Pioneer Venus 1978 Mission Support

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The current status of the Pioneer Venus 1978 Mission is described. The frequency allocation and latest version of the Deep Space Station configuration for the Multiprobe Mission are also presented.

I. Introduction

The Pioneer Venus 1978 Project will consist of two missions: an Orbiter Mission and a Multiprobe Mission. The spacecraft will be constructed by Hughes Aircraft Company, under contract to Ames Research Center, which has Project Management responsibility. The Orbiter Mission will be launched in May 1978 and the Multiprobe Mission in August 1978; both missions will arrive at the planet Venus in early December 1978. The Multiprobe Mission will last on the order of two hours, and the Orbiter Mission will last 243 Earth days, which is one Venusian day.

Reference 1 describes the Multiprobe Mission spacecraft, the science payload of the Multiprobe Mission, and the entry sequence and associated telecommunications aspects of the Multiprobe Mission. Reference 2 describes the preliminary plans of the DSN for the configuration of the Deep Space Stations (DSSs) in support of the multiprobe entry sequence. The majority of this article will concentrate on the frequency allocation, which has been approved for the Pioneer Venus 1978 Mission, the frequency profile of the multiprobe entry and its effect on bandwidth requirements, and an update to the planned DSN configuration at DSSs 14 and 43, which will be supporting the multiprobe entry.

II. Significant Recent Milestones

The Project Approval Document was signed by NASA Headquarters in October 1974. With the passing of that milestone, the key working groups, as far as Project interaction with the DSN is concerned, were able to form in order to start some of the detail work on the Ground Data System and the telecommunications aspect of the mission. There will be four working groups of concern to the DSN established for the Pioneer Venus Project. The first is a Telecommunications Working Group, whose primary purpose is to ensure that the spacecraft is compatible with the Deep Space Network of the Tracking and Data Acquisition System. The first meeting of the Pioneer Venus spacecraft/DSN Telecommunications Working Group was held on January 29, 1975, at the Jet Propulsion Laboratory. A first meeting of the Pioneer Venus Spacecraft/DSN Compatibility Testing Subgroup of the Telecommunications Working Group was held at the Ames Research Center on April 22, 1975. Key characteristics of the Compatibility Test Plan, as they are developing, will be reported in subsequent Progress Report articles.

The second working group is the Pioneer Venus Ground Data System Working Group. The purpose of this group is to determine the requirements of, and to establish the design criteria for, the Pioneer Ground Data System, and to ensure that the Ground Data System Plan is compatible with and within the capabilities of the Deep Space Network portion of the Ground Data System. The first meeting of the Ground Data System Working Group was held on April 16, 1975. This working group has been scoped to consider all aspects of the Pioneer Ground Data System, including Pioneers 6 through 11 and, therefore, will concern itself with existing Ground Data System problems as well as Ground Data System plans between now and the establishment of the Pioneer Venus Ground Data System.

The third working group will be the Mission Operations Working Group, whose purpose will be to develop the Operations Plan, operational sequences, and test and training plans for the Pioneer Venus Mission. It was decided to incorporate the Mission Operations activities into the Ground Data System Working Group for the time being, until the Mission Operations activities increase to the point to warrant a separate working group. It is estimated that the Mission Operations Working Group will be established in early 1976.

The fourth working group will be the Near-Earth Working Group for Pioneer Venus, which will be a Tracking and Data Acquisition responsibility and will be established by the Tracking and Data System Manager for the Pioneer Venus Mission. The purpose of the Near-Earth Working Group will be to coordinate the Near-Earth Network Support for the Pioneer Venus launches.

III. Pioneer Venus Frequency Allocation

The Pioneer Venus 1978 frequency allocation was completed on February 19, 1975. The Project was under considerable time constraints at the time that the frequency allocation was requested; therefore, in order to minimize the time necessary to accomplish the allocation, the allocation was made in regions of the deep space channels where there was clearly no conflict or potential conflict with other missions. Any channel that might have potential interference with another project was rejected in order to save the time necessary to do a proper analysis of the potential interference. For this reason, the Multiprobe Mission was moved to the low end of the deep space channels to avoid a potential conflict with GEOSAT, which is a European satellite that will be operating in the high end of the deep space channels. The GEOSAT problem looked workable because of basic agreements that had been reached between NASA and the European Space Agency; however, the Pioneer Project elected to go with the low end allocation in order to avoid the extensive negotiations that would be necessary with the European Space Agency. The resulting frequency allocations are shown in Table 1.

