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Final Mariner II Tracking System Data Analysis Report

W. D. Chaney

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ABSTRACT

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The analysis of the Deep Space Instrumentation Facility spacecraft tracking performance during *Mariner II* is summarized. Included are: (1) the ground system configurations, and (2) a summary of tracking histories and tracking performances during scheduled premidcourse, midcourse and postmidcourse view periods. Tracking data used to determine the spacecraft orbit are also summarized.

I. INTRODUCTION

The purpose of this Report is to summarize the analysis of the Deep Space Instrumentation Facility (DSIF) tracking performance during the *Mariner II* mission. It supersedes all previous tracking data analysis reports for this mission.

A. History of Mission

The *Mariner II* spacecraft, using the *Atlas D–Agena B* boosters, was launched from the Atlantic Missile Range (AMR) on 27 August 1962 at 06 hr, 53 min, 14 sec (065314) Greenwich Mean Time (GMT). Injection of the *Agena B–Mariner II* occurred over the South Atlantic Ocean at −14.8 deg latitude and 357.9 deg longitude at 071919 GMT. The first DSIF to acquire was DSIF-1 at 072137 GMT. DSIF-5 acquired at 072200 GMT and -4 acquired at 074900 GMT. The DSIF tracked the spacecraft continuously during scheduled tracking from injection +2.6 min until Venus encounter +20 days.

Earth acquisition command was programmed to occur at 053007 GMT, 3 September 1962; it actually occurred at 052917. The seventh orbit computation agreed with previous computations indicating a Venus dark side pass with a miss distance of 376,000 km and a flight time of 108.576 days; therefore, a midcourse maneuver was required for the desired Venus Sun side pass and a miss of 20,000 km with a flight time of 109.456 days.

The maneuver was initiated at 224900 GMT, 4 September and completed at 024525, 5 September, with the spacecraft 2,407,740 km from Earth. Postmidcourse computation indicated that a miss distance of approximately 41,000 km and a flight time of 109.546 days had been achieved by the midcourse maneuver.

Two-way doppler data were taken from 084432 GMT, 27 August until 30 December 1962, as requested by DSIF net control. Angular data were taken in an automatic tracking mode by DSIF-4 and -5 until the end of pass 4. The following primary data points (two-way doppler and angles of DSIF-4 and -5, pass 1) used in the orbit determination program (ODP) are presented in Table 1. A summary of significant events is contained in Table 2.

Table 1. Primary data used in orbit determination computation

DSIF station	Data type	Number of data points	
		Premidcourse	Postmidcourse
2	Cc-3	2539	14515
3	C-2	0	70
4	C-2	730	0
	HA	308	0
	Dec	308	0
5	C-2	1920	1600
	HA	476	0
	Dec	476	0

B. System Configuration

The detailed characteristics of the DSIF stations and the spacecraft are given in the Space Flight Operations Plan and the Tracking Information Memorandum dated 18 and 15 June 1962, respectively.

1. Ground Station Modes

The four modes of operation of the DSIF are identified as ground modes (GM) and the four doppler modes are identified as C or Cc modes and are defined as follows:

GM-1 Tracking the 960.05 Mc transponder signal in the two-way mode and obtaining angles, two-way doppler, and spacecraft telemetry. This mode is possible at DSIF-1, -4 and -5.

GM-2 Listening to the 960.05 Mc transponder signal in the two-way mode and two-way doppler and spacecraft telemetry. This mode is possible at DSIF-5 (with a 10 kw diplexer) or with the combination DSIF-2 and -3.

GM-3 Tracking the 960.05 Mc transponder signal in the one-way mode and obtaining angles, one-way doppler and spacecraft telemetry.

GM-4 Listening for the 960.05 Mc transponder signal in the one-way mode and obtaining one-way doppler and spacecraft telemetry.

GM-3 and -4 are possible at all DSIF stations.

Table 2. History of significant events

GMT	Date	Event
065314	27 Aug 1962	Liftoff from Complex 12 AMR
071919	27	Injection
073700	27	Solar panels extended
075300	27	Sun acquisition
161300	29	Science on
052917	3 Sept 1962	Earth acquisition
2249	4	Midcourse maneuver initiated
024525	5	Midcourse maneuver completion
1250	8	Gyros on; science off
202532	31 Oct 1962	Science off, solar panel shorted
212834	8 Nov 1962	Science on, solar panel normal
1222	15	Solar panel shorted
2320	9 Dec 1962	Four telemetry channels out
0521	12	Last CC & S cyclic pulse
1335	14	Encounter mode start
2040	14	Encounter mode end
0510	28	Perihelion reached
0521	3 Jan 1963	Last real-time telemetry received
0700	3	Last RF signal received

Cc-3 Two-way two-station coherent doppler (DSIF-2 only).

C-3 Two-way two-station noncoherent doppler (all stations).

C-2 Two-way one-station coherent doppler (DSIF-1, -3, -4, -5).

C-1 One-way one-station doppler (all stations).

Coherent doppler uses the transmitter station reference frequency as a reference frequency in the receiver of the receiving station.

2. Spacecraft Modes

The spacecraft modes are defined according to flight periods and are identified according to the telemetry system mode for that portion of the mission. Changes in the telemetry system mode are accomplished by the central computer and sequencer (CC & S) in the spacecraft, or in the event of a mode change malfunction, by command from the DSIF.

Mode I (Launch to Earth acquisition) – nominal duration of 167 hr. Identified by engineering telemetry transmission of 33 bits/sec data rate.

Mode II (Cruise mode) – nominal duration of Earth acquisition to encounter minus 10 hr. Identified by multiplexed transmission of telemetric engineering and scientific data at the 8 bits/sec data rate.

Mode III (Planetary encounter) – nominal duration of 67.5 hr. Identified by only science data being transmitted at 8 bits/sec data rate. After the encounter phase, the spacecraft was returned to Mode II.

3. Command Functions

A brief explanation of command functions is contained in Table 3.

C. Data Evaluation Techniques

The ODP determines a spacecraft orbit by converging on the set of initial conditions at the injection epoch, which causes the weighted sum of the squares of the differences between the actual observed values and the computed observed values to be minimized. The computational method is a modified weighted least-squares method. By this method, independent data weighting values are determined from the measured effective variances. Whereas, in the usual least-squares method, the data points are weighted independently and inversely proportional to their measured variances. When determining the effective variance for each data type at each station, consideration is given to the correlation width of all recognized noise sources, the sampling rates, counting times, elevation angles, and range to the spacecraft. Prior to being put on the ODP input tape, incoming data go through a tracking data editing program which rejects gross blunder points, points that are outside of the antenna mechanical constraints, and points with bad teletypewriter format. No attempt is made to unscramble or

Table 3. Command functions

Command		Function
RTC-1	Roll override.	Used when Earth acquisition is lost. Earth sensors are switched out and spacecraft rolls until Earth sensor detects an illuminated object.
RTC-2	Clockwise hinge override.	Changes hinge angle of Earth oriented high gain antenna. Each command causes hinge angle to change 2 deg.
RTC-3	Counter clockwise hinge override.	Same as RTC-2, except hinge angle is changed in opposite direction.
RTC-4	L-band to omniantenna.	Switches transponder output from high gain, Earth oriented antenna to omniantenna.
RTC-5	L-band to high gain antenna.	Switches transponder output to Earth oriented high gain antenna.
RTC-6	Initiate midcourse maneuver.	Initiates midcourse maneuver sequence. Spacecraft attitude control is switched to gyro control; spacecraft turns are initiated according to stored command values. Midcourse motor burn is initiated. After completion of motor burn, spacecraft is reoriented and solar and Earth acquisition procedures are initiated.
RTC-7	Command encounter mode.	Turns planet science "on". Engineering telemetry is switched out and radiometer scan begins.
RTC-8	Command planet science off.	Returns spacecraft to cruise mode. Radiometer is turned off, engineering telemetry is switched into telemetry system. This command countermands RTC-10.
RTC-9	Command sun acquisition.	Unlatches solar panels and removes solar acquisition inhibit.
RTC-10	Command cruise science off.	Switches science telemetry off. Only engineering telemetry is transmitted.
RTC-11	Spare.	
RTC-12	Command Earth acquisition.	Removes Earth acquisition inhibit; spacecraft starts a roll search. When spacecraft Earth sensor acquires and nulls on an object, telemetry data rate is automatically switched to 8.3 bits/sec.
SC-1	Midcourse roll duration.	Contains time duration of the midcourse roll maneuver.
SC-2	Midcourse pitch duration.	Contains time duration of midcourse pitch maneuver.
SC-3	Midcourse velocity increment.	Contains velocity incremental change required for midcourse motor burn.

correct bad format points. Hence, by sacrificing the utilization of the maximum number of data points there is a reduction in the sensitivity to blunder points and possible error points that might otherwise have a significant effect on the orbit. The current policy for weighting data is to assign an initial weight for each data type based on the sample rate, count time, and expected data quality. These weights may be changed (on option) when the sample rate and count time changes or when the residuals indicate periods of extremely good or relatively poor tracking data.

Data evaluation techniques, consistent with the ODP computational methods, have been developed with the goal of isolating and removing systematic errors and determining the characteristics of tracking data noise statistics, i.e., the RMS and mean values of the residuals (observed minus computed).

In the inflight phase, station reports are analyzed to detect unusual occurrences. Also, transmitter VCO drift statistics are compiled, frequency changes are noted and brought to the attention of the ODP group, and changes in transmitter assignment are evaluated. After the orbit is reasonably well known, observed values are checked against predicted values to determine validity of the tracking data and to detect blunder points before they influence the orbit. Once the ODP listings are available, the residuals and rejected points are analyzed to detect systematic error sources. The Test Director is informed of all unusual occurrences, and if applicable, corrective action is recommended.

The postflight evaluation phase consists of analyzing all available data pertaining to the DSIF tracking performance. Complete analysis of all residuals, by data type, is made to detect equipment biases, periodic noise which might be attributed to station equipment, and any other systematic errors. The validity of the noise model is checked by least-square fitting of the tracking data. All observations are evaluated and compared with preflight calibrations and past performance. All indications of equipment problems and nonstandard occurrences are investigated and recommendations made to the appropriate agencies. New data analysis techniques are investigated and implemented if applicable.

II. HISTORY OF DSIF TRACKING

A. General

The DSIF tracked the spacecraft 24 hr/day during the entire mission. The DSIF tracking net consisted of tracking stations at Goldstone, California; Johannesburg, South Africa; and Woomera, Australia. Each station received and recorded telemetry and tracking data. The telemetry was transmitted to the Jet Propulsion Laboratory's (JPL) Operations Center (Pasadena) in near real time throughout the mission. The tracking data were transmitted to Pasadena in near real time during the launch, midcourse, and encounter periods and also 1 day/wk when precision tracking data were obtained. During the remainder of the period, tracking data were forwarded in nonreal time. Tracking summaries were supplied to the JPL Operations Center, Pasadena, daily and weekly so that tracking and station conditions could be included in the data analysis.

B. Launch Phase (Launch to Midcourse)

Liftoff occurred at 065319, 27 August. At that time DSIF-0 was in lock and maintained lock until 070056. The received signal level varied between −80 and −125 dbm. After DSIF-0 lost lock, the various AMR stations tracked the launch vehicle and spacecraft, and at 072137 DSIF-1 acquired the spacecraft in one-way lock. Three minutes later DSIF-5 also acquired the spacecraft in one-way lock.

After this initial acquisition, DSIF-1 achieved two-way lock at 073020. The DSIF-1 transmitter was turned off at 074800, since DSIF-5 was having difficulty maintaining pseudo two-way lock. DSIF-5 turned its 200 w transmitter on at 081200. DSIF-5 attempted to obtain two-way lock until 083900 when it was instructed to turn its transmitter off. While DSIF-5 attempted to acquire two-way lock, both DSIF-1 and -4 tracked the spacecraft with intermittent loss of lock. DSIF-4 acquired the spacecraft at 073700 in one-way lock with a received signal level of −110 dbm. At 084432, DSIF-4 acquired two-way lock with radiated power of 58 w. After this, there were few problems in obtaining two-way lock.

RTC-8 was transmitted by DSIF-5 at 161300, 29 August and verified at 161357. This command changed the telemetry to the cruise mode, and reduced the telemetry transmission bit rate from 33⅓ to 8⅓ bits/sec. This was a deviation from the test plan in that the mode change was to have been effected by a command from within the spacecraft.

The DSIF continued to track the spacecraft 24 hr/day. DSIF tracking from launch to midcourse is presented in Table 4.

C. Midcourse Phase (Midcourse Only)

The midcourse maneuver command sequence was performed completely from the Goldstone Station; DSIF-2 functioned as the receiving station and -3 as the transmitting station. DSIF-3 locked up the command loop at 210100. The received signal level at that time was −129 dbm. Commands were transmitted as follows:

Command	Initiated	Transmitted	Verified
SC-1	213000	213032	213057
SC-2	213200	213231	Inhibited[1]
SC-2	213500	213530	213557
SC-3	213700	213728	Inhibited[1]
SC-3	222300	222328	222356
RTC-4	223900	223931	223958
RTC-6	224900	224929	224957

[1] When SC-7 was inhibited, the cause was assumed to be a momentary loss of sync between the read, write, verify (RWV) modulator and detector. When SC-3 was inhibited, a thorough investigation showed the temperature in the modulator compartment of the RWV system to be much lower than normal. The compartment was left open, allowing the temperature to rise, and the system functioned normally throughout the remainder of the command sequence.

The received signal level at DSIF-2 was −129 dbm before the spacecraft started the midcourse maneuver. During the maneuver the received signal level dropped as low as −162 dbm. DSIF-2 had several momentary out-of-lock periods during this time. When the maneuver was completed the received signal level returned to −130 dbm at 023445.

DSIF-4 acquired at 013023. The received signal level at that time was −152 dbm. DSIF-4 was in and out of lock until 023427, when the received signal level increased to −130 dbm. Good data were obtained throughout the remainder of the tracking period.

D. Cruise Phase (Midcourse to Encounter)

The DSIF was originally committed to provide 24 hr/day coverage from launch through L plus ten days, 10 hr/day during the cruise phase, and 24 hr/day coverage through 9 September, and then reduce its coverage to approximately 12 hr/day. On 16 September the DSIF returned to the 24 hr/day schedule and remained on that schedule until the encounter phase was completed. DSIF coverage during the cruise phase is shown in Table 5.

