Pioneer Venus 1978 Mission Support

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This article reports on the Deep Space Network support of the Pioneer Venus Mission. It describes the Orbiter's Venus Orbit Insertion, Multiprobe Entry, and Orbiter Occultation Experiment support.

I. Venus Orbit Insertion (VOI)

A. Supporting Stations

DSSs 11 and 14 were the prime stations for support of VOI. DSS 43 provided support for the reorientation of the spacecraft into the orbit insertion attitude at approximately 45 hours prior to VOI. They also supported the loading of spacecraft Stored Command Logic (SCL) with the orbit insertion parameters.

The DSN Real-Time Telemetry System Analyst (NAT TEL) provided monitoring for spacecraft stored command load address pointers beginning at VOI minus 7 hours.

The Ground Communications Facility (GCF) provided critical support during the VOI period.

B. VOI Support Procedures

The VOI sequence was executed by the spacecraft by preprogrammed commands. To insure a successful VOI, a contingency plan was formulated. The plan included an uplink and downlink strategy for Pre-VOI, an uplink and downlink strategy for Post-VOI, and monitoring of SCL issued commands during Pre-VOI.

1. Pre-VOI Strategies. The Pioneer Venus Orbiter and Bus Spacecrafts had experienced random single bit changes in their SCLs during the entire transit phase of the mission. The bit changes occurred about once per week and were thought to be caused by cosmic rays passing through the solid state memories. Since the ignition of the Orbit Insertion Motor was to be initialized by the SCL, there was concern that a bit change could cause ignition to be earlier or later than the programmed time. To guard against such an occurrence, a plan was devised to provide for continuous monitoring of the address pointers in the redundant SCLs during the 7 hours prior to VOI. The DSN extracted these words from the telemetry data and made comparative counts with Ames Research Center (ARC).

In the event of a computer failure at ARC, the DSN would then have relayed the SCL count to ARC by voice until the computer could be restored. No ARC computer failure occurred, and this failure strategy was not required.

The Pre-VOI uplink strategy was essentially to maintain the uplink until approximately 10 minutes prior to occultation in order to retain a command capability. DSS 14 provided an uplink with the prime spacecraft receiver while DSS 11 acquired an uplink with the backup receiver. This configuration provided redundant command capabilities and, in the event of a problem at the prime station, the other stations command modulation would be turned on and commanding continued.

Both stations turned off their transmitters at 10 minutes prior to occultation to insure a one-way doppler mode at entry.

Pre-VOI downlink strategy involved ramping the ground receiver during the hour prior to occultation in order to minimize the receiver phase error at entry and exit occultation.

2. **Post-VOI Strategies.** For Post-VOI, the desire was to obtain uplink lock as quickly as possible and transmit commands that would complete the VOI sequence in the event the preprogrammed sequence failed. It was estimated that a burn command reaching the spacecraft at the time of exit occultation would result in an orbit with a 48-hour duration instead of the desired 24-hour orbit for the nominal burn. For each minute's delay in the execution of the burn command, the orbit duration would increase by an estimated 5 hours.

The strategy for uplink acquisition was to use both DSS 11 and DSS 14 to simultaneously attempt to acquire the prime spacecraft receiver. The sweep was to cover a range of best lock frequency plus or minus 5 sigma or about 1700 Hz at S-band.

Following transmitter turn on for uplink acquisition sweep, command modulation was turned on and motor arm and fire commands were transmitted by both supporting stations.

Burn occurred at the nominal time and resulted in an orbit of slightly longer than the desired 24-hour duration.

The Post-VOI uplink with the spacecraft was missed by both stations. This was because the uplink tuning sweep strategy had been optimized for the anomalous no-burn case. Commanding for the no-burn case would have been mission critical. As a consequence, the uplink strategy was very conservative for the no-burn predicted doppler, but quite optimistic compared to the uncertainties for the burn case.

For Post-VOI downlink acquisition, a rapid lock was desired to determine the status of the orbit insertion and the health of the spacecraft.

DSS 14 used the Spectral Signal Indicator (SSI) in conjunction with an open loop receiver to detect downlink presence. A 300-kHz filter was used to detect signals in any of the possible modes (i.e., one-way, two-way, three-way, burn, no-burn).

DSS 11 concentrated on downlink acquisition for a nominal orbit insertion with their prime receiver used for two-way search and the backup used for one-way search.

Following the failure to acquire uplink lock upon exit occultation, a second sweep was performed by DSS 14 and uplink established.

II. Occultation Experiment Support

The occultation experiment is divided into three major scientific objectives.