For the multiprobe, the frequencies were selected to be adjacent because of the Differential Very Long Baseline Interferometry (DVLBI) experiment's requirement to pack all the received frequencies from the multiprobe as close together as possible. Because of this requirement, the probe frequencies that were selected do not correspond to official deep space channels, but this violation of the usual philosophy of selecting specified deep space channels was considered acceptable, since these probes will be active for only two hours during the entire mission. The bus, however, will be active for the cruise phase of the mission; therefore its frequency was selected corresponding to a deep space channel. In the nominal mission, referring to Table 1, the frequencies that will be present during the multiprobe entry phase will be from small probe 1 through small probe 3. The spare small probe frequency will be the only spare transmitter available and would be used in any one of the three small probes in the event of a failure before launch. The bus has a prime frequency, which has been allocated Channel 6, and a flight redundant frequency, which has been allocated Channel 8. The redundant frequency can be switched to in the event of an in-flight failure of the prime transponder.

For the Orbiter Mission, the prime transponder was selected as Channel 12 and the flight redundant as Channel 11. In addition, there is a spare transponder, which was allocated Channel 17. That spare transponder could end up either in the orbiter, the bus, or the large probe in the event of a pre-flight failure. Because of the DVLBI requirement, it is most likely if the large probe transponder fails before launch that one of the bus channels would be put in the large probe and the spare transponder put as the redundant channel for the bus. In that way, it would take a double failure before one of the probe or bus frequencies fell outside of this contiguous set of frequencies, making it unusable for the DVLBI experiment.

Note that there is no uplink to the small probes and no X-band downlink, except from the orbiter and in the spare transponder. The X-band is for radio science purposes only; therefore there will be no X-band telemetry.

IV. Multiprobe Frequency Separation and Total Bandwidth Requirement

The typical doppler profile for the multiprobe entry is shown in Fig. 1. The large, over 80 kHz, doppler pulse at entry corresponds to the time of blackout; therefore this doppler pulse will not have to be tracked by the DSN receivers. However, the DSN will have to reacquire after blackout and the doppler pulse is completed. Notice that the RF signals from the four probes turn on only 22 minutes prior to entry. For the first 5 minutes after RF turn-on, however, there will be no modulation on the downlink, so that a stronger, unmodulated carrier will be available for the initial acquisition. Also note in this and subsequent figures that the probe entries are shown as simultaneous for simplicity; however, their actual time of entry and corresponding time of RF turn-on will be separated by 5 to 10 minutes from probe to probe.

Figure 2 shows the origin of the total bandwidths required for each of the spacecraft involved in the multiprobe entry. For the small and large probes, the large doppler pulse of Fig. 1 is included and results in shift "b"; the pre-entry doppler is shown as shift "a." The small and large probe doppler shifts are shown as the same even though the large probe is in two-way, because it is assumed that the DSN will have acquired the uplink and will be ramping to compensate for the doppler. If the uplink is not acquired, the large probe will be in one-way and the one-way shift would still be correct. Ten times the subcarrier frequency (out to the fifth harmonic) is added to the doppler shift for the small probes, large probe, and bus, shown as item "c." The subcarriers for the small probes are 4 kHz; for the large probe, 8 kHz; and for the bus, 32.7 kHz. Notice that no doppler shift is shown for the bus, because the bus will have been retarded in flight prior to the entry phase so that all probes will have completed their entry before the bus hits the atmosphere of Venus.

Frequency uncertainty, "d," is added to allow for uncertainty in the transmitted frequency from the probes. This uncertainty is 10 kHz for the small probes because of their very stable oscillators, while it is 30 kHz for the large probe because a conventional auxiliary oscillator is used.

The final amount added to the bandwidth is the doppler uncertainty, "e," for which 5 kHz has been allowed. The result is a total bandwidth of 156 kHz for the small probes and 237 kHz for the large probe, while the bus requires 338 kHz. These bandwidths determined the spacing in the frequency allocation shown in Table 1. These bandwidths are shown together with the doppler profile with the proper frequency spacing in Fig. 3.