E. Encounter Phase (Encounter Only)

The Venus encounter was programmed to take place during the Goldstone view period. Telemetry, obtained prior to the encounter date, indicated that it would be necessary to transmit RTC-7, commanding the spacecraft to the encounter mode. DSIF-2 acquired the spacecraft signal in one-way lock at 1216. Two-way lock was obtained at 1224. DSIF-3 turned command modulation on at 1242 and obtained command loop lock and vehicle sync at 1256. RTC-7 was initiated at 133500 and verified at 133557. At 1346 DSIF-2 confirmed that the spacecraft was in Mode III. DSIF-3 turned the command modulation off at 1351. DSIF-3 turned command modulation on at 2020. RTC-8, the command to end the encounter mode and return to cruise mode, was initiated at 203200 and verified at 203257. Command modulation was turned off at 2043. DSIF-3 turned the transmitter off at 2210. DSIF-4 acquired the spacecraft signal at 1810; therefore, there were two DSIF stations receiving the spacecraft telemetry during the planet scan. Both DSIF-2 and -3 were secured at 2211.

DSIF-3 radiated 10 kw throughout the encounter phase. The received signal level at DSIF-2 was approximately −150.5 dbm throughout the period.

Table 4. Summary of DSIF operations, launch to midcourse

DSIF station	Pass No.	Day of year	GMT Acquisition	GMT Loss	Max recd sig, dbm	Remarks
1	1	239	072137	210846	−100	Two-way lock at 073038. DSIF-1 had trouble maintaining two-way lock. Also trouble in data system resulted in approximately 2 hr of data being lost.
5			073145	210435	−82	Initial attempts to obtain two-way lock unsuccessful. Two-way lock acquired at 1002.
4			073730	131800	−110	Two-way lock at 084443. Receiver in and out of lock between 081400 and 084400 while DSIF-5 was attempting two-way lock.
2			193405	033120	−122	Variations of 12 db in received signal were noted: caused by MASER and paramp drift. Two-way lock at 2012.
3			201215	033120	——	Transmitter power (7kw).
4	2	240	014800	135200	−128	Two-way lock at 030113.
5			093548	211035	−132.5	There was no telemetry sent by TTY until 112700 because of telemetry demodulator difficulties.
2			193730	060900	−132	The MASER was bypassed for this tracking period. Two-way lock at 202623.
3			200035	060900	——	
4	3	241	015110	135800	−134.5	Two-way lock at 061000.
5			093434	21064	−126	Two-way lock from 115100 to 201800. RTC-8 transmitted at 161300.
2			194100	062545	−138.2	Two-way lock at 200149.
3			200149	05488	——	
4	4	242	015130	135700	−138	Two-way lock at 055300.
5			094020	210220	−142	Two-way lock at 132050.
2			193200	062748	−137	Two-way lock at 210545. MASER back in operation.
3			200500	062700	——	
4	5	243	014600	135306	−140	DSIF-4 had a 50-w transmitter which was not used after day 242.
5			093205	210101	−140.5	Two-way lock at 093315. During this period transmitter power was decreased from 400 to 20w to determine transponder threshold.
2			192815	062140	−138	Two-way lock at 193025.
3			192000	062000	——	
4	6	244	015300	135000	−142.5	
5			093000	205635	−142	Listening feed installed before this track.
2			192300	062021	−142	Considerable variation in received signal level because of MASER and paramp gain variation.
3			192500	062000	——	
4	7	245	014400	134100	−144	
5			115815	195600	——	Noise problem in transmitter prevented attempt for two-way lock.
2			192030	061600	−128	Received signal level was −145 dbm before Earth acquisition. Two-way lock at 192030.
3			192000	061500	——	
4	8	246	014100	133800	−124	Received signal level decreased to −161 dbm and receiver dropped lock before Earth acquisition.
5			134500	205134	−125	
2			191550	061400	——	Two-way lock at 192700.
3			192700	061500	——	
4	9	247	014000	134200	−125	
5			091562	204740	——	Two-way lock at 091827.
2			190900	060029	−129	Signal level decreased to −156 dbm during midcourse maneuver.
3			190900	060000	——	Transmitted commands for midcourse maneuver.

Table 5. Summary of DSIF operations, midcourse to encounter

DSIF station	Pass No.	Day of year	GMT		Max recd sig, dbm	Remarks
			Acquisition	Loss		
4	10	248	0130	1331	−125	
5	↓	↓	0919	2043	−126	Two-way 0956–1850
2	↓	↓	1904	0600	−127	Two-way at 1915
3	↓	↓	1915	0600	—	
4	11	249	0140	1334	−128	
5	↓	↓	0907	1914	−125.5	Two-way 0922–1850
2	↓	↓	1900	0610	−127	Two-way at 1940
3	↓	↓	—	—	—	
4	12	250	0120	1331	−127.5	
5	↓	↓	0900	2036	−126.5	Two-way 0936–1850
2	↓	↓	1857	0605	−128.5	Two-way at 1859
3	↓	↓	1859	0600	—	
4	13	251	0115	1327	−126	
5	↓	↓	0902	1950	−127.5	Two-way 0928–1845
2	↓	↓	1853	0601	−130	Two-way at 1853
3	↓	↓	1853	0600	—	
4	14	252	0352	1000	−128	
5	↓	↓	0854	2028	−128.5	One-way only
2	↓	↓	1848	0555	−126.5	One-way only
3	↓	↓	—	—	—	Not scheduled
4	15	253	—	—	—	Not scheduled
5	↓	↓	0850	2020	−129.5	One-way only
2	↓	↓	1839	0548	−131	One-way only
3	↓	↓	—	—	—	Not scheduled
4	16	254	0104	1315	−130	
5	↓	↓	—	—	—	Not scheduled
2	↓	↓	—	—	—	Not scheduled
3	↓	↓	—	—	—	Not scheduled
4	17	255	—	—	—	Not scheduled
5	↓	↓	0901	2013	−132	One-way
2	↓	↓	—	—	—	Not scheduled
3	↓	↓	—	—	—	Not scheduled
4	18	256	0055	1305	−132.5	
5	↓	↓	—	—	—	Not scheduled
2	↓	↓	1831	0540	−133	One-way
3	↓	↓	—	—	—	Not scheduled
4	19	257	—	—	—	Not scheduled
5	↓	↓	0848	2006	−131.5	
2	↓	↓	1828	0527	−132	Two-way at 1838
3	↓	↓	1837	0520	—	
4	20	258	0055	0900	−131	
5	↓	↓	0829	2001	−132.5	
2	↓	↓	—	—	—	Not scheduled
3	↓	↓	—	—	—	Not scheduled
4	21	259	0042	1252	−131.5	
5	↓	↓	—	—	—	Not scheduled
2	↓	↓	1820	0315	−132	One-way
3	↓	↓	—	—	—	Not scheduled

Table 5. (Cont'd)

DSIF station	Pass No.	Day of year	GMT Acquisition	GMT Loss	Max recd sig, dbm	Remarks
4	22	260	0238	1100	−131.5	
5	↓	↓	1030	1915	−132	
2			1830	0400	−132	One-way
3			—	—	—	Not scheduled
4	23	261	0320	1230	−131.5	
5	↓	↓	1145	1900	−132	
2			1830	0300	−132.5	One-way
3			—	—	—	Not scheduled
4	24	262	0226	1100	−134	
5	↓	↓	1033	1900	−132.5	
2			1830	0300	−132.5	One-way
3			—	—	—	Not scheduled
4	25	263	0213	1100	−134.5	
5	↓	↓	1030	1845	−133.5	
2			1815	0245	−134	One-way
3			—	—	—	Not scheduled
4	26	264	0211	1045	−134.7	
5	↓	↓	1008	1846	−133	
2			1815	0245	−130	One-way
4	27	265	0205	1045	−133.8	
5	↓	↓	1015	1845	−134	
2			1808	0445	−135	Two-way at 1808
3			1758	0445	—	
4	28	266	0208	1045	−134	
5	↓	↓	1012	1857	−133.5	
2			1747	0433	−135	Two-way at 1757
3			1752	0430	—	
4	29	267	0145	1030	−135	
5	↓	↓	0931	1830	−134	
2			1800	0230	−134	One-way
4	30	268	0157	1030	−135	
5	↓	↓	0945	1830	−134	
2			1740	0300	−137	One-way
4	31	269	0154	1030	−135.4	
5	↓	↓	1002	1830	−134.5	
2			1738	0435	−135.5	One-way
4	32	270	0152	1030	−136	
5	↓	↓	0946	1815	−135	
2			1729	0300	−135.5	One-way
4	33	271	0146	1015	−136.3	
5	↓	↓	0945	1815	−135	
2			1807	0245	−134.5	
4	34	272	0139	1015	−135.7	
5	↓	↓	0944	1845	−135.1	
2			1719	0401	−136.3	Two-way at 1719
3			1704	0400	—	
4	35		2351	1000	−137.4	
5	↓	273	0928	1800	−136.1	
2		↓	1724	0230	−136.5	One-way

Table 5. (Cont'd)

DSIF station	Pass No.	Day of year	GMT		Max recd sig, dbm	Remarks
			Acquisition	Loss		
4	36	274	0125	1100	−137.9	
5	↓	↓	0930	1800	−136.3	
2	↓	↓	1708	0230	−136.2	One-way
4	37	275	0115	0945	−137.8	
5	↓	↓	0907	1745	−136.4	
2	↓	↓	1704	0215	−136.5	One-way
4	38	276	0111	0945	−136.5	
5	↓	↓	0906	1745	−136	
2	↓	↓	1658	0215	−137.5	One-way
4	39	277	0115	0945	−138	
5	↓	↓	9099	1730	−136	
2	↓	↓	1713	0200	−137.5	One-way
4	40	278	0100	0930	−138.2	
5	↓	↓	0858	1730	−136.8	
2	↓	↓	1651	0200	−136.4	One-way
4	41	279	0103	0930	−138.1	
5	↓	↓	0862	1730	−137.7	
2	↓	↓	1643	0330	−136.4	One-way
4	42	280	0042	0915	−138.4	
5	↓	↓	0845	1715	−136	
2	↓	↓	1650	0200	−137.5	One-way
4	43	281	0042	0915	−139.1	
5	↓	↓	0826	1700	−137.7	
2	↓	↓	1635	0145	−139	One-way
4	44	282	0026	0900	−139.1	
5	↓	↓	0851	1700	−138.4	
2	↓	↓	1625	0145	−141.5	One-way
4	45	283	0033	0900	—	No signal strength due to AGC trouble
5	↓	↓	0901	1615	−138.3	
2	↓	↓	1628	2315	−139.5	One-way
4	46	↓	2300	0815	−143.4	
5	↓	284	0807	1700	−143	
2	↓	↓	1626	0130	−139.2	One-way
4	47	285	0023	0900	−143.6	
5	↓	↓	0811	1702	−140.1	
2	↓	↓	1617	0130	−139	One-way
4	48	286	0012	0845	−143.4	
5	↓	↓	0819	1615	−139	
2	↓	↓	1606	2312	−139	
4	49	↓	2238	0830	−149.9	
5	↓	287	0809	1715	−139.4	
2	↓	↓	1616	0300	−139.2	Two-way at 1616
3	↓	↓	1530	0250	—	
4	50	↓	2220	0830	−144.6	
5	↓	288	0759	1650	−139.3	
2	↓	↓	1554	0130	−138.5	One-way

Table 5. (Cont'd)

DSIF station	Pass No.	Day of year	GMT		Max recd sig, dbm	Remarks
			Acquisition	Loss		
4	51	289	0028	0832	−139.4	
5	↓	↓	0826	1645	−139.4	
2	↓	↓	1550	0130	−139.5	One-way
4	52	290	0045	0900	−140	
5	↓	↓	0800	1630	−139.3	
2	↓	↓	1603	0117	−141	One-way
4	53	291	0015	0045	−140.5	
5	↓	↓	0812	1530	−142.1	
2	↓	↓	1538	0240	−140.3	One-way
4	54	292	0435	0958	−141	Late acquisition due to *Ranger V* tracking
5	↓	↓	1120	1536	−141	
2	↓	↓	1633	0234	−140	One-way
4	55	293	0346	0952	−141.1	Late acquisition due to *Ranger V* tracking
5	↓	↓	1109	1703	−141.1	
2	↓	↓	1607	0233	−141	One-way
4	56	294	0346	0048	−138.2	Late acquisition due to *Ranger V* tracking
5	↓	↓	1102	1659	−141	
2	↓	↓	2054	0226	−142.5	One-way
4	57	295	0342	0941	−140.8	Late acquisition due to *Ranger V* tracking
5	↓	↓	0826	1654	−143.1	
2	↓	↓	1526	0100	−142.5	One-way
4	58	↓	2359	0830	−139	
5	↓	296	0800	1630	−141.5	
2	↓	↓	1521	0100	−141.9	One-way
4	59	↓	2338	0815	−137.6	
5	↓	297	0745	1642	−141.7	
2	↓	↓	1431	0150	−141.5	Two-way at 1438
3	↓	↓	1438	0150	——	
4	60	↓	2242	0811	−142.1	
5	↓	298	0653	1600	−142.5	
2	↓	↓	1459	0027	−141	One-way
4	61	↓	2321	0745	——	No signal level recorded due to paramp trouble
5	↓	299	0649	1545	——	No AGC calibration
2	↓	↓	1456	0015	−142	One-way
4	62	↓	2316	0745	−145.6	
5	↓	300	0649	1615	−142	
2	↓	↓	1452	0132	−142.5	Two-way at 1537
3	↓	↓	1452	0132	——	
4	63	↓	2225	0730	−146.8	
5	↓	301	0622	1530	−143.9	
2	↓	↓	1447	2310	−142.1	One-way
4	64	↓	2245	0730	−145.9	
5	↓	302	0627	1530	−142	
2	↓	↓	1441	2351	−142.4	One-way
4	65	↓	2257	0730	−145.6	
5	↓	303	0630	1530	−142.2	
2	↓	↓	1435	0000	−143.8	One-way

Table 5. (Cont'd)

DSIF station	Pass No.	Day of year	GMT		Max recd sig, dbm	Remarks
			Acquisition	Loss		
4	66	303	2259	0730	−146.7	
5		304	0620	1530	−144.5	Horn feed installed after this tracking period
2			1447	2345	−145	Two-way 2000 to 2042
3			1957	2042	—	RTC-10 was initiated at 202530 and verified at 202627
4	67		2230	0715	−147.1	
5		305	0620	1515	−142.4	
2			1434	2345	−143	One-way
4	68		2241	0654	−147.1	
5		306	0619	1515	−142.4	
2			1423	0113	−146	One-way
4	69	307	0026	0715	−147.4	
5			0610	1515	−143.6	
2			1417	0108	−143.5	One-way
4	70	308	0112	0700	−144.4	
5			0607	1500	−143.4	
2			1412	2330	−143.5	One-way
4	71		2145	0700	−145.5	
5		309	0604	1530	−143	
2			1407	0032	−143.5	Two-way at 1407
3			0030	1355	—	
4	72		2115	0732	−144.2	
5		310	0539	1445	−144.7	
2			1403	2315	−144	One-way
4	73		2159	0645	−144.9	
5		311	0539	1445	−144	
2			1358	2300	−144.5	One-way
4	74		2136	0630	−145.4	
5		312	0522	1430	−143.2	
2			1354	2300	−144.7	Two-way 2046–2232
3			2045	2232	—	RTC-8 was initiated at 212500 and verified at 212600
4	75		2142	0630	−145.1	
5		313	0590	1520	−143.7	
2			1350	2208	−144	One-way
4	76		2117	0630	−147.3	
5		314	0528	1530	−144	
2			1345	0032	−145.5	Two-way at 1345
3			1343	0035	—	
4	77		2024	0615	−146.8	
5		315	0514	1415	−143.4	
2			1340	2245	−146	One-way
4	78		2122	0600	−145.6	
5		316	0510	1415	−145.3	
2			1336	2330	−145.5	One-way
4	79		2105	0600	−146.8	
5		317	0459	1400	−145	
2			1333	2230	−145	One-way
4	80		2106	0600	−146.7	

