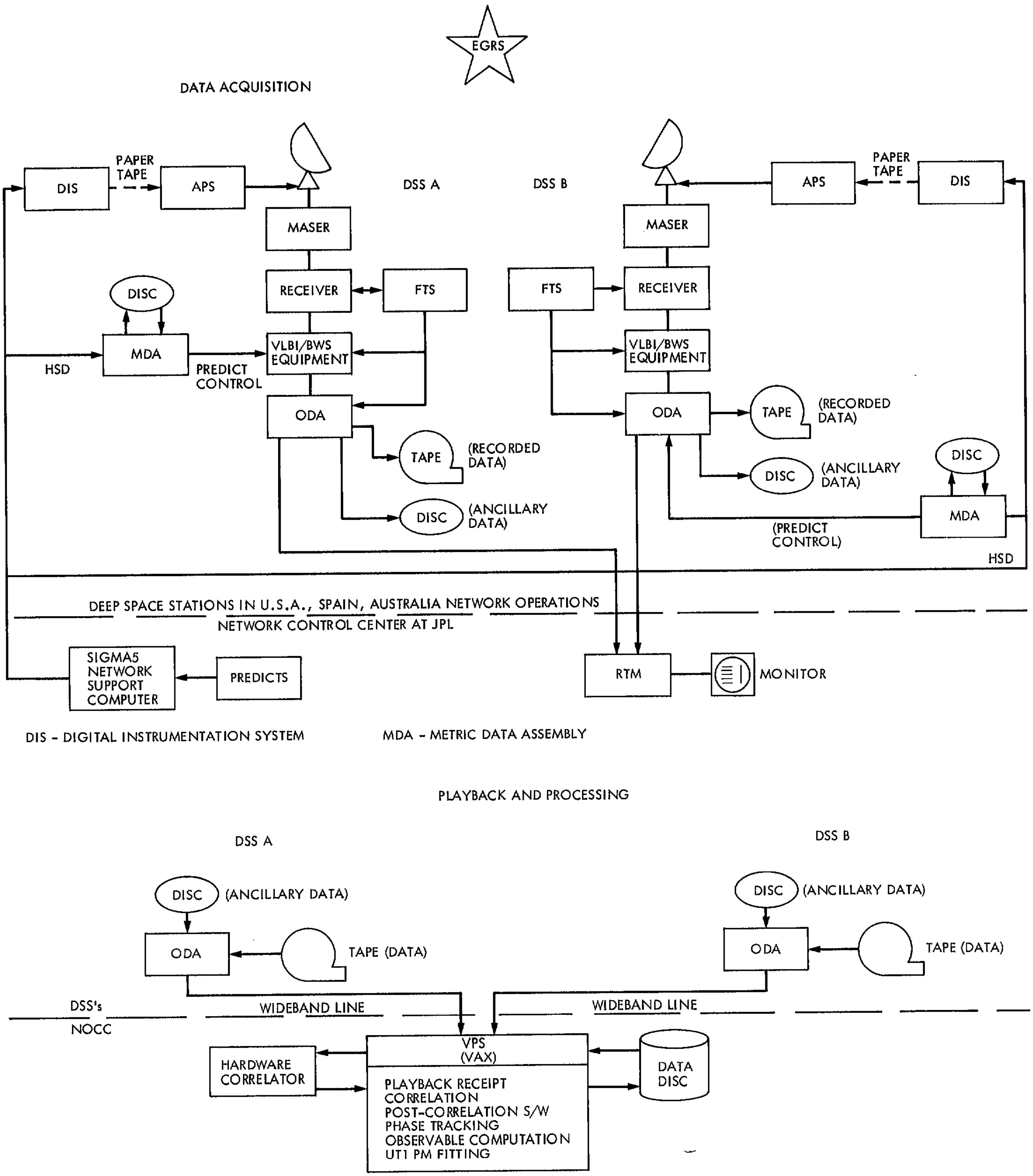


**Fig. 1. VLBI system overview**

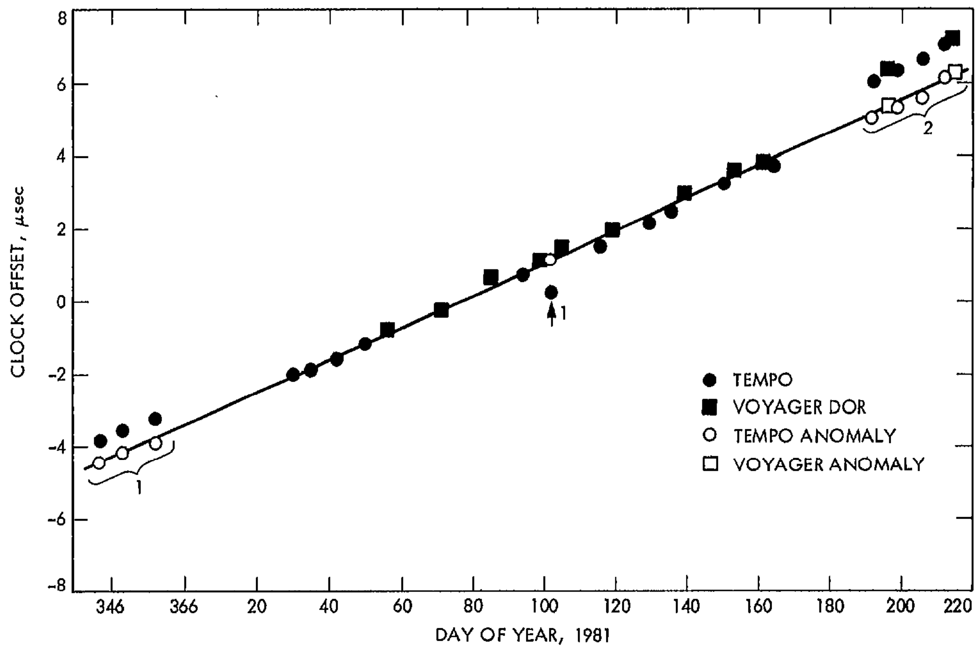