The DSN is also required to produce a reference tone on the top and bottom of the total bandwidth of the entry for the sake of calibration purposes for the DVLBI experiment. Therefore, the total bandwidth that has to be captured through a single open-loop receiver for the DVLBI experiment is 1.142 MHz. Recalling the sparing philosophy, described in Section III, Fig. 4 shows the worst-case total bandwidth that might have to be acquired in the event that the prime transponder on the bus failed, and one of the small probe's transmitters failed prior to launch, requiring the use of the spare small probe transmitter. This would expand the total bandwidth, including the DSN-generated tones, to 1.727 MHz.

V. Deep Space Station Configuration for the Multiprobe Entry

Figure 5 shows the currently planned configurations for Deep Space Stations 14 and 43 for the multiprobe entry. This is an update of the corresponding figure in Ref. 2. The configuration has been determined from the strategy of trying to capture the most data in real-time in digital form via closed-loop receivers, while providing a backup pre-carrier detection analog recording via individual open-loop receivers to recover data for those time periods when the closed-loop receivers are not in lock. During the multiprobe entry, a 26-meter antenna will receive telemetry from the bus, although the bus signal will be present through one port of open-loop receiver 4 for the purpose of the DVLBI experiment.

There are five closed-loop receivers, which is one more than the standard 64-meter configuration. The fifth receiver is necessary since the large probe may be in two-way or one-way. Since there are only four Symbol Synchronizer Assemblies (SSAs), the strategy is to switch one of the SSAs after the Subcarrier Demodulator Assembly (SDA) output to whichever receiver has locked up on the large probe (either in two-way or one-way). The configuration shown assumes that sequential decoding will be accomplished in the new Telemetry Processor Assemblies (TPAs), therefore enabling the elimination of the Data Decoder Assemblies. Because there will only be two TPAs at each station and therefore a capability to process only two sequentially decoded streams in real-time, it is planned to provide a recording of the soft decisions out of the SSAs. Determining which streams at each of the two stations are decoded in real-time and which are merely recorded after the SSA will be a Project decision based on the total mission design. This is the reason that the actual connections between the SSAs and the SSA recordings and TPAs are left open. The result is that the DSN will be capable of outputting two different probe streams from each of the two stations in real-time all the way back to the control center at the Ames Research Center if the Project desires.

For the predetection recording, the actual bandwidths determined from the frequency allocation are 300 kHz for the large probe and 200 kHz for each of the three small probes. The actual bandwidth requirement for the DVLBI port of the open-loop receiver is in the range of 1.14 to 1.73 MHz, depending upon whether it is a nominal mission or not. The required rate of the digital recorder for the DVLBI experiment is 6.85 to 10.36 megabits per second. This comes from double sampling the bandwidth required plus 3-bit quantization, which makes the digitization rate six times the required bandwidth at S-band.

For the predetection recordings, the data from each probe are recorded on a separate track of an analog recorder. Recovery of the predetection data will be accomplished by playing back the data from one probe at a time through an up-converter back to S-band into a conventional closed-loop receiver and associated telemetry stream of SDA, SSA, and TPA. The DSN has committed to the Project that the loss in this playback will be only 1 dB plus or minus 0.5 dB compared to the closed-loop receiver's real-time performance.

The interface with the Project for the wind drift measurement using DVLBI is assumed to be the digital recording that is produced in real-time. This issue is still being negotiated with the Project and the experimenter. In addition, the experimenter requires that two or three non-DSN stations be equipped to support the DVLBI experiment. The relative responsibilities of the Project and the NASA Office of Tracking and Data Acquisition in providing the necessary equipment for the non-DSN stations are still being negotiated.

References

1. Miller, R. B., "Pioneer Venus 1978 Mission Support," in *The Deep Space Network Progress Report 42-23*, pp. 37–40, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 15, 1974.
2. Miller, R. B., "Pioneer Venus 1978 Mission Support," in *The Deep Space Network Progress Report 42-20*, pp. 17–19, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1974.