Table 5. (Cont'd)

DSIF station	Pass No.	Day of year	GMT		Max recd sig, dbm	Remarks
			Acquisition	Loss		
5	80	318	0502	1400	−146	
2	↓		1328	2230	−145	One-way
4	81	↓	2115	0600	−147.2	
5		319	0454	1400	−145.2	
2	↓		1324	2230	−145.5	One-way
4	82	↓	2119	0659	−146	
5		320	0548	1400	−147.1	
2	↓		1322	2155	−146	One-way
4	83	↓	2116	0600	−146.2	
5		321	0500	1440	−146	
2			1320	2358	−146	Two-way at 1320
3	↓		1313	2400	—	
4	84	↓	2101	0545	−148.2	
5		322	0452	1345	−146.6	
2	↓		1314	2215	−146	One-way
4	85	↓	2056	0546	−146.9	
5		323	0451	1345	−147.1	
2	↓		1315	2215	−146	One-way
4	86	↓	2114	0545	−148.8	
5		324	0446	1345	−146.4	
2	↓		1313	2200	−146.5	One-way
4	87	↓	2043	0530	−148.7	
5		325	0436	1330	−146.7	
2	↓		1305	2200	−146	One-way
4	88	↓	2037	0656	−148.7	
5		326	0444	1400	−148.3	Very little telemetry by TTY due to demodulator trouble
2	↓		1257	2200	−146.5	One-way
4	89	↓	2044	0530	−149.1	
5		327	0434	1330	−148.2	
2	↓		1257	2145	−146.5	One-way
4	90	↓	2030	0515	−148.7	
5		328	0415	1315	−149	
2	↓		1256	2145	−146.5	One-way
4	91	↓	2027	0515	−149.2	
5		329	0401	1315	−149.3	
2	↓		1254	2145	−147.5	One-way
4	92	↓	2016	0515	−148.2	
5		330	0417	1400	−148.6	
2			1246	2311	−147.5	Two-way at 1313
3	↓		1313	2315	—	
4	93	↓	2031	0515	−148.8	
5		331	0409	1315	−148.8	
2	↓		1245	2145	−147.5	One-way
4	94	↓	2013	0515	−149.3	
5		332	0402	1315	−149	
2			—	—	—	Station not scheduled
3	↓	↓	1257	2145	−148	Functional as "receive only" station

Table 5. (Cont'd)

DSIF station	Pass No.	Day of year	GMT Acquisition	GMT Loss	Max recd sig, dbm	Remarks
4	95	332	2039	0615	−150	
5	↓	333	0549	1315	−151.9	Paramp trouble during most of this period
2	↓	↓	—	—	—	Not scheduled
3	↓	↓	1212	2146	−148.4	Receive only
4	96	↓	2027	0515	−148.4	
5	↓	334	0411	1315	−148.5	
2	↓	↓	—	—	—	Not scheduled
3	↓	↓	1208	2140	−148.3	
4	97	↓	2039	0515	−150.6	
5	↓	335	0421	1345	−150.5	
2	↓	↓	1235	2055	−147.8	Two-way at 1235
3	↓	↓	1225	2145	—	Transmitter only
4	98	↓	2015	0643	−150.5	
5	↓	336	0527	1300	−148.7	
2	↓	↓	1236	2130	−148.8	One-way
4	99	↓	1957	0500	−150.9	
5	↓	337	0356	1300	−150.3	
2	↓	↓	1230	2130	−149.2	One-way
4	100	↓	2030	0530	−149.7	
5	↓	338	0356	1300	−150.3	
2	↓	↓	1227	2130	−148	One-way
4	101	↓	1953	0530	−151.5	
5	↓	339	0355	1300	−150.1	
2	↓	↓	1241	2130	−148.1	One-way
4	102	↓	2001	0500	−151	
5	↓	340	0349	1300	−146.1	Sudden gain change during calibrations
2	↓	↓	1223	2130	−149.4	One-way
4	103	↓	2017	0500	−150.6	
5	↓	341	0348	1300	−152.3	
2	↓	↓	1224	2130	−148.7	Two-way at 1224
3	↓	↓	1214	2130	—	
4	104	↓	2008	0530	−151.1	
5	↓	342	0444	1300	−150	
2	↓	↓	1224	2230	−149.5	Two-way at 1224
3	↓	↓	1212	2230	—	Command modulation tests conducted during this period
4	105	↓	1944	0510	−150.4	
5	↓	343	0350	1300	−150	
2	↓	↓	1220	2130	−149.2	One-way
3	↓	↓	1401	2130	−151	Receive only
4	106	↓	1938	0500	−150.5	
5	↓	344	0347	1301	−150.8	
2	↓	↓	1218	2230	−149.2	One-way
3	↓	↓	1303	2015	−152.5	Receive only. Conducted tests to determine telemetry threshold
4	107	↓	2216	0445	−149.7	Listening feed installed before this period
5	↓	345	0345	1245	−152.1	
2	↓	↓	1217	2226	−149	Two-way at 1217
3	↓	↓	1208	2220	—	Transmit only

Table 5. (Cont'd)

DSIF station	Pass No.	Day of year	GMT		Max recd sig, dbm	Remarks
			Acquisition	Loss		
4	108	345	1828	0500	−148	
5			0345	1328	−151.9	
2		346	1220	2223	−150.5	Two-way at 1231
3			1231	2220	——	Transmit only
4	109		1832	0500	−149.3	
5		347	0349	1331	−151.5	
2			1213	2220	−150.6	Two-way at 1213–1306, 1706–1743, 1930–2210
3			1204	2210	——	Command loop tests conducted
4	110		1815	0500	−149.5	
5		348	0136	1331	−152.3	
2			1216	2216	−150.6	Two-way at 1227. Routine *Venus* encounter
3			1224	——	——	RTC-7 was initiated at 1335 and verified at 133557. RTC-8 was initiated at 203200 and verified at 203257.
4	111		1810	0500	−149.7	
5		349	0137	1327	−152	
2			1217	2212	−151.4	Two-way at 1217. Conducted tests on telemetry demodulator threshold
3			1207	2210	——	RTC-2 was initiated at 1325 and verified at 132556 and again initiated 1340 and verified at 134056. Between 1350 and 220630, 165 RTC-0 commands were transmitted
4	112		1829	0430	−149.1	
5		350	0300	1326	−152.2	
2			1212	2215	−151	Two-way at 1234
3			1234	2150	——	Between 1308 and 1350 25 RTC-0 commands were transmitted
4	113		1831	0400	−150.6	
5		351	——	——	——	Not scheduled
2			1208	2208	−151	Two-way at 1234
3			1202	2155	——	
4	114		——	——	——	Not scheduled
2		352	1320	2206	−151.5	Two-way at 1739. Acquisition delayed because of water in the feed line
3			1739	2155	——	7 RTC-0 commands were transmitted between 2102 and 2108. Spacecraft transponder threshold tests were conducted
4	115		——	——	——	Not scheduled
5		353	——	——	——	Not scheduled
2			1207	2205	−150.6	Two-way at 1207
3			1159	2145	——	
4	116		——	——	——	Not scheduled
5		354	——	——	——	Not scheduled
2			1227	2201	−152.4	Two-way at 1227
3			1158	2150	——	6 RTC-2 commands were transmitted between 1605 and 1720
4	117		——	——	——	Not scheduled
5		355	0209	1200	−154.2	
2			——	——	——	Not scheduled
4	118		——	——	——	Not scheduled
5		356	0206	1200	−156	
2			——	——	——	Not scheduled

Table 5. (Cont'd)

DSIF station	Pass No.	Day of year	GMT Acquisition	GMT Loss	Max recd sig, dbm	Remarks
4	119	356	1900	0500	−153.8	
5	↓	357	—	—	—	Not scheduled
2	↓	↓	—	—	—	Not scheduled
4	120	↓	1858	0500	−153.7	
5	↓	358	—	—	—	Not scheduled
2	↓	↓	—	—	—	Not scheduled
4	121	↓	—	—	—	Not scheduled
5	↓	359	—	—	—	Not scheduled
2	↓	↓	—	—	—	Not scheduled
4	122	↓	—	—	—	Not scheduled
5	↓	360	0154	1200	−154.5	
2	↓	↓	—	—	—	Not scheduled
4	123	↓	1848	0500	−153.9	
5	↓	361	—	—	—	Not scheduled
2	↓	↓	—	—	—	Not scheduled
4	124	↓	1853	0530	−155	
5	↓	362	—	—	—	Not scheduled
2	↓	↓	1200	2130	−154.2	Two-way at 1210
3	↓	↓	1210	2130	—	In and out of two-way several times due to synthesizer. Unable to obtain vehicle sync for transmission of RTC-2
4	125	363	—	—	—	Not scheduled
5	↓	↓	0441	0822	−156	
2	↓	↓	—	—	—	Not scheduled
4	126	↓	1752	0200	−155.3	
5	↓	364	—	—	—	Not scheduled
2	↓	↓	1201	2135	−155.5	Two-way at 1230
3	↓	↓	1230	2135	—	Demodulator and decommutator kept dropping lock and it was determined that the spacecraft's 4F's had dropped by 13 cps
4	127	↓	—	—	—	Not scheduled
5	↓	365	0245	1200	−156.6	
2	↓	↓	—	—	—	Not scheduled
4	128	↓	2315	0200	−157.1	
5	↓	001	—	—	—	Not scheduled
2	↓	↓	1910	2000	—	One-way
4	129	↓	—	—	—	Not scheduled
5	↓	002	0951	1302	−156.4	
2	↓	↓	—	—	—	Not scheduled
4	130	↓	—	—	—	Not scheduled
5	↓	003	0354	0700	−157	This was the last signal received from the spacecraft
2	↓	↓	—	—	—	Not scheduled
4	131	↓	—	—	—	Searched for spacecraft signal from 2058 through 0315 with no success
5	↓	004	—	—	—	Secured from mission
2	↓	↓	—	—	—	Searched for spacecraft signal from 1200 to 2046 without success
4	132	↓	—	—	—	Secured from mission
2	↓	005	—	—	—	Not scheduled

Table 5. (Cont'd)

DSIF station	Pass No.	Day of year	GMT Acquisition	GMT Loss	Max recd sig, dbm	Remarks
2	133	006	—	—	—	Not scheduled
2	134	007	—	—	—	Not scheduled
2	135	008	—	—	—	Searched for spacecraft signal from 1710 to 2100. No signal received
3	↓	↓	—	—	—	Starting at 1830, 40 RTC-2 commands were sent. Starting at 1912, 10 RTC-1 commands were sent
2	136	009	—	—	—	Station placed on standby

F. Postencounter Phase

The DSIF continued to track on a reduced basis after 16 December (day 350) as indicated in Table 5. After 30 December, the DSIF schedule was planned around the spacecraft radiometer calibration periods in an attempt to obtain a calibration. DSIF-5 completed its scheduled track at 0700, 3 January; the received signal level at that time was a −157 dbm. DSIF-4 started its scheduled track at 2058 on 3 January and searched until 0315, 4 January without success. DSIF-5, therefore, received the last signal from the spacecraft at 0700, 3 January 1963. DSIF-2 searched for the signal from 1200 through 2046 on 4 January, again with no success. On 5 January, DSIF-4 and -5 were secured. On 8 January, DSIF-2 searched for the signal from 1710 until 2100 without success. During the same period, DSIF-3 transmitted 40 RTC-2 commands and 10 RTC-1 commands in an attempt to update the spacecraft antenna hinge angle. There were no indications that the commands were received or acted on by the spacecraft. On 9 January, the Goldstone Stations were placed on standby.

III. PERFORMANCE ANALYSIS

A. Preflight Calibrations

In order to improve the quality of the primary angular data used in the ODP, it is first corrected for the antenna optical pointing error (OPE). For the angle data stations, DSIF-4 and -5, this error was determined from a series of independent, horizon-to-horizon, star tracks conducted in 1961-62. A polynomial curve fitted by the method of least squares was made to the differences between the refraction corrected ephemeris values and the observed values read from the angle encoders. The OPE is then represented by the coefficients of the resulting polynomial. In general, the preflight calibration star tracks are required for two purposes: (1) to detect gross system errors, and (2) to test the validity of the correction polynomial. The coefficients describing the OPE for the *Mariner II* mission may be seen in the Appendix along with the RF boresight versus polarization angle (B/P) test results.

The B/P test was an attempt to study the RF errors. The test was designed to correlate the optical and RF errors observed at the collimation tower over a range of signal levels and polarization angles. Experience has shown that the results of the test cannot be applied to the inflight data in a meaningful manner. Hence, for the purpose of describing the RF pointing error, the test is inadequate, and a new method for determining the RF antenna calibration is required. However, the tests are required to add to the composite statistical data, and they are an excellent indication of RF system status and autotrack capabilities.

1. DSIF-1

A B/P test was conducted on 15 July 1962. This test, originally conducted for the *Mariner I* mission, was considered adequate for the *Mariner II* mission. The test was conducted at polarization angles of 0, 180 and 240 deg for signal strengths of −120 and −140 dbm. The mean error in azimuth exceeded *Ranger III* and *Ranger IV* by a factor of 2 and the angle tracking jitter exceeded *Ranger III* and *Ranger IV* by a factor of 4. Results of the B/P test are presented in the Appendix. Since angular data from DSIF-1 are not primary data, the B/P test was considered satisfactory for the *Mariner II* mission. Star tracks were not conducted by DSIF-1 because angular data are not considered primary data.

2. DSIF-2

A star track of Alpha Aquila (Altair) was conducted on 3 August 1962. Hour angle and declination residuals (observed minus computed) compared favorably with previous star tracks. Angular correction coefficients were not determined for DSIF-2 since the station was in slave mode only for the *Mariner II* mission. A plot of the star track is presented as Fig. 1. B/P tests were not required for *Mariner II*.