**Fig. 2. Clock offset, DSS 43/DSS 14**

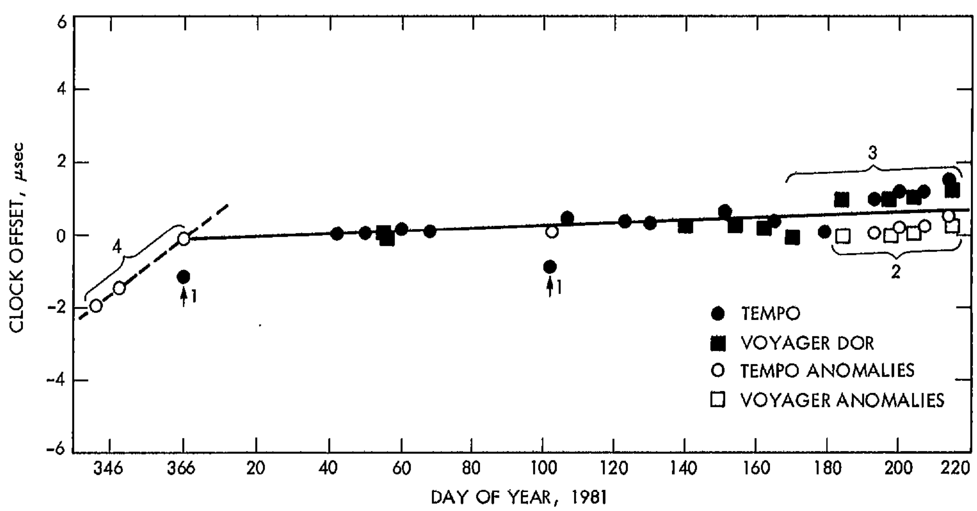


**Fig. 3. Clock offset, DSS 63/DSS 14**