(1) *Radio Science Occultation I.* To determine refractivity profiles in the lower atmosphere of Venus, at different longitudes, from the analysis of phase perturbations of the S- and X-band telemetry carriers during occultation. The refractivity profiles are used to obtain temperatures, pressures, and densities in the neutral atmosphere above about 35 km. Also measurements of dispersive (S- and X-band) absorption by analysis of signal attenuation during occultation. These yield data on possible radio absorptive layers below about 50 km in the lower atmosphere of Venus, data used to measure electron-density height profiles by analysis of dispersive S- and X-band phase effects observed during occultations at a variety of solar illumination angles over the life of the mission, and data used to observe dynamics of the lower atmosphere as obtained from the horizontal pressure and temperature gradients, as well as pressure and density variations with respect to time. Dr. A. J. Kliore of JPL is principal investigator.

(2) *Radio Science Corona Turbulence.* To observe and interpret the small-scale turbulence characteristics of the Venus atmosphere above about 35 km, measuring the intensity variation of turbulence with altitude, planetary latitude and longitude, and the distribution of scale sizes in the atmosphere. A secondary objective is to determine the solar-corona turbulence and solar-wind velocity near the Sun. R. T. Woo of JPL is the principal investigator.

(3) *Radio Science Occultation II.* Determination of atmospheric and ionospheric structures from radio occultations; solar wind irregularity detection through S-X differential delay coupled with adjunct information; search for relationships between solar wind variations and Venus ionospheric reactions; comparison of orbiter scintillations to one another and to probe scintillations to deduce evidence of turbulence or layering, and possibly also a study of solar wind scintillations. T. A. Croft of Stanford Research Institute is principal investigator.

The DSN supports this experiment with four separate data taking configurations. The open loop receivers in conjunction with the Occultation Data Assembly (ODA) are used to produce digital tapes containing digital data decimated to a reduced bandwidth. The wide bandwidth Multimission Open Loop Receiver (MMR) together with the Digital Recording Assembly (DRA) is used to produce wide bandwidth recordings of S-band only as backup to the prime narrow bandwidth ODA recordings.

The closed loop receivers are used to produce S- and X-band doppler that is transmitted to JPL in real-time.

The closed loop receiver and Digital Instrumentation Subsystem produce high-rate sampling of X-band AGC for real-time transmission to JPL. The AGC data were not originally committed to the mission until concern over reliability of the new ODA made the taking of the AGC data prudent.

Figure 1 shows the Occultation Experiment (S/X) configuration.

Support of the Radio Science Experiments began on 5 December 1978. DSS 14 provided support on this date with good results, using the newly installed ODA. The S-band 10-kHz OLR bandwidth was used to allow for any uncertainties in predicts or ODA operation.

Support continued for the next two days with data taking suspended on 8 and 9 December for Multiprobe Entry Support. A spurious signal was detected during these first three occultation passes and was found to be caused by the OLR local oscillator mixer.

The S-band OLR bandwidth was reduced to 5 kHz during the third occultation pass as confidence in the system was gained. The bandwidth was further reduced on orbit 7 to 2 kHz.

The initial occultations occurred over DSS 14 only. The spacecraft periapsis passage was allowed to move later each day until it reached the mutual DSS 14 and 43 view period. Spacecraft maneuvers maintain the periapsis passage in the mutual view period.

DSS 43 support of the occultation experiment began during orbit 29 on 2 January 1979, in parallel with DSS 14.

Parallel support continued when possible through orbit 90 when the first occultation season ended. Table 1 illustrates the performance of the DSN and Pioneer Project in terms of total data taken and lost during the first occultation season.

During the first 36 occultations there were 144 data events. There were four events during each occultation, defined as entry S-band, entry X-band, exit S-band and exit X-band. Of these 144 events, 22 percent were lost due to various problems. Since a wide bandwidth recording of S-band data was taken by the MMR/DRA in parallel with the OLR/ODA data, the total percentage of data lost was reduced to 14 percent.

Table 1 shows that for the first 36 occultations, the majority of problems were associated with errors at the supporting Deep Space Stations (DSS). The second highest loss of data was due to hardware problems. These problems were mainly due to the operator unfamiliarity with the equipment, and problems uncovered through operational use of the equipment.

For the next 36 occultations, the total loss of data increased slightly, however DSS operator errors decreased to 21 percent, while Project errors increased to 31 percent. The Project experienced difficulties in maintaining spacecraft high-gain antenna pointing during the data taking periods.