3. DSIF-3

A star track of Alpha Aquila was conducted on 8 August 1962. Hour angle and declination residuals (observed minus computed) compared favorably with previous star tracks. Angular correction coefficients were not determined for DSIF-3 since the station acted as a transmitter only for the *Mariner II* mission. A plot of the star track is presented as Fig. 2. B/P tests were not required for *Mariner II*.

4. DSIF-4

A star track of Alpha Aquila was conducted on 16 August 1962. A curve generated from a polynomial using the angular correction coefficients compared very favorably with the hour angle (HA) and declination (Dec) residuals (observed minus computed) from the star track.

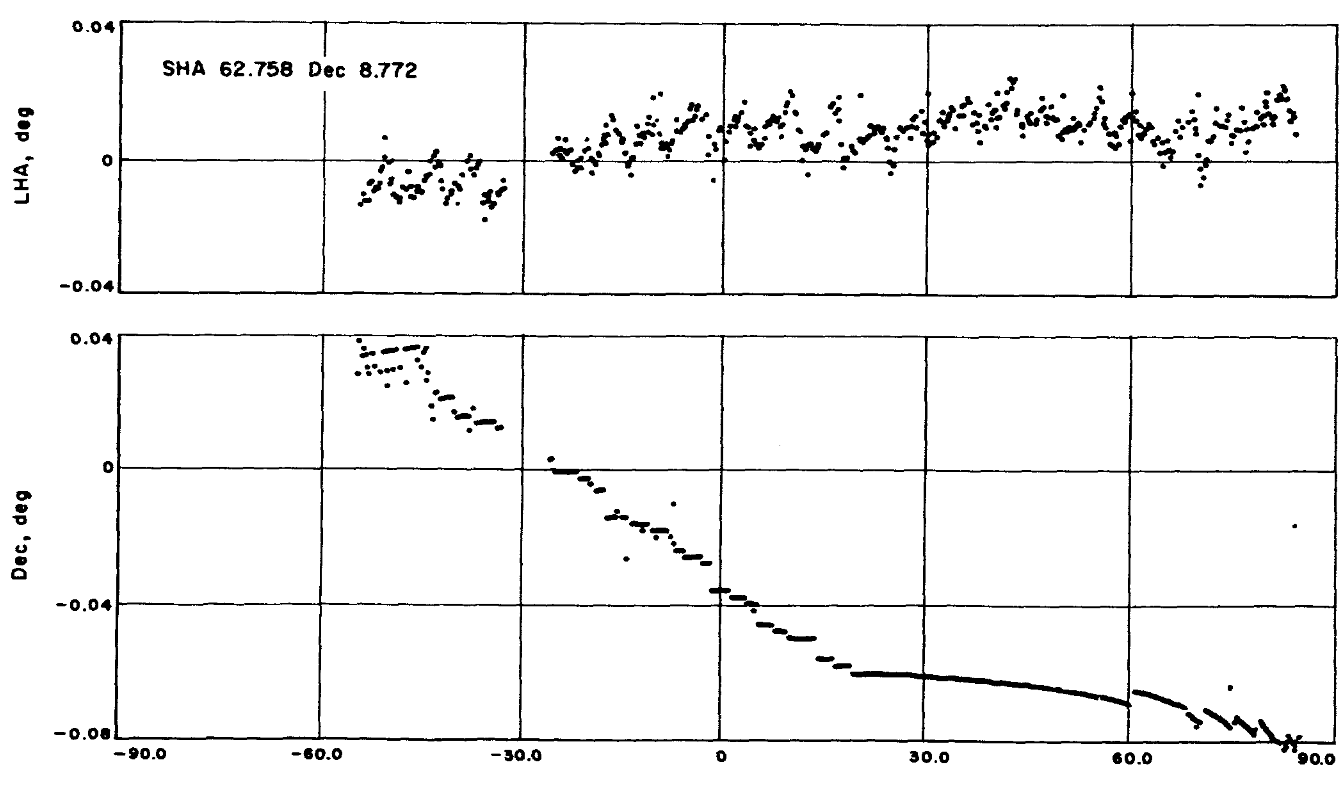

Fig. 1. DSIF-2 star track, 3 Aug 1962

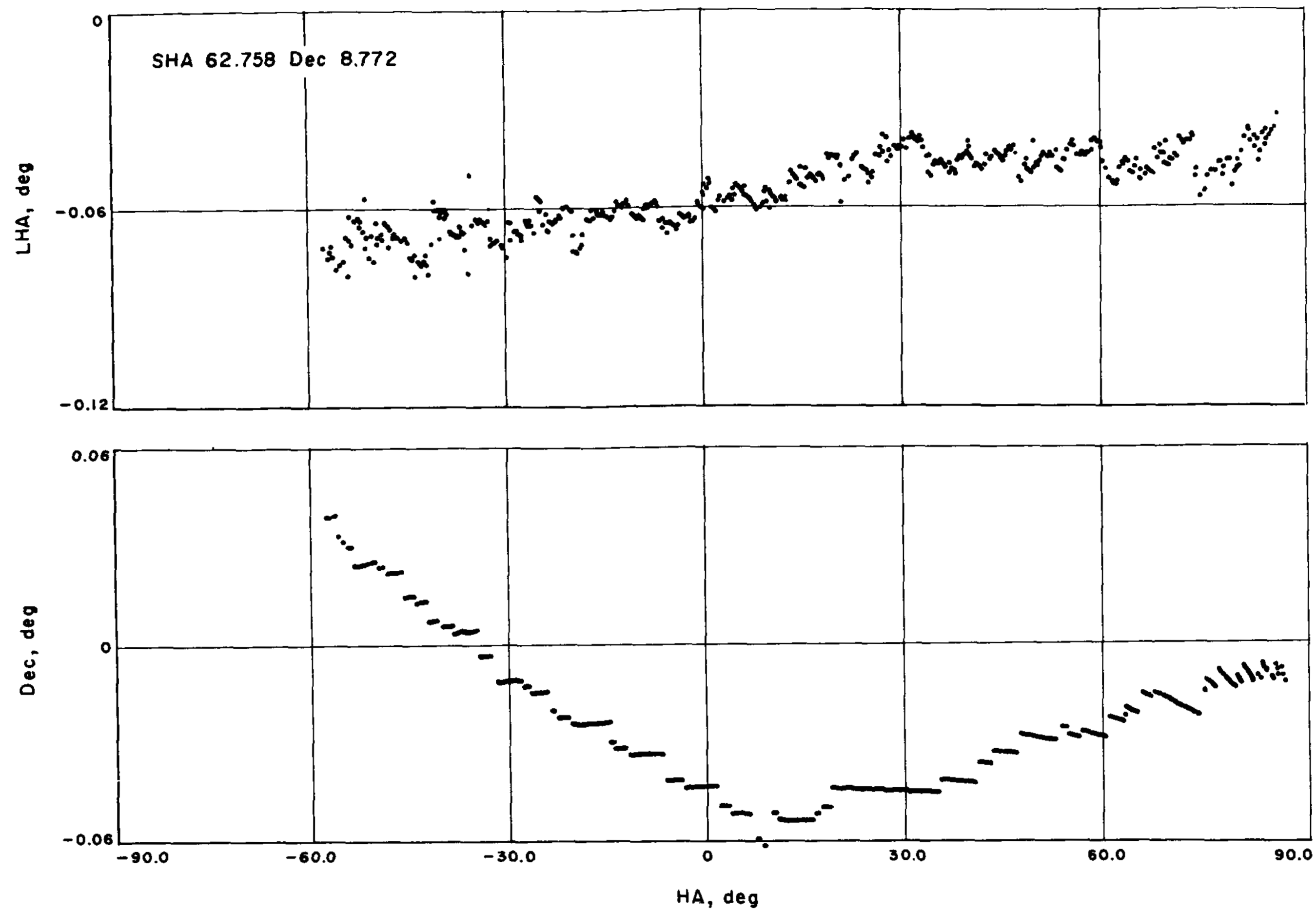

Fig. 2. DSIF-3 star track, 8 Aug 1962

Based on the 16 August 1962 star track the angular correction coefficients determined from the 1961–62 star tracks were considered to be the best estimate of the OPE. A plot of the star track is presented as Fig. 3. A B/P test was conducted on 12 July 1962 at signal strengths of −120, −130 and −140 dbm. Results compared favorably with previous tests.

5. DSIF-5

A star track of Alpha Aquila was conducted on 2 August 1962. A curve generated from a polynomial using the angular correction coefficients determined from 1961–62 star tracks compared very favorably with the hour angle residuals; however, the declination residuals were biased approximately −0.01 deg for the *entire* star track. A second star track of Alpha Aquila was conducted 17 August 1962. The HA residuals from this star track again agreed favorably with the curve generated from the polynomial, using the angular correction coefficients. Declination residuals for $-30 < HA < 30$ agreed with the polynomial. Film data were not taken to verify that the star was centered during these tracks. It was decided to use the angular correction coefficients from the 1961–62 star tracks for the *Mariner II* mission. Plots of results of the star tracks are presented as Fig. 4 and 5.

A B/P test was conducted on 10 August 1962 at signal strengths of −120, −130 and −140 dbm.

B. Postflight Analysis of Station Performance During Mission

Postflight analysis of DSIF performance during the mission is based on real time tracking data, inflight station reports, station logs, calibration books and station parameters recorded on Midwestern recordings and magnetic tape. All times refer to GMT. Tables of doppler mode tracking and transmitter frequencies are presented in the Appendix.

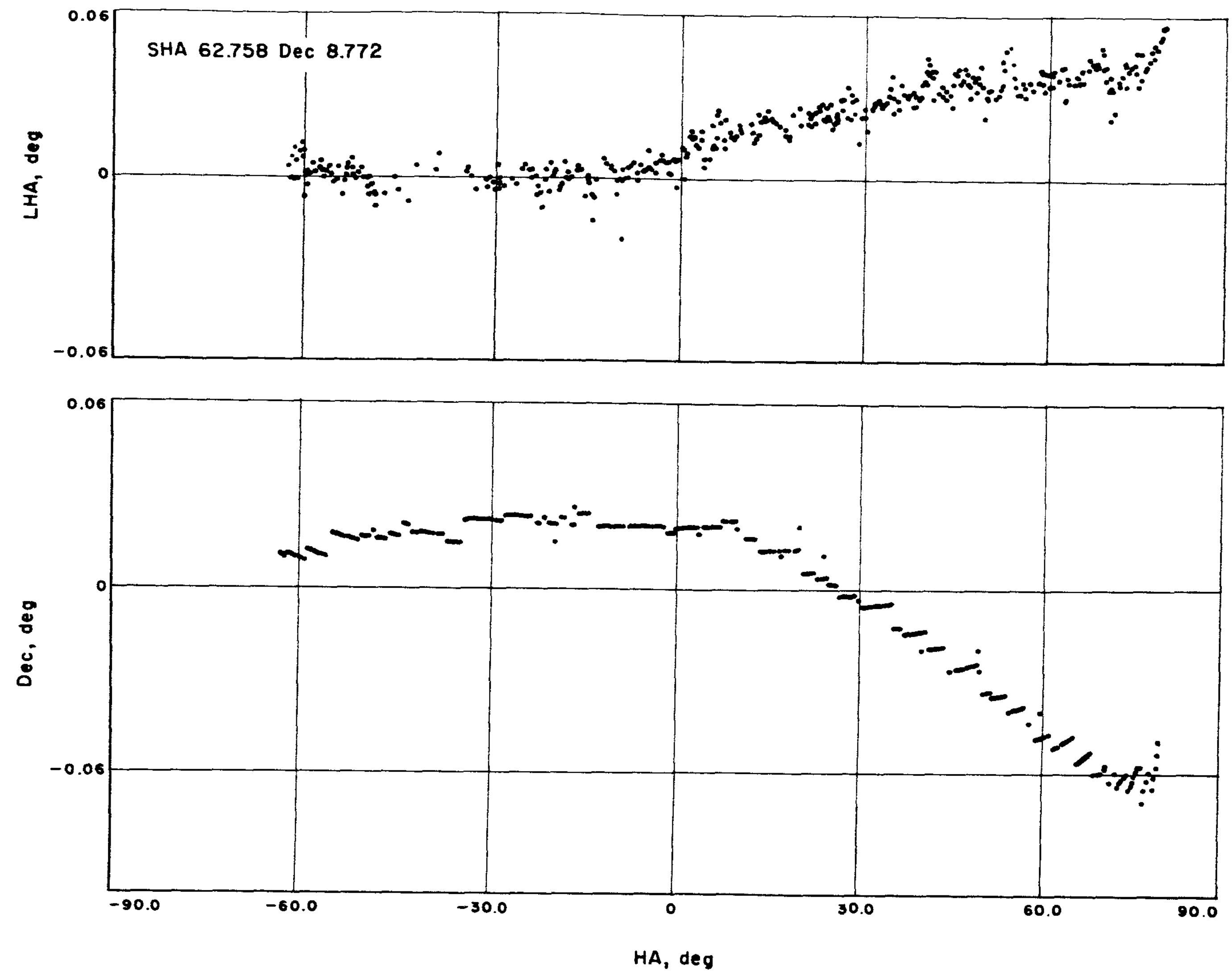

Fig. 3. DSIF-4 star track, 16 Aug 1962

1. DSIF-1

DSIF-1 acquired *Mariner II* in one-way mode at 072137, 27 August 1962, at a signal strength of −100 dbm. It reported having trouble establishing two-way doppler lock and at 073048 reported two-way doppler lock. No data were transmitted from 072721 to 074128. The time of the first good data condition code was 074551. From 074551 until transmitter shutoff at 074800, seven data points with a good data condition code were received at the computing facility at JPL.

The transmitter at DSIF-1 was turned on again from 080400 to 081112. Attempts to establish two-way lock were unsuccessful. One-way lock was established at 081133 and DSIF-1 continued to track in this mode until the end of pass 1 (210841). DSIF-1 was secured from the *Mariner II* mission at the end of pass 1.