Table 1. Pioneer Venus 1978 Frequency Allocations

Spacecraft or radio unit	Deep space channel	Uplink S-band, MHz	Downlink S-band, MHz	Downlink X-band, MHz
Multiprobe				
Spare small probe	N/A	None	2291.394837	None
Small probe 1	N/A	None	2291.550797	None
Large probe	N/A	2110.317247	2291.747237	None
Bus prime	6a,b	2110.584105	2292.037037	None
Small probe 2	N/A	None	2292.281357	None
Small probe 3	N/A	None	2292.437317	None
Bus redundant	8a,b	2111.266204	2292.777778	None
Orbiter				
Redundant	11a,b,c	2112.289352	2293.888889	8410.925927
Prime	12a,b,c	2112.630401	2294.259259	8412.283950
Spare transponder	17a,b,c	2114.335648	2296.111111	8419.074073

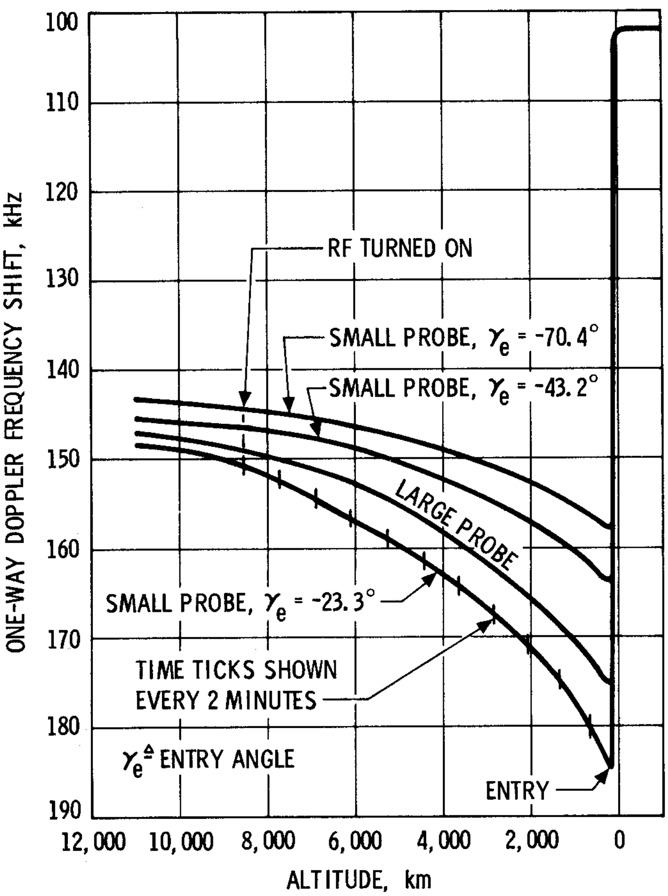

Fig. 1. Pioneer Venus 1978 representative doppler profiles for multiprobe entry

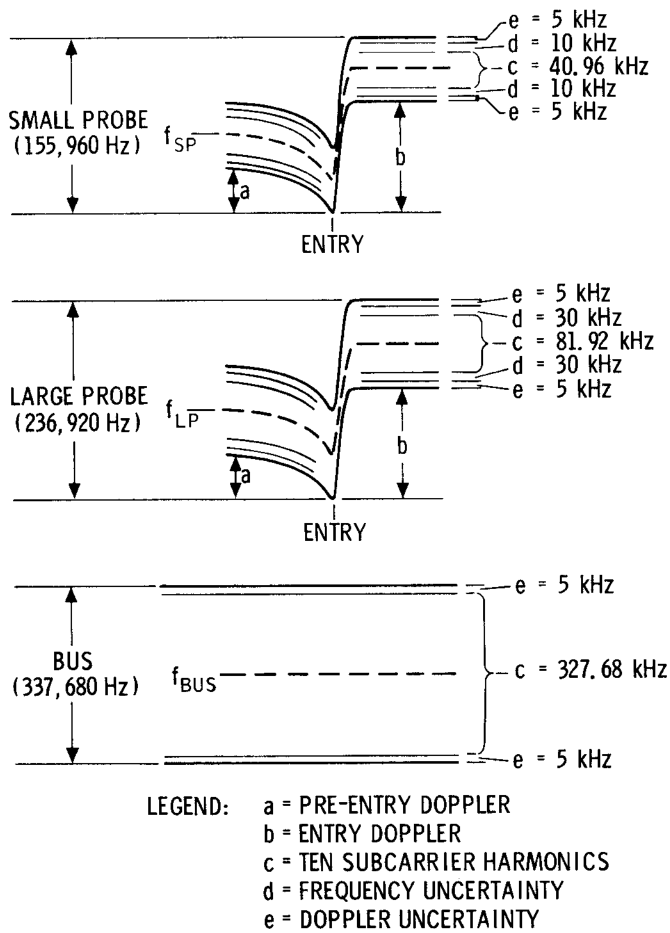

Fig. 2. Pioneer Venus 1978 multiprobe frequency bandwidths required

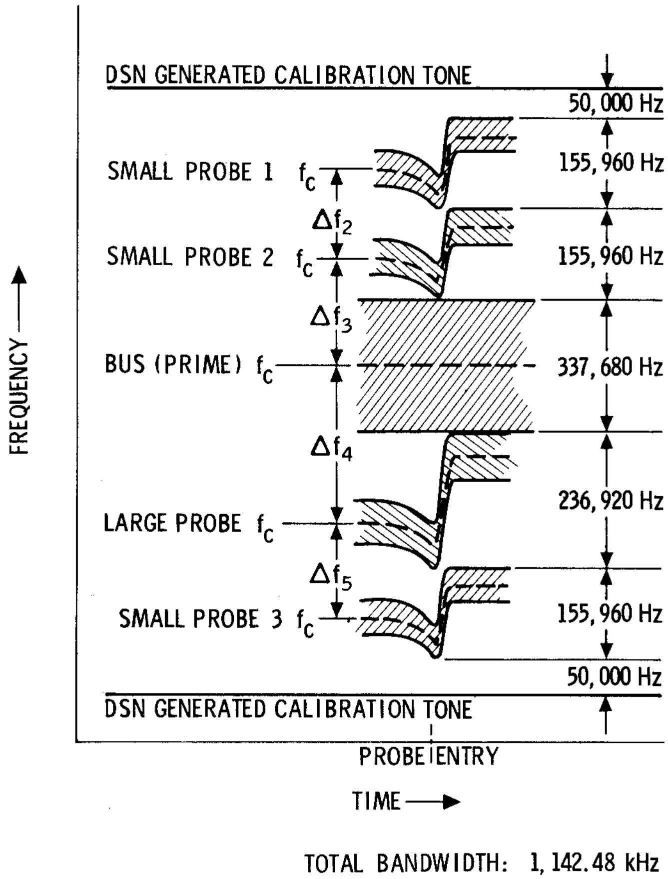

Fig. 3. Pioneer Venus 1978 nominal multiprobe frequency separation and doppler profile

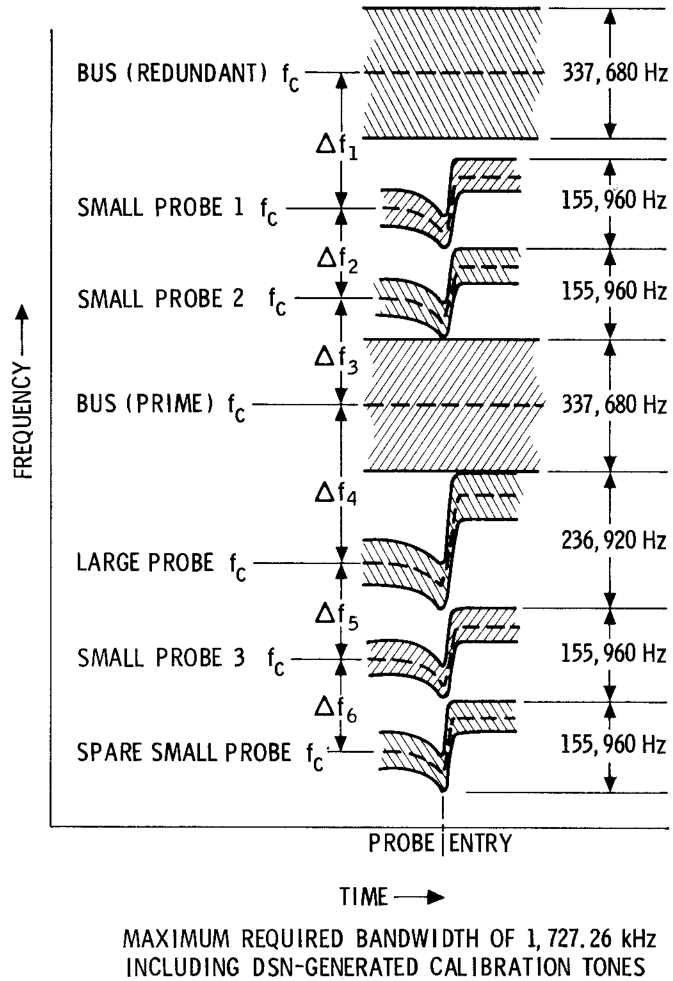

Fig. 4. Pioneer Venus 1978 maximum multiprobe frequency separation and doppler profile