During the final 18 occultations, data loss continued at a constant level. DSS operator errors were decreased still further to just 9 percent. Again, mainly due to high gain antenna pointing problems, the Project contributed to 72 percent of the total data lost. The second occultation season is scheduled to begin during May 1979.

III. Multiprobe Entry

A. Supporting Stations

DSSs 14 and 43 had the prime responsibilities of supporting probe entry real-time telemetry, radio metric data, precarrier analog recording, DLBI recording, and uplink to the large probe during the entry period of the four probes. DSSs 14 and 43 also supported the Bus after probe impact on the surface. DSSs 11 and 44 supported the Bus during the entry sequence.

DSS 11's prime responsibility was to support the uplink for the Bus for command and 2-way radio metric data and telemetry during the entry period.

DSS 44 acted as a backup to DSS 11 for Bus coverage.

DSS 42 equipment provided a radio metric data processing channel for small probe three.

Spaceflight Tracking and Data Network (STDN) stations at Santiago, Chile, and Guam supported the Differential Long Base Interferometry (DLBI) experiment.

B. Configurations

Figure 2 illustrates the telemetry and DLBI configuration used by DSS 14/43.

This configuration provided one closed loop receiver for each of the four probes and one open loop receiver for each of the probes. Receiver numbers 3 and 4 (Blk IV Receivers) were both used to support the large probe. One was tuned to the one-way downlink frequency, while the other was configured for either the two-way (DSS 14) or three-way (DSS 43) doppler mode. The Multi-Mission Open Loop Receiver (MMR) was used to support the DLBI experiment.

Figure 3 shows the DSS 14 Radio Metric Data configuration, while Fig. 4 gives the DSS 42/43 radio metric data configuration. This cc· .guration provided real-time doppler from each of the four probes.

C. DSN Multiprobe Entry Sequence

A preliminary DSN Multiprobe Entry Sequence was developed as early as March 1978 and remained basically unchanged for the actual event.

Development of this Sequence of Events (SOE) was described in Progress Report 42-46 while the actual SOE was shown in Progress Report 42-48.

Preparations for the entry event began on 8 December 1978 when DSS 14/43 commenced an entry countdown sequence. During this sequence the stations checked out all of their support equipment in the entry support configuration. A Configuration Verification Test (CVT) was then conducted with each station. Following successful completion of these tests, the stations were placed under configuration freeze. Following the implementation of a freeze, the stations were not allowed to alter their configuration or support any other flight project.

The entry sequence of events timing was related to entry (E) of the large probe with entry defined as an altitude of 200 kilometers.

At E - 3^h a check list was performed.

The Bus was acquired at E - 2^h49^m by DSS 14 and they began their large probe uplink acquisition sweep at E - 2^h30^m. At this time the large probe downlink had not yet been turned on. Table 2 shows the uplink tuning performed by DSS 14 for large probe acquisition. The sawtooth sweep pattern was used to insure a successful uplink acquisition.

At E - 1^h19^m DSS 43 acquired the Bus downlink.

Throughout this early period, both stations were using their Signal Spectrum Indicators to look for probe downlinks. This was done to see if any of the probes had accidentally turned on early. There was concern that the same SCL radiation effects described above for the Orbiter and Bus could cause the probe coast timers to time out prematurely and cause the downlinks to be turned on.

Another checklist was performed at E - 60^m by both DSS 14 and 43. At this time DSS 11 was providing an uplink to the Bus (S/C 13) and DSS 12 was supporting the Pioneer Venus Orbiter (S/C 12). At E - 21^m, the large probe downlink was detected and found to be in two-way lock with DSS 14. Each of the probes was to follow the same sequence of events. First, the RF downlink was turned on. This was followed by the subcarrier being turned on five minutes later. Entry into the atmosphere of Venus occurred some 16-1/2 minutes later. The time from entry until impact on the planet was approximately 56 minutes. Figure 5 illustrates the predicted timing of each of the probe events. Table 3 gives probe entry parameters while Table 4 gives the predicted event times versus actual times. Prior to ground observed entry of the large probe, a specially designed uplink acquisition sweep was performed to reacquire the large probe uplink following atmospheric entry blackout. This began at E - 3^m.

The criteria used for uplink acquisition were:

(1) Unperturbed large probe downlink for at least 190 seconds after the observed entry. This was required to allow time for the reverse telemetry playback data to lock up.

(2) Minimized sweep times.

(3) A good probability of uplink acquisition.

The final plan used both DSS 14 and 43 for the uplink acquisition. DSS 43 performed the primary acquisition sweep while DSS 14 performed a secondary sweep. The total sweep range covered 20 kHz centered at the predicted best lock frequency. Figure 6 shows the sweep range versus time for each station. It shows an overlap in coverage centered at best lock frequency, which insured the chance for an early acquisition.