Subsequent investigation revealed that the seven two-way doppler (C-2) data points taken from 074551 to 074800 were biased by −13.6 cps. Several orbits had been computed assuming that these C-2 points were valid. Analysis of these orbits indicated a bias of approximately 5.0 cps at 084900 in the C-2 data received from DSIF-4 decreasing to 0.5 cps at the end of the pass. C-2 doppler from DSIF-1 and -5 revealed no bias, and as a result it was assumed that the C-2 doppler from DSIF-4

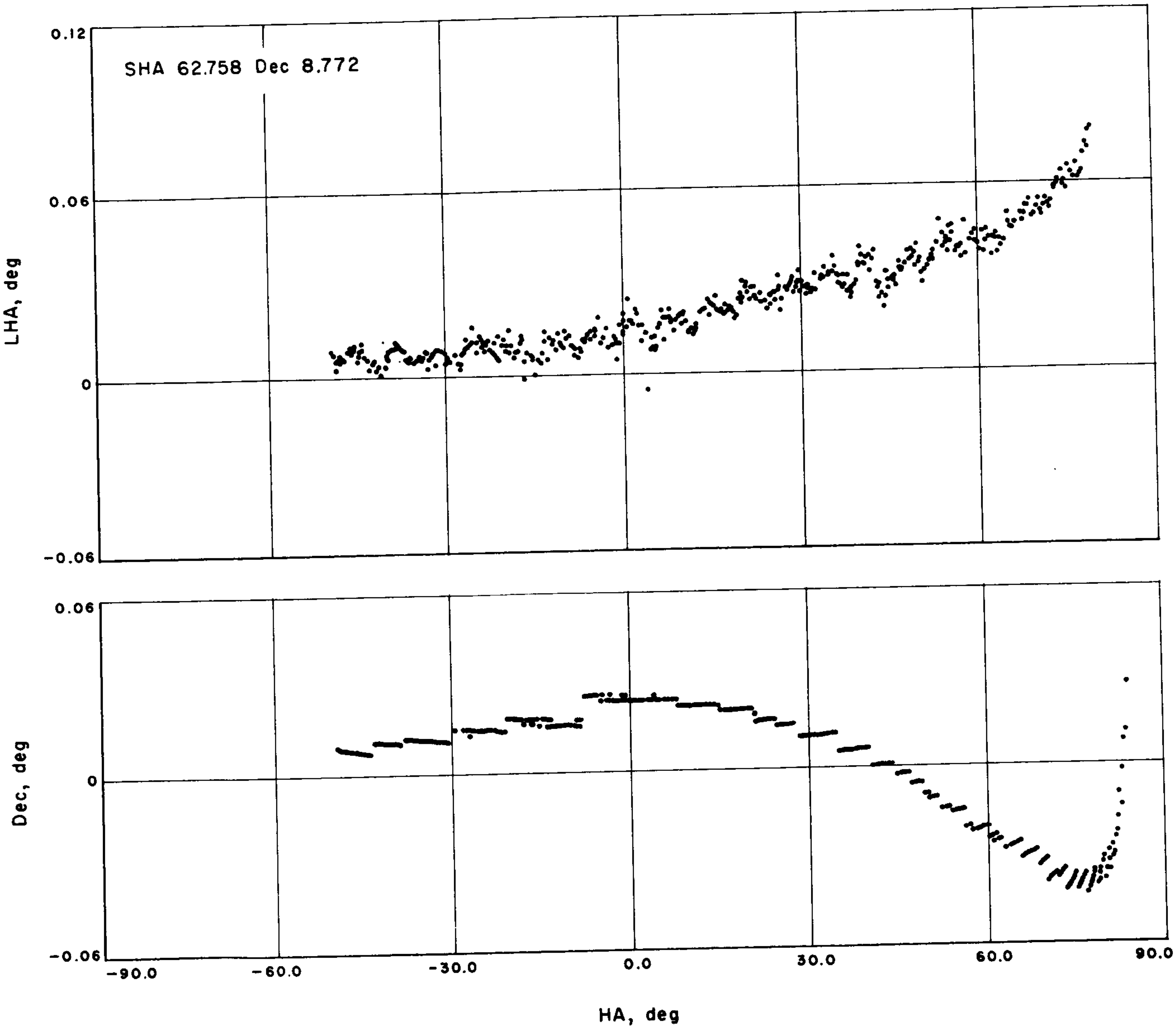

Fig. 4. DSIF-5 star track, 2 Aug 1962

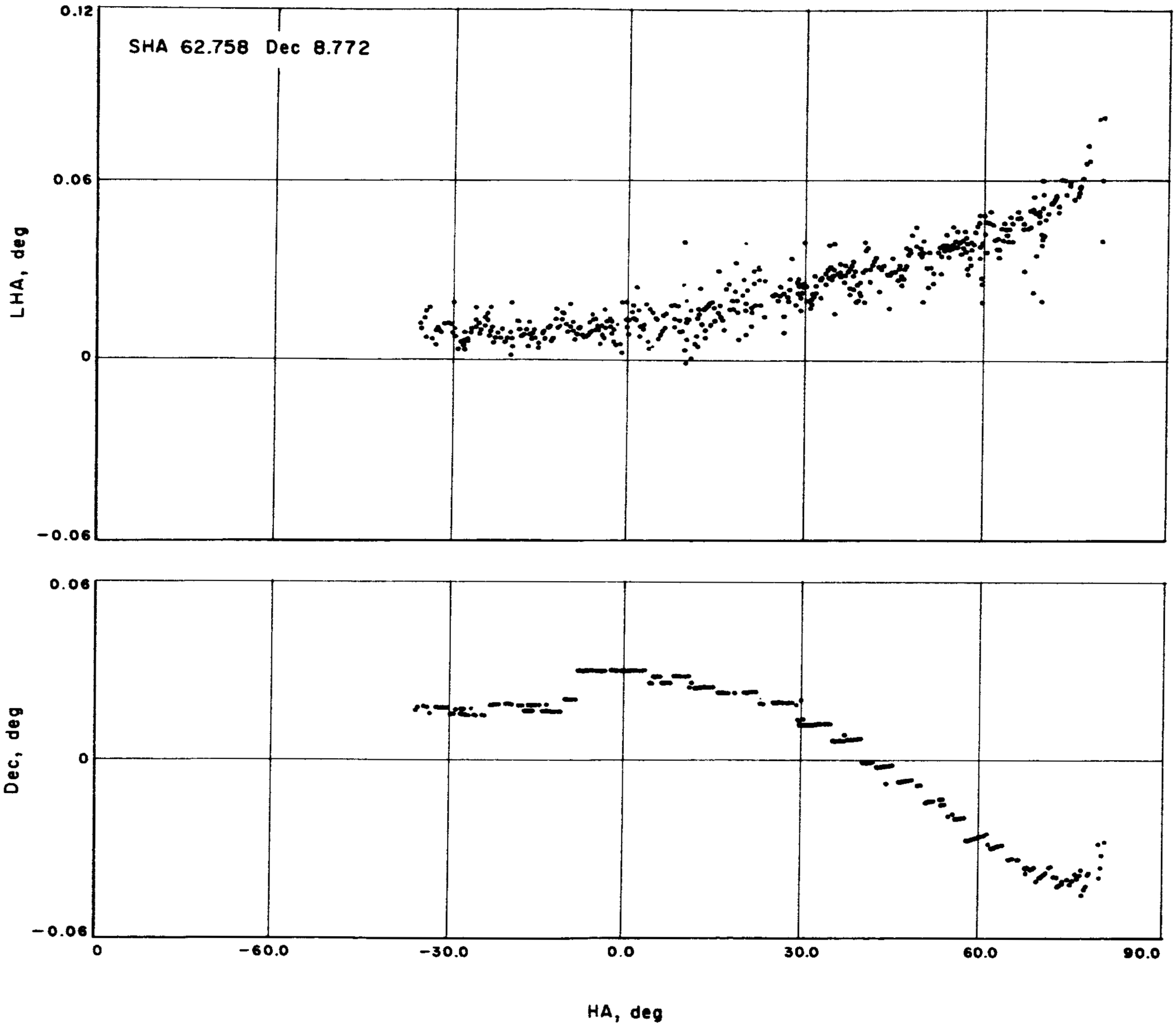

Fig. 5. DSIF-5 star track, 17 Aug 1962

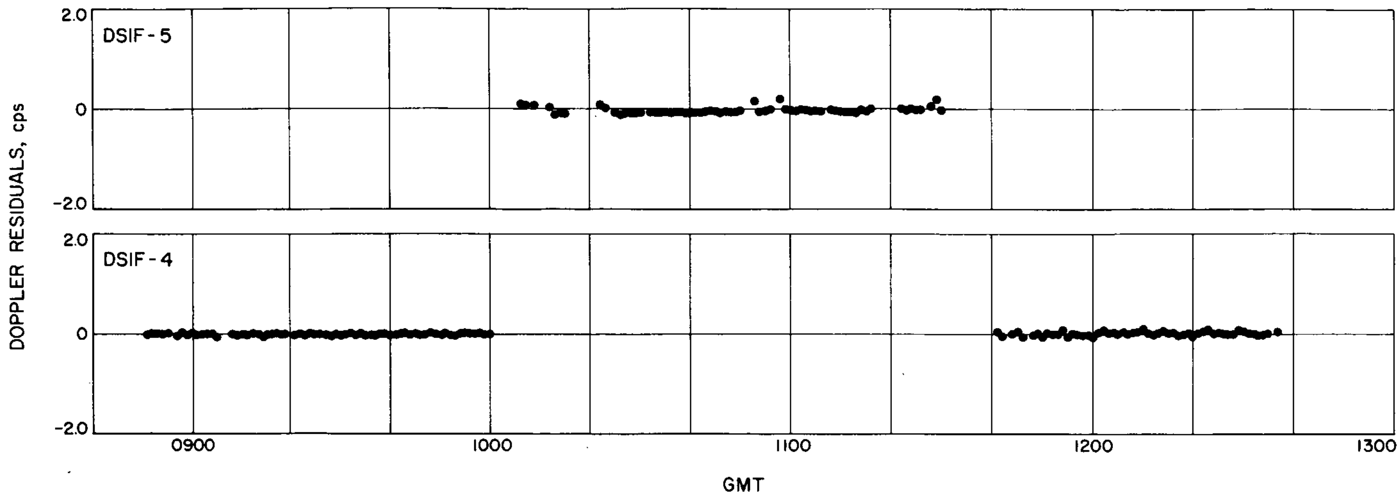

Fig. 6. DSIF-4 and -5 C-2 doppler residuals vs time

was in error. The following possible causes were investigated.

1. Error in station location
2. Error in station time
3. Equipment malfunction
4. Excessive doppler rates

Results of the investigation indicated that none of the above would explain the apparent bias.

Mariner II orbit was recomputed using only data available thru 024351 GMT, 28 August 1962 and deleting the data from DSIF-1. Weighting of angular data for DSIF-4 and -5 and of the two-way doppler data for DSIF-2, -4 and -5 were the same as for real time orbits. As can be seen in Fig. 6, the bias error has been removed from the two-way doppler data as for DSIF-4. Mean error and standard deviation of the angular and doppler residuals for the orbit computed, deleting DSIF-1 data and the real time orbit at the end of pass 1, are presented in Table 6.

The two-way doppler residuals from DSIF-2, -4 and -5 for the real time orbit computed with DSIF-1 data deleted indicate that the seven data points from DSIF-1 were bad.

Table 6. ODP statistics for DSIF-4 C-2 bias investigation

DSIF station	Data type	No. of points	Real time orbit		Orbit with DSIF-1 deleted		
			Mean	Standard deviation	No. of points	Mean	Standard deviation
1	C-2 (cps)	7	−0.208	1.19	0	—	—
2		314	−0.007	0.023	314	−0.005	0.027
4[a]		103	—	—	103	0.005	0.027
5		337	0.006	0.065	337	0.016	0.066
4	HA deg	285	−0.057	0.029	285	−0.024	0.013
	Dec deg	308	0.008	0.015	308	−0.003	0.009
5	HA deg	520	−0.010	0.026	509	0.005	0.009
	Dec deg	520	0.006	0.014	520	0.002	0.009

[a]DSIF-4 two-way doppler not used for orbit determination.

Investigation of the transmitter VCO and other recordings revealed that DSIF-1 locked up to the transponder in two-way doppler mode after a possibly too fast transmitter frequency scan. The point of lock coincided within several cycles of the predicted transmitter VCO frequency. No subloops were reported out of lock, and the bias is attributed to an unrevealed malfunction at DSIF-1.[2]

2. DSIF-2

DSIF-2 acted as only a receiver for the entire *Mariner II* mission. First acquisition was at 193405 and first coherent pseudo two-way doppler (Cc-3) lock was at 201500. Except for short intervals, DSIF-2 tracked as scheduled for the entire mission. The Cc-3 data were extremely noisefree with a standard deviation on the order of 0.020 cps for the entire mission.

a. Premidcourse. Table 7 presents the statistics of data investigated for premidcourse as determined from the ODP.

The parameters considered in determining the premidcourse statistics were the position and velocity parameters only. The premidcourse orbit solution is considered as preliminary only, and the biases observed may be the result of parameters ignored, such as station location, etc. Because of a nonoptimum orbit solution, the standard deviation and mean doppler residual do not necessarily represent true station performance.

Periodic excessive Cc-3 doppler residuals were observed at 15 min intervals during all of the premidcourse Cc-3 doppler tracking (Fig. 7). These excessively

[2]Tracking Operation Memorandum, dated 6 February 1964.