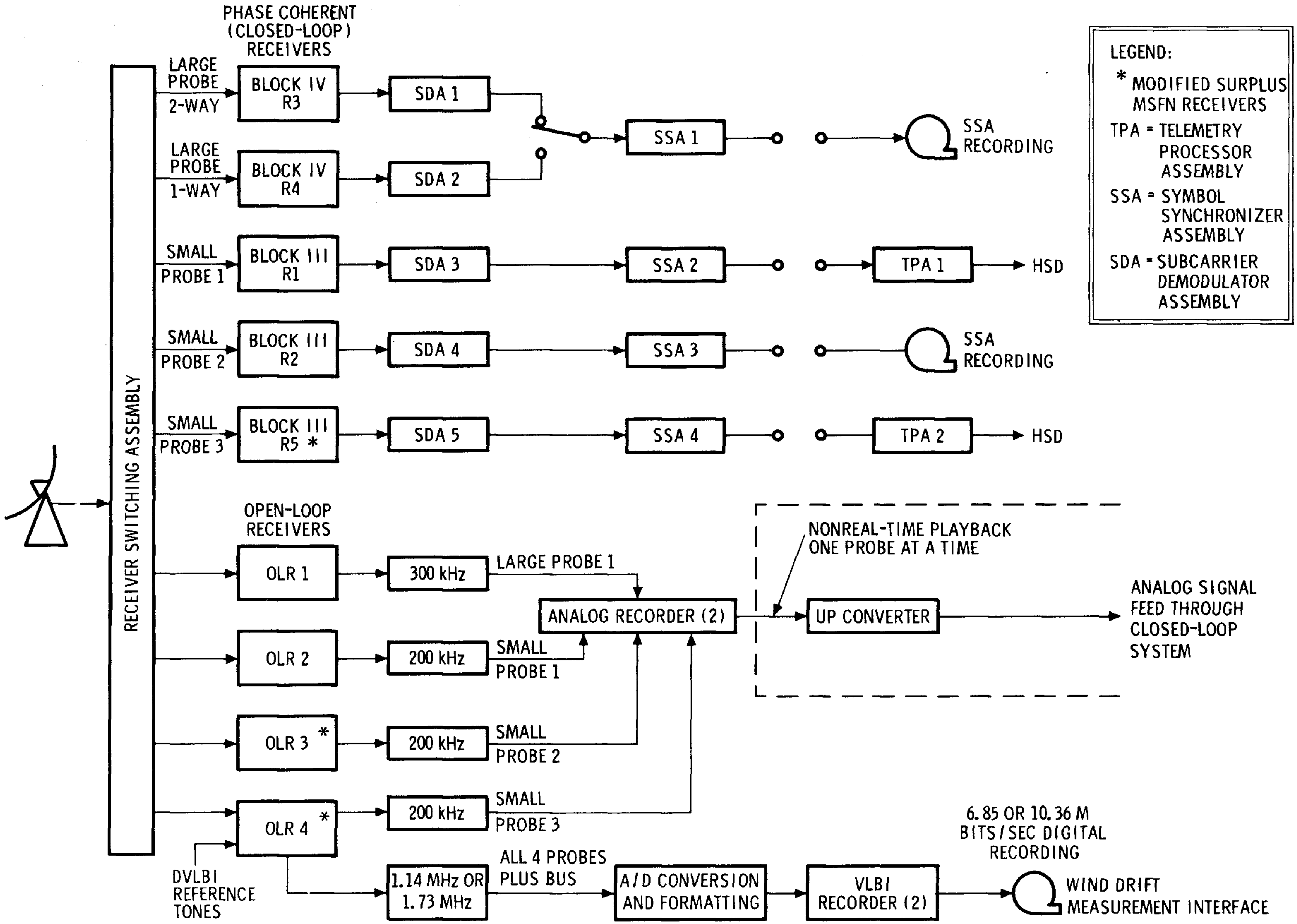

Fig. 5. Configuration for telemetry data recovery and interferometry experiment for Pioneer Venus 1978 multiprobe entry