The DSS 43 sweep began at the predicted atmospheric entry blackout time minus three minutes to preserve criterion (1) above.

DSS 14's sweep began one minute later causing a separation of 1000 Hz at S-band to minimize any uplink interference.

Once the determination of which station had actually acquired the uplink had been made, the three-way station was to turn off their transmitter and tune to a frequency 460 Hz (S-band) away from the final frequency of the two-way station. This was done so that if a problem occurred at the two-way station, the other station could turn on their transmitter and have a good chance of capturing the uplink as the transponder drifted toward its rest frequency.

Due to a late exit from blackout, DSS 43 was unsuccessful in acquiring the uplink, and DSS 14 reacquired the uplink during the secondary sweep.

Table 5 gives the actual sweep message used by DSS 43 for large probe postentry uplink reacquisition. Table 6 shows the DSS 14 sweep.

All probes with the exception of Small Probe 2 impacted Venus on schedule and were presumed destroyed. Small Probe 2 survived the landing and continued to send data for some 67 minutes. The DLBI Principal Investigator reported later that from the DLBI data processing at M.I.T. he could detect the Small Probe 3 lasted about one second on the surface. This may not sound like much, but it meant that Probe 3 as well as 2 provided an anchor for the DLBI wind measurement. Last to enter the atmosphere was the Bus. It appeared to burn up some 2-1/2 minutes after entry when the signal was lost.

Support by all stations was excellent. Telemetry lock was obtained quickly after entry and data rate changes. The amount of real-time data returned was:

95 percent for the Large Probe,

95 percent for Small Probe 1,

84 percent for Small Probe 2,

88 percent for Small Probe 3.

Other than DSS 14 acquisition of the large probe uplink following blackout and the survival of Small Probe 2 following impact, everything went according to plan. The multiprobe entry planning and training described in Progress Report 42-48 had paid off.

Table 1. DSN occultation performance

Occultation number	Total data events	Data lost, %	Data lost after DRA recovery, %	Causes of data loss: DSS error, %	Hardware problem, %	Project error, %	NOCT error, %	S/W problem and unknown, %
1 – 36	144	22	14	63	20	7	5	5
37 – 72	256	25	14	21	25	31	23	–
73 – 90	148	22	15	–	9	72	10	9

Table 2. DSS 14 large probe preentry uplink acquisition (Revision 1)

TXR on:	16:19:00	GMT
TXR power:	20	kW
Frequency:	43966874.51	Hz
Start tuning up (T0):	16:20:00	GMT
Tuning rate (R0):	+1.16	Hz/s
Tune to:	43967823.39	Hz
Start tuning down (T1):	16:33:38	GMT
Tuning rate (R1):	–1.13	Hz/s
Tune to:	43966899.05	Hz
Start tuning up (T2):	16:47:16	GMT
Tuning rate (R2):	+1.17	Hz/s
Tune to:	43967856.11	Hz
Start tuning down (T3):	17:00:54	GMT
Tuning rate (R3):	–1.13	Hz/s
Tune to:	43966932.77	Hz
Start tuning up (T0):	17:14:32	GMT
Tuning rate (R0):	+1.18	Hz/s
Tune to:	43967897.01	Hz
Start tuning down (T1):	17:28:10	GMT
Tuning rate (R1):	–1.11	Hz/s
Tune to:	43966989.03	Hz
Tune to TSF (T2):	17:41:48	GMT
Tuning rate (R2):	+1.19	Hz/s
TSF:	43968254.0	Hz
Stop tuning (R3/T3):	17:59:31	GMT

Table 3. Predicted probe entry parameters

Probe	Entry time[a], GMT	Entry angle, deg	Maximum g's	Descent time, min:s
Sounder Probe (LP)	18:48:44	–32.8	308	54:36
North Probe (SP-1)	18:53:08	–67.9	503	55:54
Day Probe (SP-2)	18:55:11	–25.3	241	56:18
Night Probe (SP-3)	18:58:45	–41.8	382	56:16
Bus	20:24:06	–9.0	b	b

[a]Earth receive time of entry at 200 kilometers altitude.

[b]Communication with the bus was lost at approximately 60 s at 120 km altitude when aerodynamic forces began to tumble and destroy the bus.