Table 7. Premidcourse ODP statistics

Day of year	Pass	Date	Number of Cc-3 doppler data points	Standard deviation, cps	Mean, cps
239	1	27 Aug	313	0.0195	−0.0257
240	2	28	474	0.0286	0.0021
241	3	29	346	0.0282	0.0076
242	4	30	415	0.0215	0.0077
243	5	31	288	0.0352	0.0278
244	6	1 Sept	431	0.0381	0.0215
245	7	2	498	0.0449	−0.0255
246	8	3	419	0.0368	−0.0683
247	9	4	39	0.0140	−0.0004

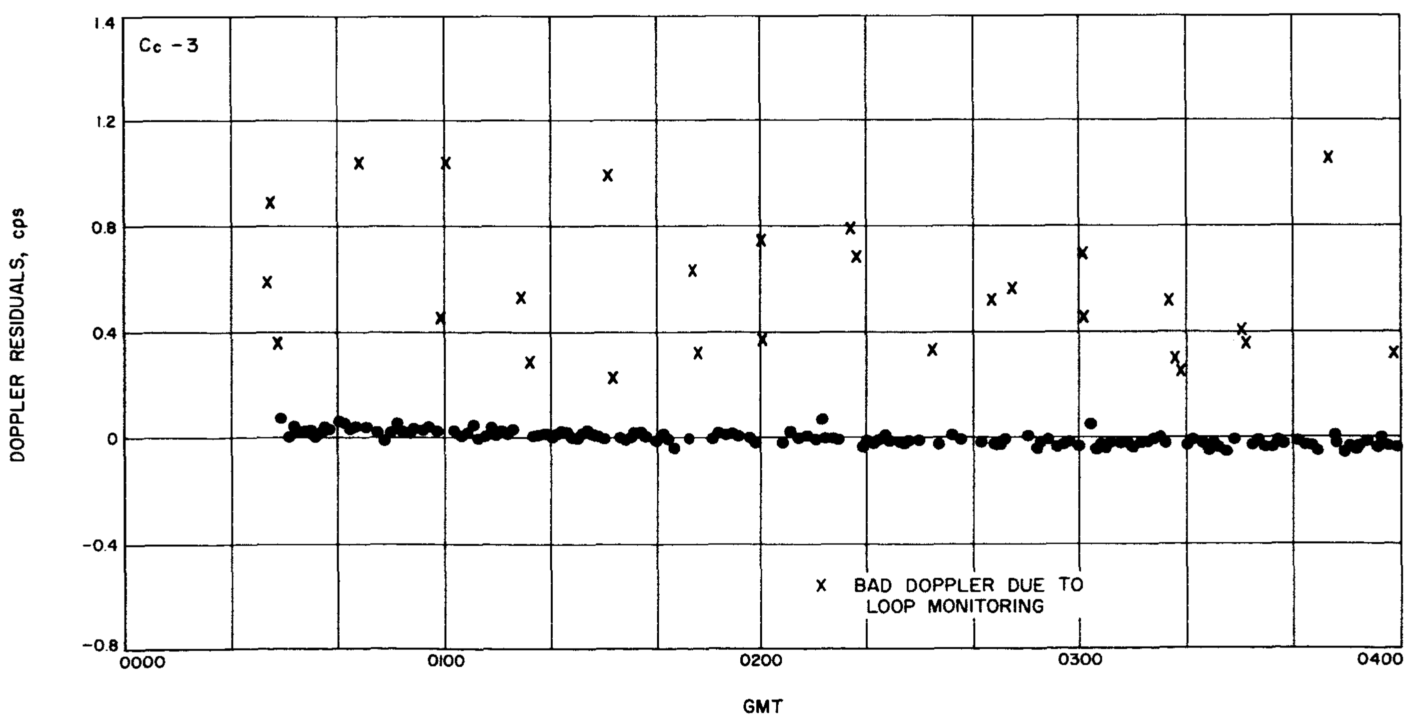

Fig. 7. DSIF-2 Cc-3 two-way doppler vs time

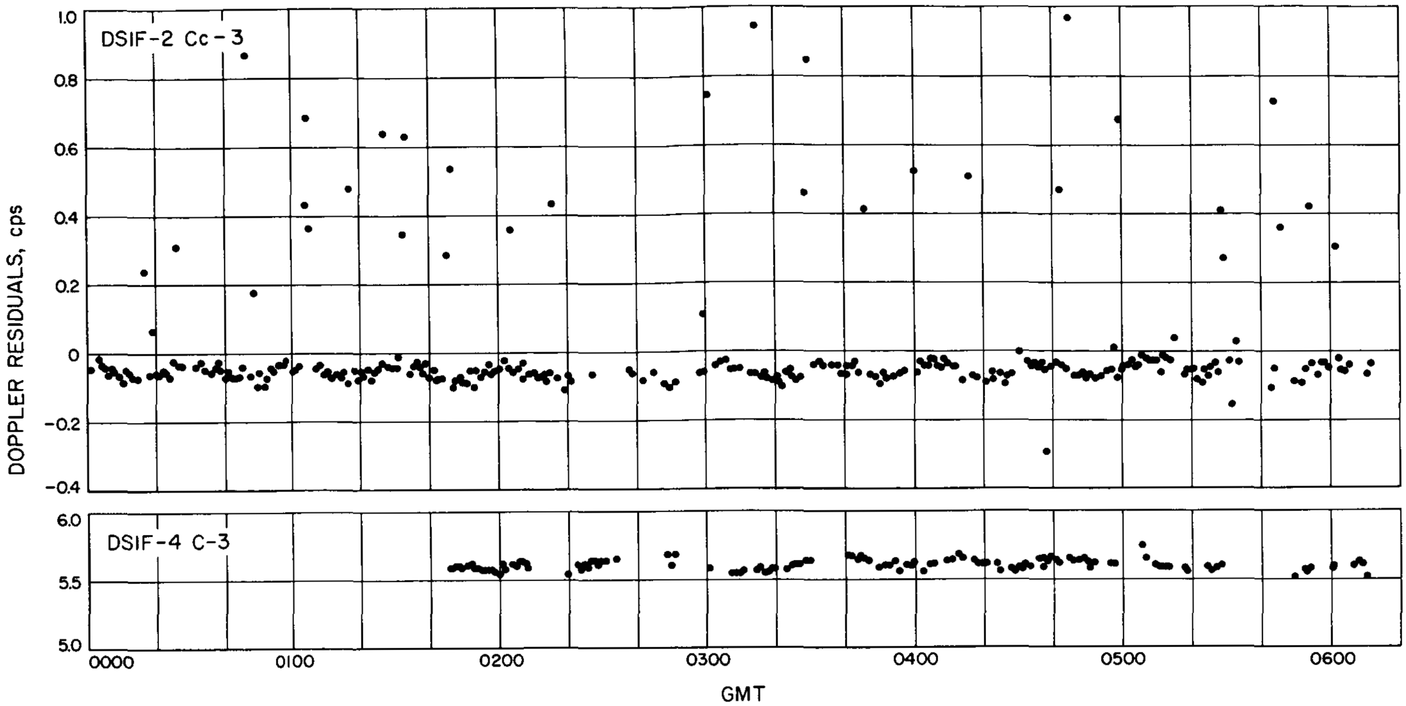

Fig. 8. DSIF-2 and -4 doppler residuals vs time, 2 Sept 1962

large Cc-3 residuals were later correlated with the monitoring of the various doppler loop frequencies. A temporary but inadequate fix was made 14 September 1962 in that the doppler loop frequencies would be monitored in the 10 sec noncounting period when taking Cc-3 doppler at a count time of 50 sec and sample intervals of 60 sec. A permanent fix was later made at DSIF-2 by the installation of isolation amplifiers.

Cc-3 residuals for passes 6 and 7 on 1 and 2 September 1962 show a periodic trend with a peak-to-peak amplitude of approximately 0.04 cps and a period of 40 and 30 min for passes 6 and 7, respectively. Investigation of the C-3 residuals at DSIF-4 revealed a similar cyclic function (Fig. 8 and 9). The periodic trend was not apparent during pass 8. Since Earth acquisition occurred at 052917 GMT, 3 September 1962, it was presumed that prior to this time the spacecraft had been rolling about the spacecraft/Sun axis. Investigation of the signal strength recordings for DSIF-2 and -4 revealed that the signal strength was changing periodically. The period of signal strength variation was approximately ⅓ that observed in the Cc-3 doppler residual (Fig. 10 and 11). Because of the variation of the signal strength at DSIF-2 and -4, it appears that the spacecraft may have been rolling so that there was a systematic variation due to the omni-antenna radiation pattern.

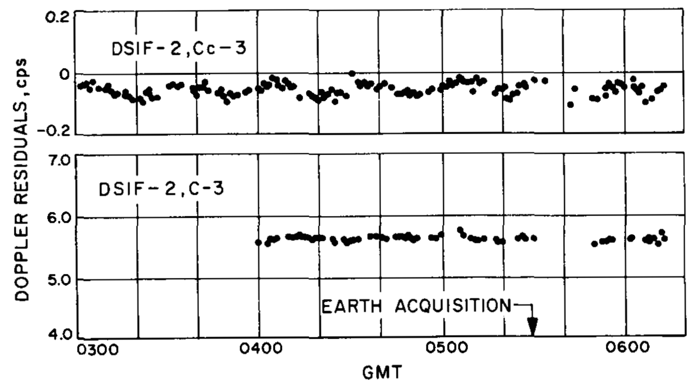

Fig. 9. DSIF-2 and -4 doppler residuals vs time, 3 Sept 1962

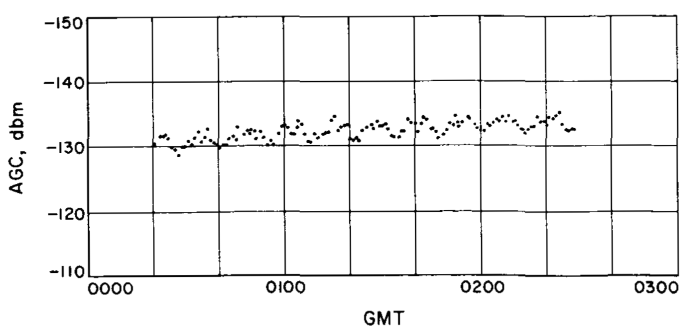

Fig. 10. DSIF-2 AGC vs time, 2 Sept 1962

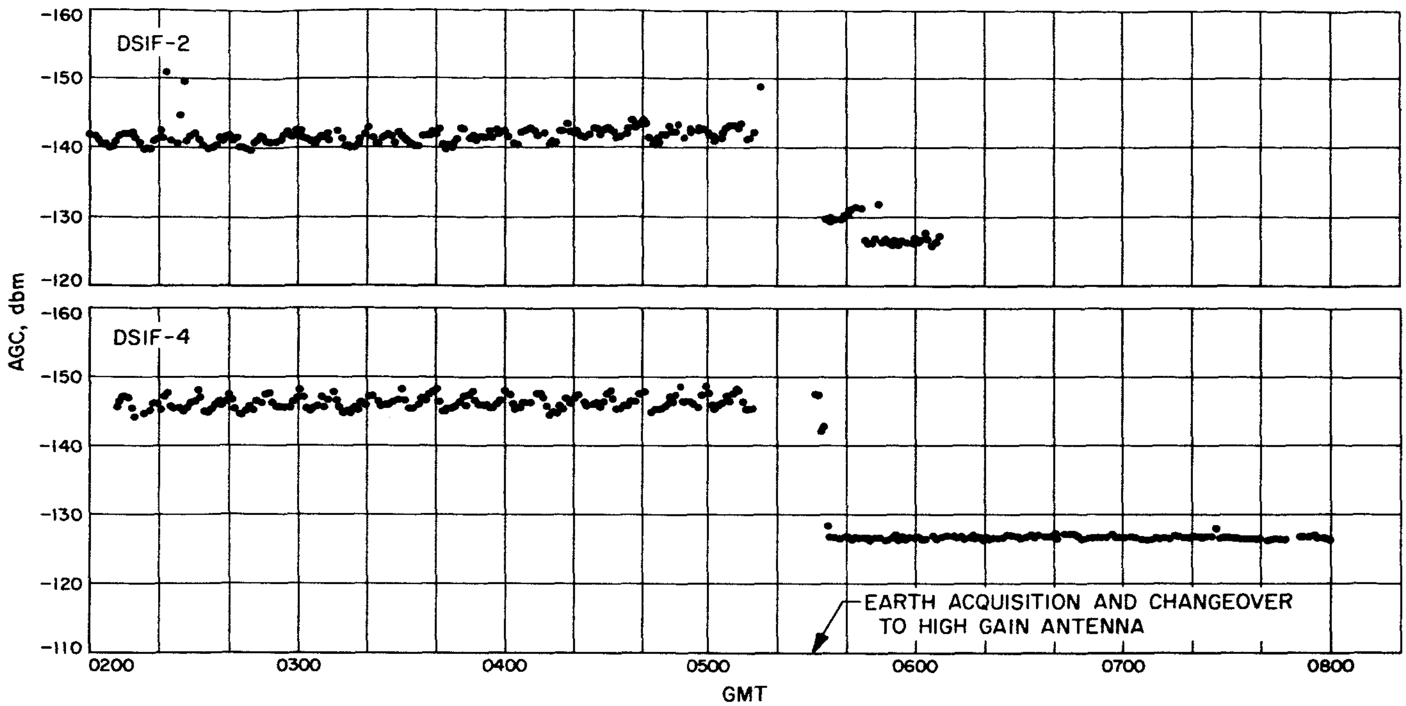

Fig. 11. DSIF-2 and -4 AGC vs time, 3 Sept 1962

b. Midcourse Maneuver. One-way doppler obtained from DSIF-2 during midcourse maneuver was evaluated to determine the time of midcourse maneuver motor ignition and burnout:

5 Sept 1962	Nominal, GMT	Observed, GMT
Ignition	002336	002303
Burnout	002403.8	002332

The drift in the one-way doppler before midcourse maneuver was approximately 12 cps/min, and when extrapolated to burnout time it indicated that the one-way doppler shift during the midcourse maneuver was −89 cps or approximately −28.6 m/sec along the $\dot{\mathbf{r}}$ vector. Plots of the one-way doppler during midcourse maneuver are presented as Fig. 12 and 13 for DSIF-2 and -3, respectively. One-way nondestructive count was recorded at DSIF-2, and one-way destructive count was recorded at -3 during midcourse maneuver.

The drift in the one-way doppler data for approximately the 20 sec following midcourse motor burnout was 49 cps/min, and at 002350 it changed to 21 cps/min. A possible explanation is that the change in the one-way doppler drift results from a change in the spacecraft transponder frequency due to temperature changes during midcourse maneuver. The one-way doppler drift just prior to midcourse maneuver was 12 cps/min.