Table 4. Predicted probe event time vs actual time

Probe	Event	Predicted Z, GMT	Actual Z, GMT	ΔT, s
LP	RF on	182724	182739	+15
SP1	RF on	183112	183110	- 2
SP2	RF on	183344	183340	- 1
SP3	RF on	183706	183721	+15
LP	TLM on	183224	183240	+16
SP1	TLM on	183612	183608	- 4
SP2	TLM on	183841	183840	- 1
SP3	TLM on	184206	184221	+15
LP	Entry	184844	184845	+ 1
SP1	Entry	185308	185253	-15
SP2	Entry	185511	185531	+20
SP3	Entry	185845	185926	+41
LP	Impact	194353	194306	-47
SP1	Impact	194906	184553	-193
SP2	Impact	195154	185112	-42
SP3	Impact	195502	185518	+16

Table 5. DSS 43 large probe postentry uplink acquisition (Revision 1)

TXR on:	18:45:44	GMT
TXR power:	20	kW
Frequency:	43966747.0	Hz
Start tuning (T0):	18:45:45	GMT
Tuning rate (R0):	-1.17	Hz/s
Tune to:	43966513.0	Hz
Stop tuning (T1/R1):	18:49:05	GMT
If confirmed three-way: turn TXR off and snap to:		
TSF:	43966926.0	Hz

Table 6. DSS 14 large probe postentry uplink acquisition (Revision 1)

Start tuning (T0):	18:46:44	GMT
Tuning rate (R0):	-1476.0	Hz/s
Tune to:	43966778.0	Hz
Tune to TSF (T1):	18:46:45	GMT
Tuning rate (R1):	+1.125	Hz/s
TSF:	43967003.0	Hz
Stop tuning (R2/T2):	18:50:05	GMT
If confirmed three-way by NOC, turn transmitter off and snap to		
TSF:	43966590.0	Hz

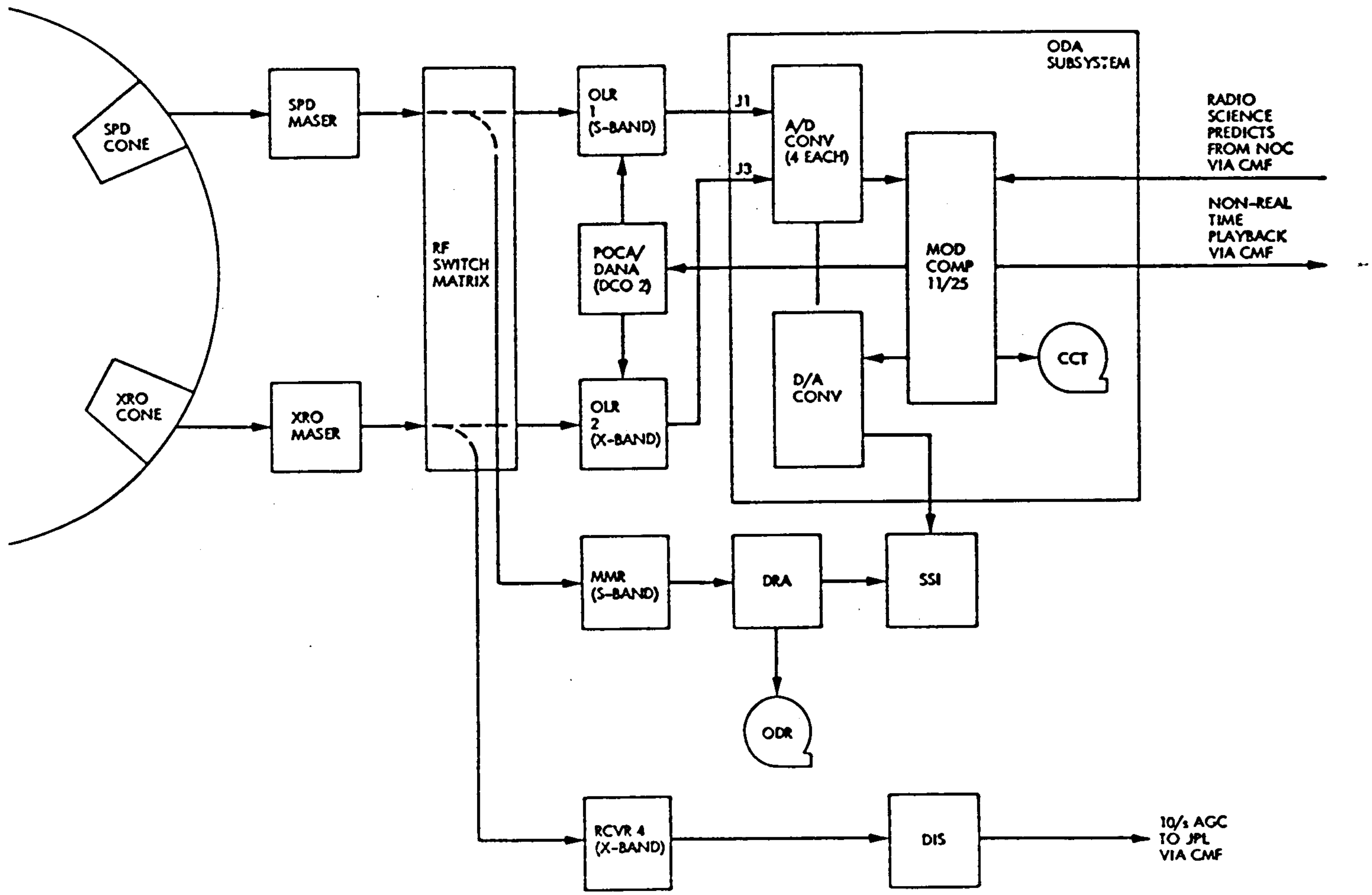

Fig. 1. Occultation experiment (S/X) configuration

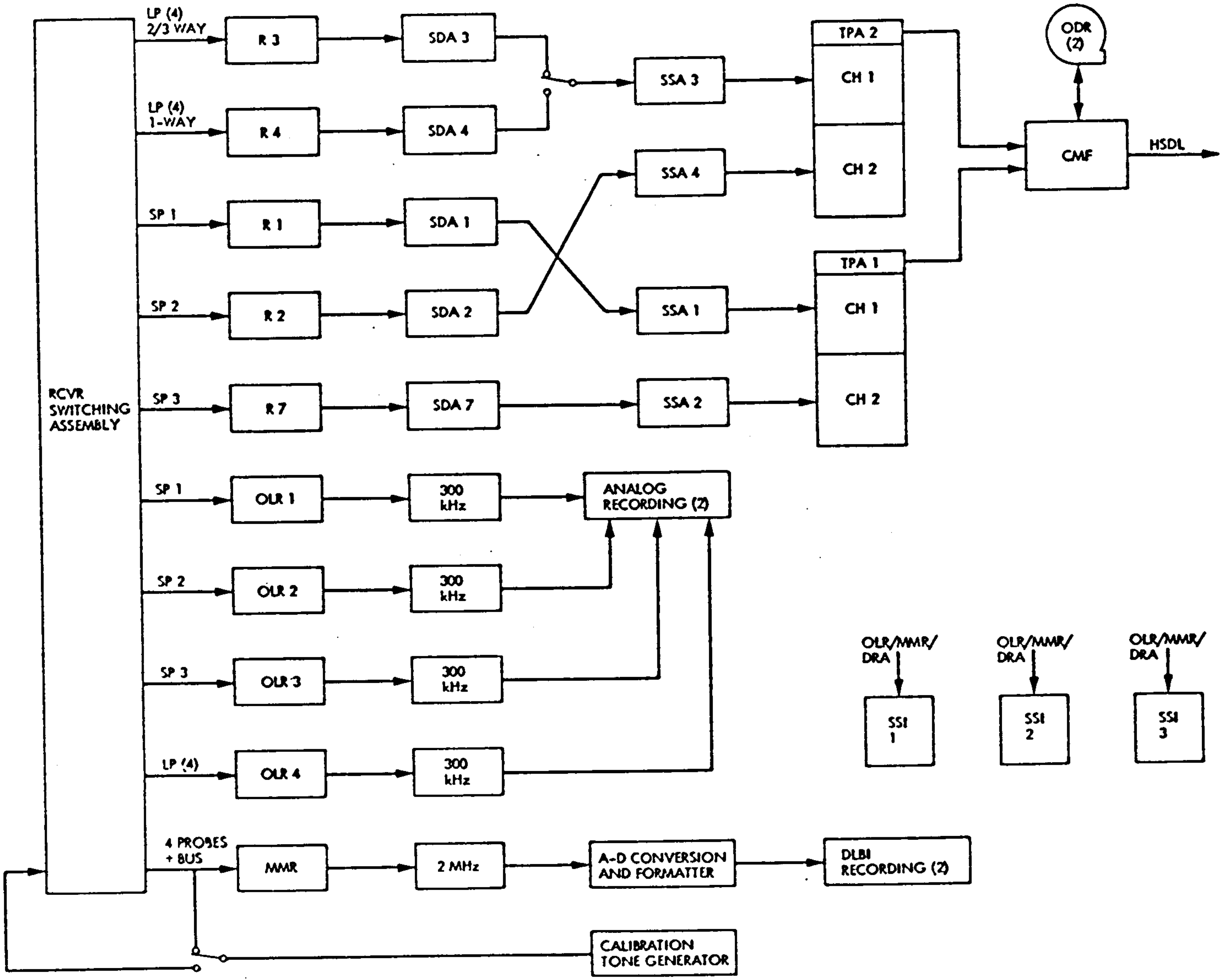

Fig. 2. DSS 14/43 telemetry and DLBI configuration for multiprobe entry