The two-way doppler data before midcourse maneuver and after midcourse maneuver were differenced with prediction data obtained from premidcourse initial conditions. These differenced data were then plotted and extrapolated to the time of midcourse maneuver. The shift in two-way doppler due to midcourse maneuver was −181.8 cps or −28.4 m/sec along the **r** vector. A plot of the two-way doppler data from DSIF-2 differenced with the prediction data is presented as Fig. 14. A detailed discussion is contained in the *Mariner II* Flight Performance Report, dated 22 February 1963.

c. Postmidcourse. Table 8 presents statistics of data evaluated for the postmidcourse cruise and encounter phase, as determined from the ODP. This table also presents the standard deviations (SD) determined from fitting a polynomial by the method of least squares to the observed Cc-3 data. The curve fitting routine was established in near real time utilizing the IBM 1620 at Goldstone when the ODP revealed a large increase in the Cc-3 residual SD between 9 and 15 September. Further investigation revealed that the ODP precision was insufficient for the increased ranges. A fix was made in the ODP and good correlation was obtained

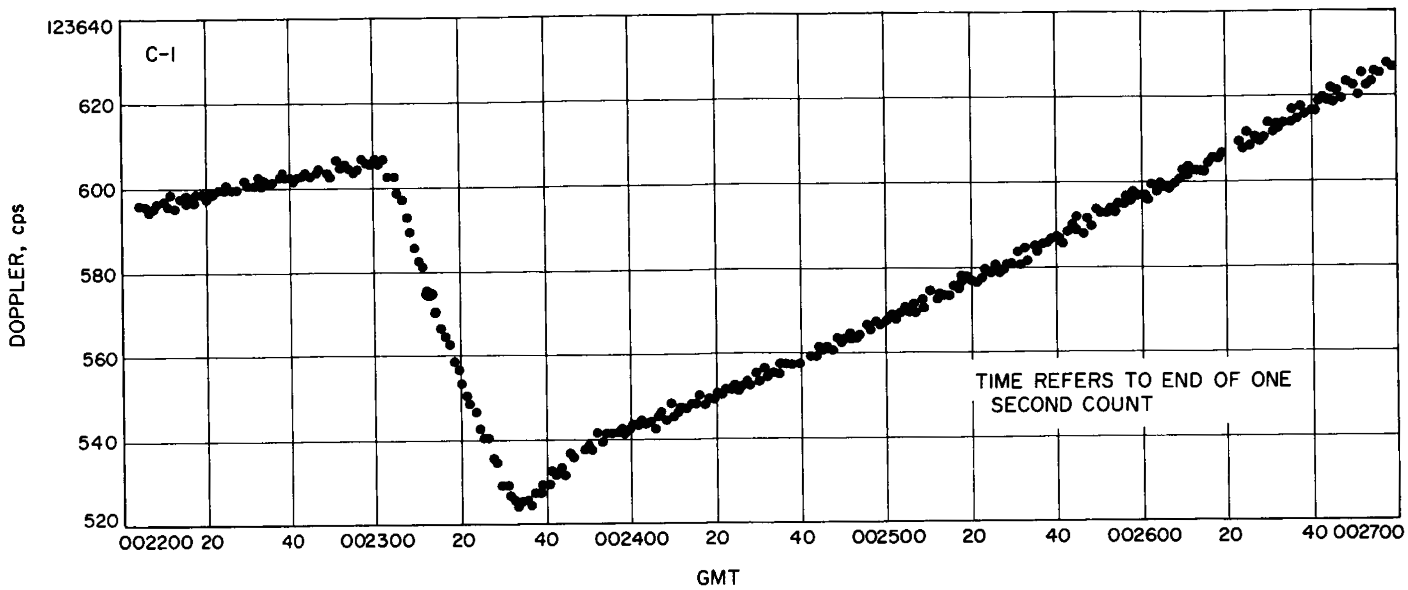

Fig. 12. DSIF-2 C-1 doppler vs time during midcourse, 5 Sept 1962

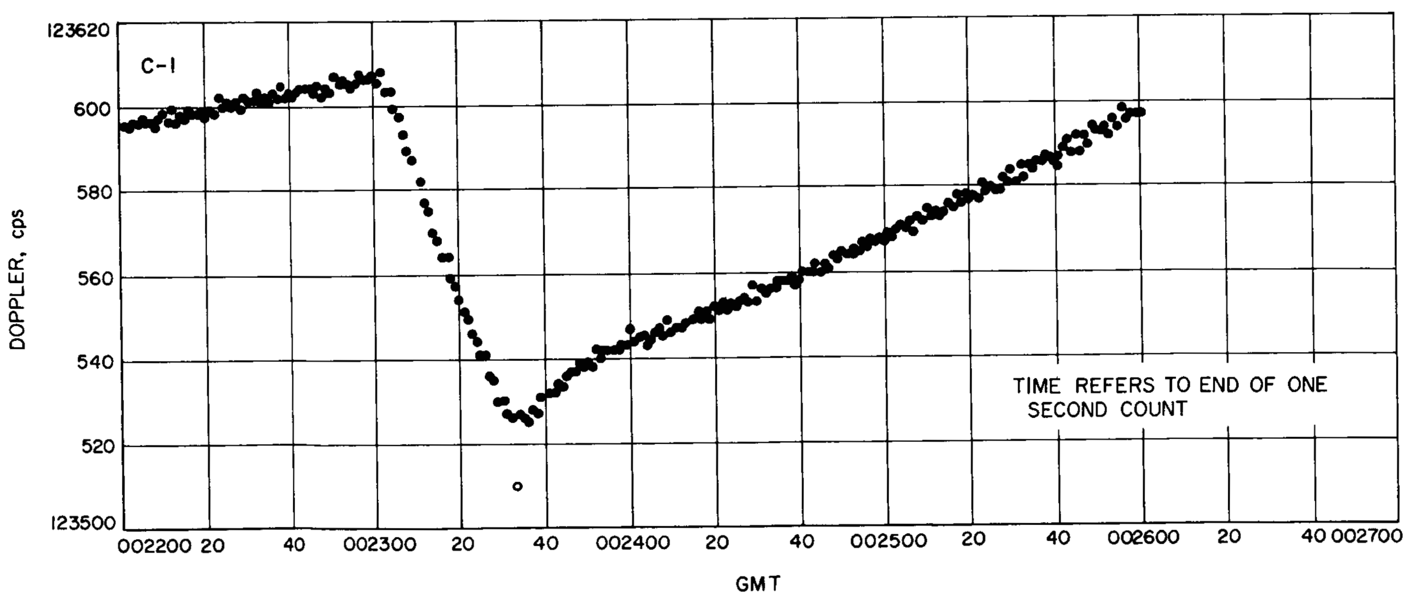

Fig. 13. DSIF-3 C-1 doppler vs time, 5 Sept 1962

Table 8. DSIF-2 doppler statistics

Date	Pass	Day of year	Data type	No. of data points	Mean, cps	Standard deviation, cps	
					ODP	ODP	Polynomial
4 Sept	9	247	Cc-3	241	0.025	0.016	Not computed
5	10	248	↓	559	0.017	0.020	0.012
6	11	249		540	0.006	0.018	0.020
7	12	250		554	−0.001	0.017	0.017
8	13	251		590	−0.007	0.019	0.012
14	19	257		611	−0.013	0.023	0.012
22	27	265		508	−0.003	0.017	0.013
23	28	266		613	−0.005	0.020	0.015
6 Oct	41	279		570	0.008	0.025	0.015
14	49	287		581	0.006	0.018	0.009
24	59	297		502	−0.013	0.016	0.011
27	62	300		541	−0.004	0.015	0.014
5 Nov	71	309		505	0.001	0.016	0.011
10	76	314		544	0.001	0.019	0.012
17	83	321		620	−0.002	0.022	0.016
26	92	330		555	0.005	0.018	0.013
1 Dec	97	335		464	0.002	0.015	0.014
7	103	341		479	0.001	0.021	0.020
8	104	342		420	−0.002	0.017	0.023
11	107	345		243	0.002	0.014	0.012
12	108	346		434	−0.002	0.016	0.021
13	109	347		175	−0.001	0.016	0.013
14	110	348		382	0.011	0.029	0.016
15	111	349		204	0.012	0.033	0.019
16	112	350		466	0.008	0.036	0.020
17	113	351		457	0.015	0.024	0.021
19	115	353		276	0.008	0.018	0.016
20	116	354		410	0.006	0.019	0.018
28	124	362		189	−0.020	0.051	0.055
30	126	364	↓	99	0.034	0.078	0.076
							Transponder Frequency, cps
5 Oct	40	278	C-1	411	−232.9	1.64	960.035964
7	41	279	↓	118	−229.8	0.38	960.035964
8 Nov	74	312	↓	41	364.3	0.63	960.036244

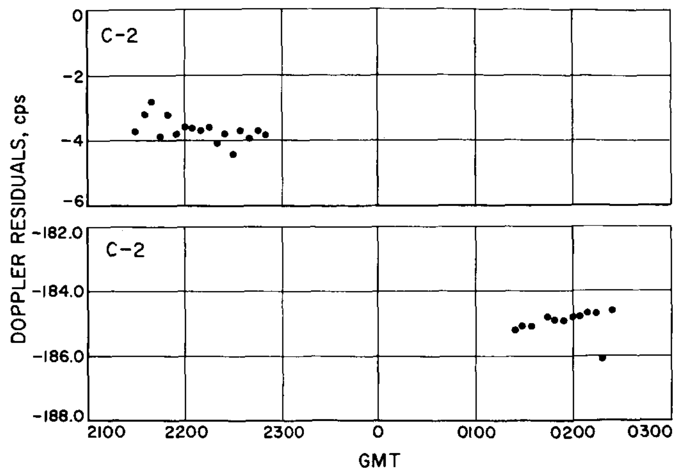

Fig. 14. DSIF-2 C-2 doppler vs time, 4–5 Sept 1962

between the SD from curve fitting the raw Cc-3 data and the Cc-3 residual SD from the ODP. Monitoring of the Cc-3 data in near real time at DSIF-2 continued until the end of the mission.

Cc-3 data were extremely noise free with the SD of <0.023 cps for each pass until the passes of 28 and 30 December. During these passes the SD increased to 0.055 and 0.076 cps for 28 and 30 December, respectively. The increase in noise on the Cc-3 doppler is attributed to the reduced signal strength that resulted from nearing the null of the spacecraft transponder.

Plots of Cc-3 doppler mean and SD versus range are given in Fig. 15. The Cc-3 SD computed from the polynomial curve fit is, in general, less than that of the ODP. The basic reason for this is that the polynomial was computed over 1 hr intervals rather than over the entire pass. The Cc-3 doppler SD from the ODP exceeded that of the polynomial by a factor of 1.5 near encounter and is attributed to biases in the ODP solution near encounter.

The Cc-3 doppler SD computed from the polynomial fitting procedure increased from 0.012 cps at midcourse maneuver (signal strength $\simeq -127$ dbm) to 0.020 cps at encounter (signal strength $\simeq -151$ dbm). The relatively noise free data are attributed to the ultra-stable frequency synthesizer used as a reference frequency for the transmitter station. The increase in SD from 0.012 to 0.020 cps is attributed to the reduction in signal strength due to increased ranges.

3. DSIF-3

During the *Mariner II* mission, DSIF-3 acted as the transmitter station and did not have tracking capability except for the passes on 14 and 24 October when *Ranger*

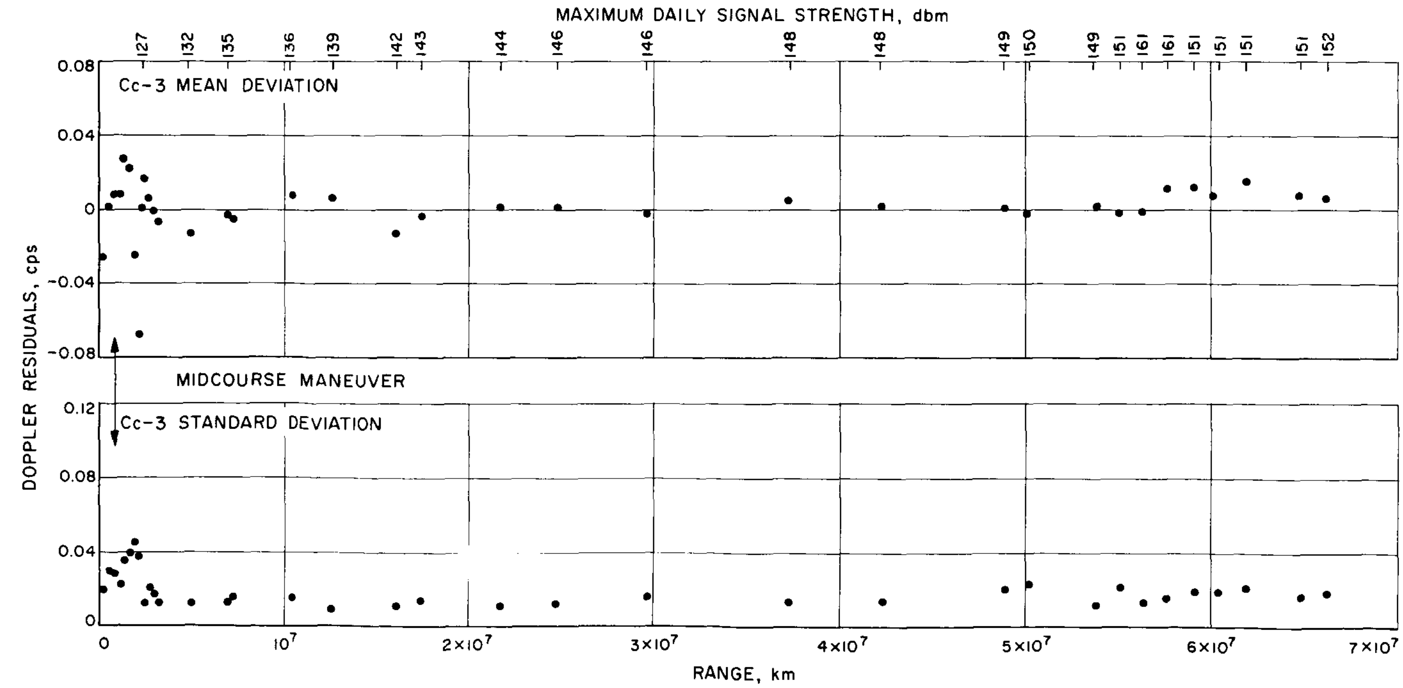

Fig. 15. DSIF-2 Cc-3 doppler mean and standard deviation vs range

Table 9. DSIF-4 ODP statistics

Date	Pass	Day of year	Type data	No. of data points	Mean	Standard deviation
					deg	deg
27 Aug	1	239	HA	285	−0.024	0.013
28	2	240	↓	459	−0.001	0.004
29	3	241		385	−0.012	0.010
30	4	242		353	−0.006	0.013
31	5	243		180	−0.063	0.033
1 Sept	6	244		517	−0.059	0.039
2	7	245		515	−0.046	0.047
3	8	246		385	−0.050	0.038
4	9	247		348	−0.015[a]	0.006[a]
27 Aug	1	239	Dec	308	−0.003	0.009
28	2	240	↓	459	0.000	0.006
29	3	241		335	−0.012	0.009
30	4	242		355	0.002	0.029
31	5	243		180	0.004	0.014
1 Sept	6	244		517	0.001	0.011
2	7	245		515	0.001	0.010
3	8	246		386	0.011	0.019
4	9	247		352	0.004	0.018
					cps	cps
27 Aug	1	239	C-2	103	0.005	0.027
28	2	240	↓	353	0.047	0.100
29	3	241		188	0.157	0.438
30	4	242		251	0.071	0.426
28	2	240	C-3	147	−7.65	6.50
29	3	241	↓	228	1.95	3.92
30	4	242		117	4.63	0.151
31	5	243		135	−4.69	2.51
1 Sept	6	244		144	5.14	0.621
2	7	245		275	6.46	4.64
3	8	246		145	5.61	0.195
4	9	247		234	8.56	4.35

[a]Changed to spacecraft directional antenna.

V preflight checkouts were conducted. Successful commands were transmitted and verified for the following:

1. Midcourse maneuver, 4 September
2. Science off, 31 October
3. Science on, 8 November
4. Encounter mode start, 14 December
5. Encounter mode end, 14 December
6. Update antenna hinge angle, 15 and 20 December

During periods of Cc-3 doppler tracking, the output of the DSIF-2 doppler detector was transmitted via microwave to the doppler counting system at DSIF-3. Data were then counted in a continuous mode at DSIF-2 and in a 50 sec destruct mode at DSIF-3. Results between the two counting systems compared favorably.