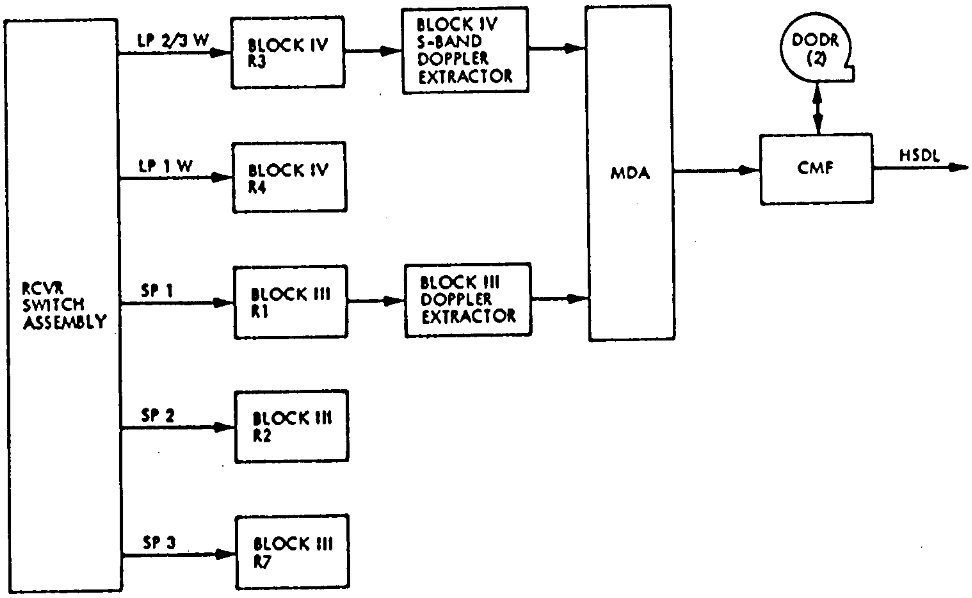

Fig. 3. DSS 14 radio metric data configuration for PV 78 multiprobe entry

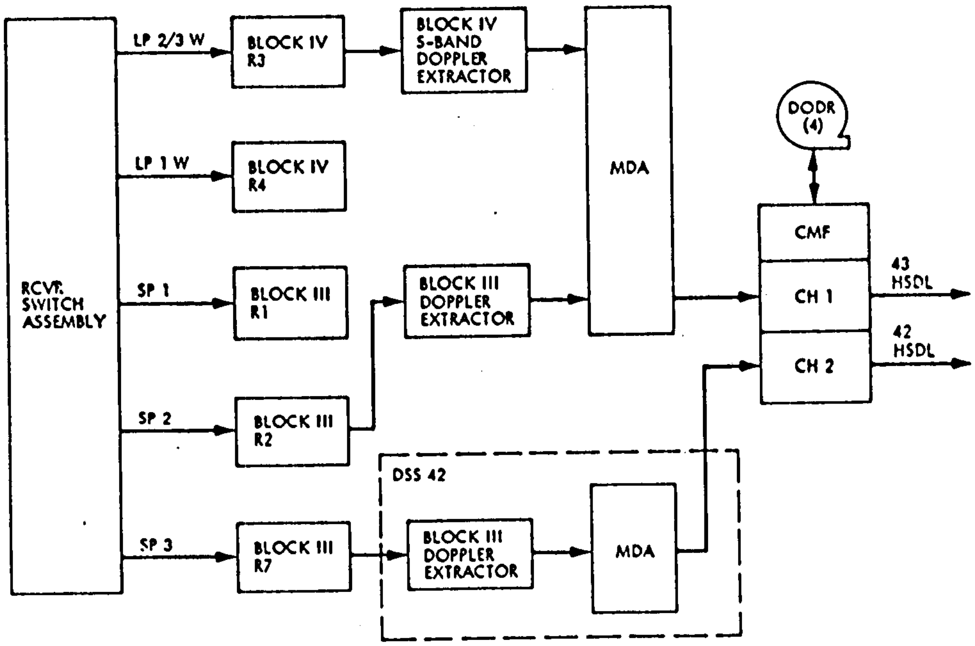

Fig. 4. DSS 43 radio metric data configuration for PV 78 multiprobe entry

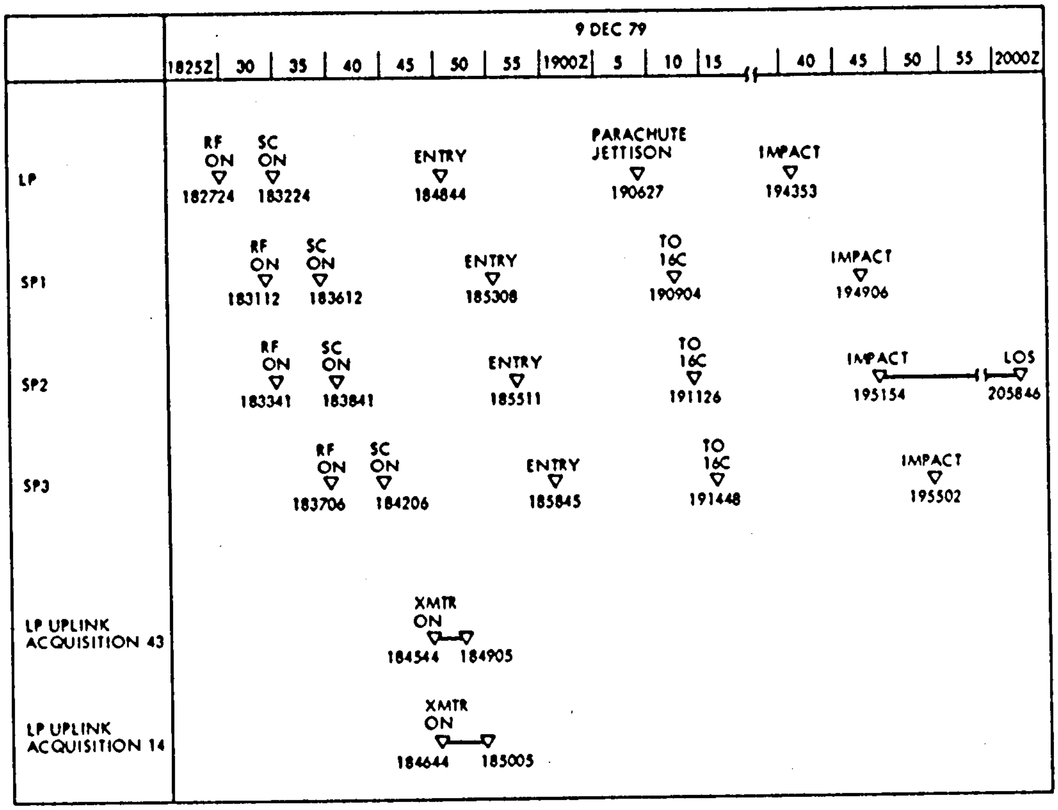

Fig. 5. Predicted probe event timing

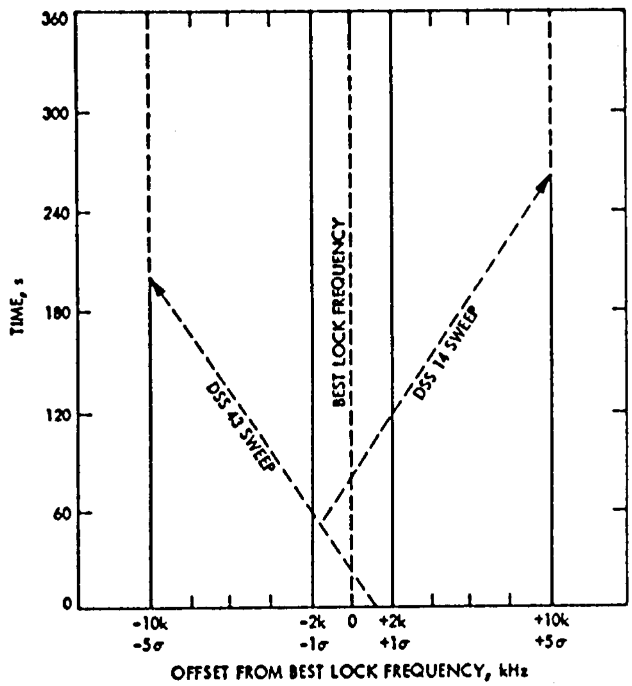

Fig. 6. Large probe uplink sweep strategy