4. DSIF-4

a. Acquisition. DSIF-4 acquired the spacecraft at 073730 and the transmitter was turned on at 0751 in an attempt to acquire two-way doppler lock. The transmitter was turned off at 0754 to assure telemetry during Sun acquisition. Two-way lock was not achieved primarily because of lack of time for sweeping the transmitter VCO frequency for acquisition. The receiver was in and out of lock from 0812 to 0839 while DSIF-5 was attempting two-way lock. The transmitter was turned on at 0844 and two-way lock was achieved at 084432. DSIF-4 continued in the two-way doppler mode until 1000 when the transmitter was turned off on instructions by net control.

b. Premidcourse. Tracking data statistics as determined by the ODP are presented in Table 9.

Angular data were corrected for the optical pointing error determined from star tracks during 1961–1962. The error remaining is attributed to RF pointing error due to thermal deflections, uncompensated refraction and additional deflections due to gravity (Fig. 16–18). There is an additional discontinuity of 0.02 deg in the HA residuals at the HA corresponding to approximately 18 deg elevation angle. The refraction correction is changed at this elevation angle and results in this discontinuity.

The HA and Dec residuals from the ODP during pass 2 were curve fitted to a polynomial by the method of least squares to determine the additional error due to RF axis deflections. Plots of HA and Dec residuals from

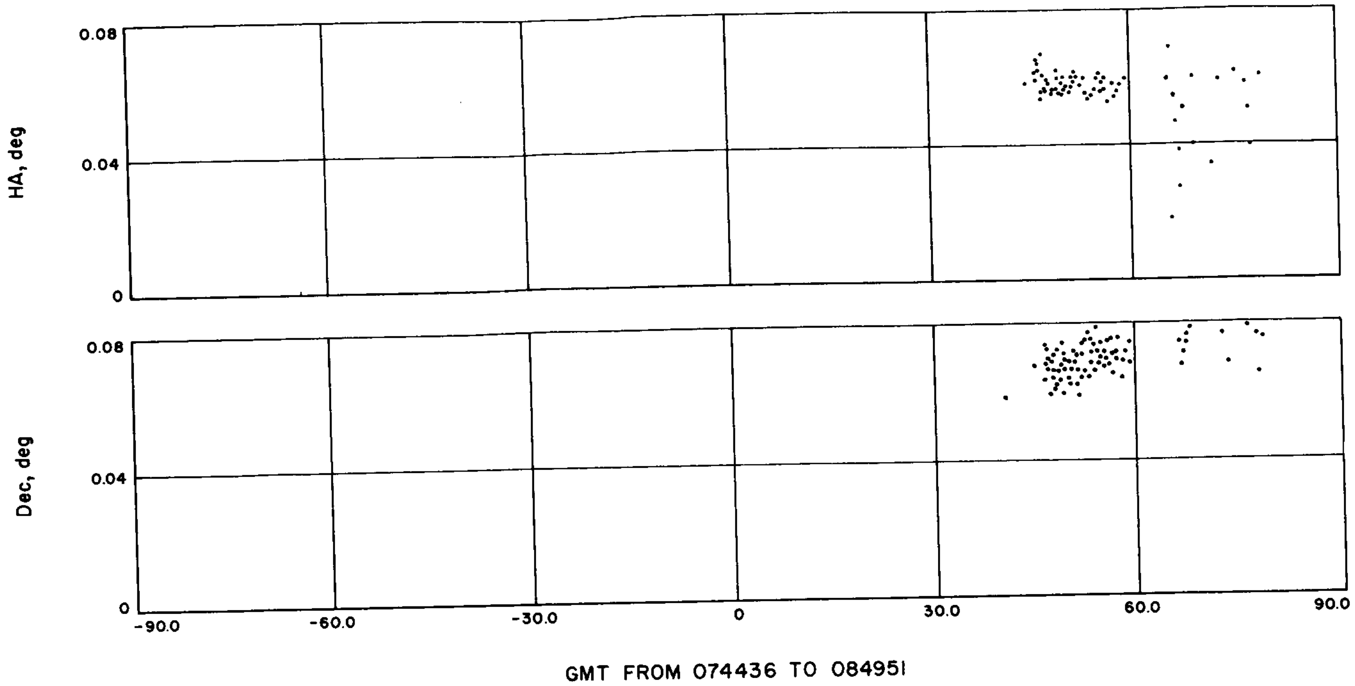

Fig. 16. DSIF-4 Dec and HA residuals vs time (pass No. 1)

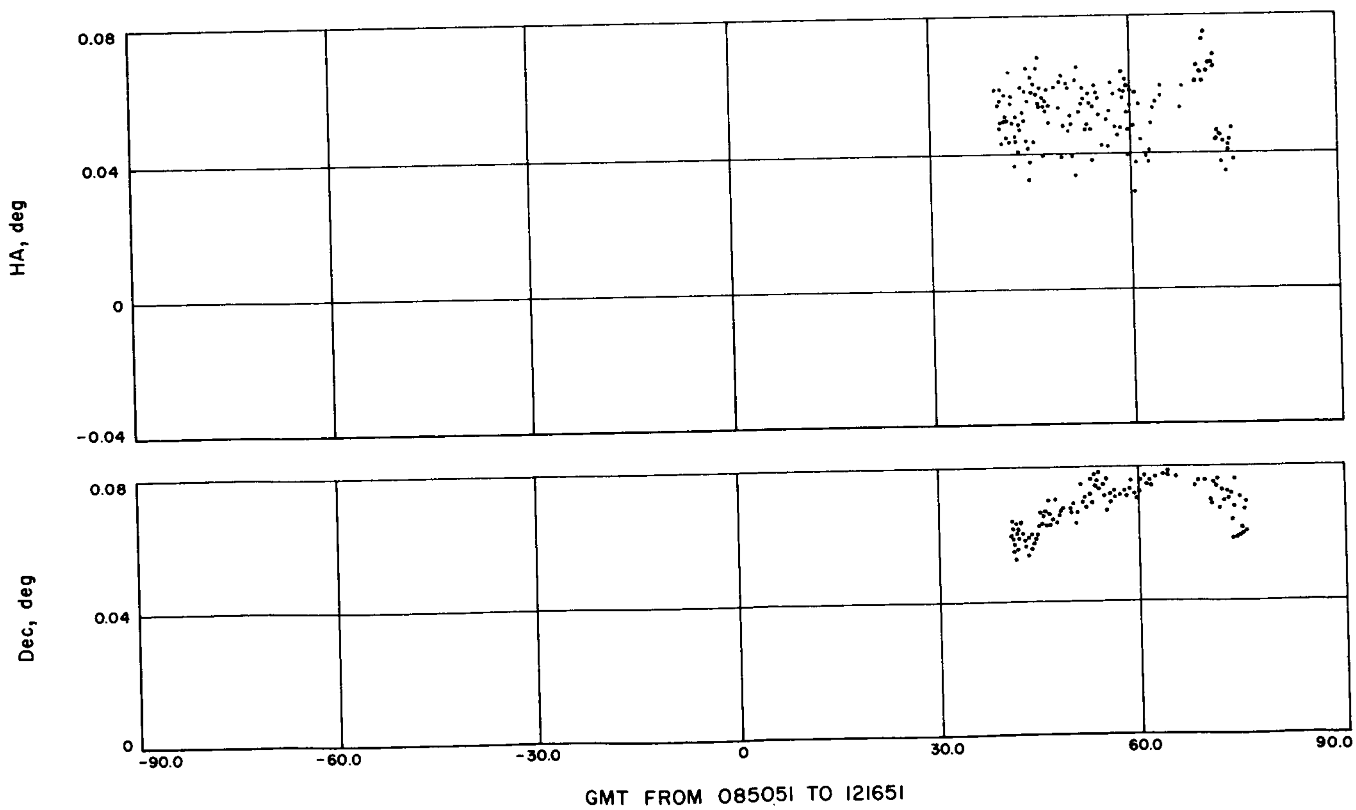

Fig. 17. DSIF-4 Dec and HA residuals vs time (pass No. 1A)

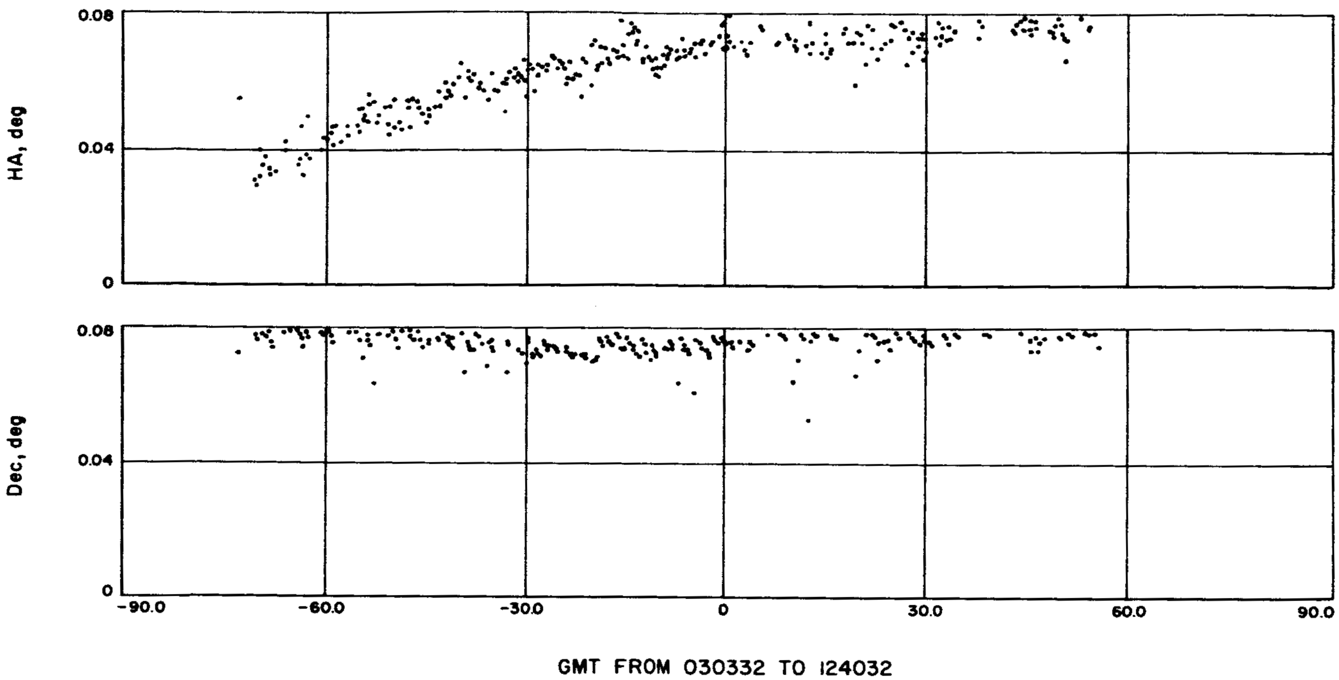

Fig. 18. DSIF-4 Dec and HA residuals vs time (pass No. 2)

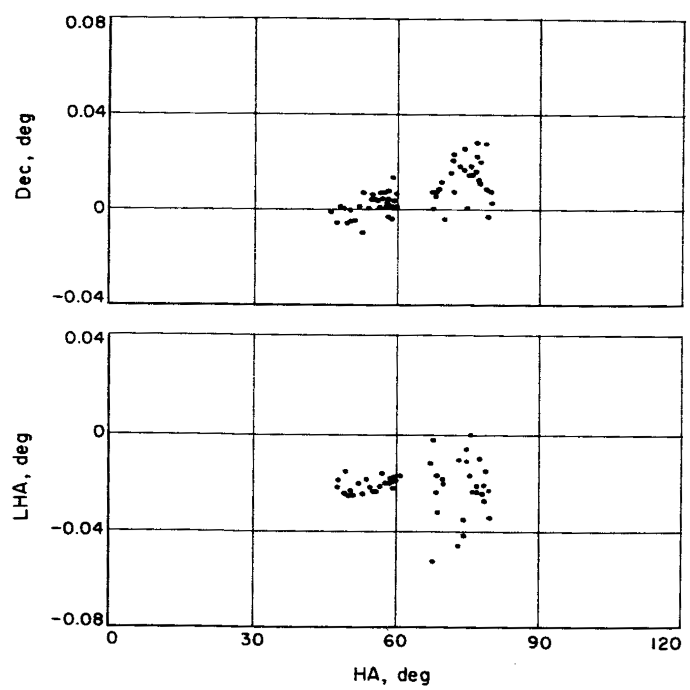

Fig. 19. DSIF-4 LHA and Dec residuals vs HA, 27 Aug 1962 (pass No. 1)

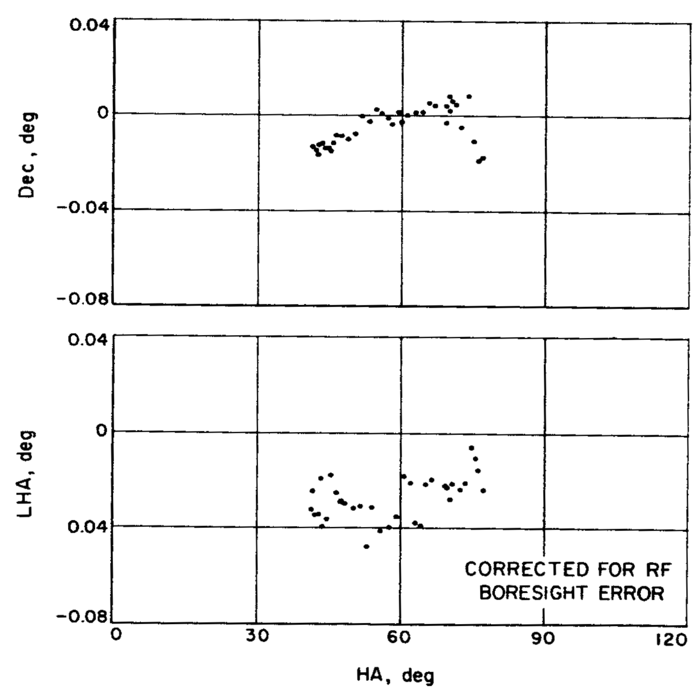

Fig. 20. DSIF-4 LHA and Dec residuals vs HA, 27 Aug 1962 (pass No. 1A)

the ODP during pass 1 and 2 utilizing these new coefficients are presented as Fig. 19–21. The mean error resulting from these coefficients is given in Table 9 and is <0.012 deg for passes 2 thru 4. The mean error during pass 1 was 0.024 deg and is attributed to the high tracking rates during the early part of the pass. The total angular error coefficients representing the optical pointing error and RF boresight errors are contained in Table 10.

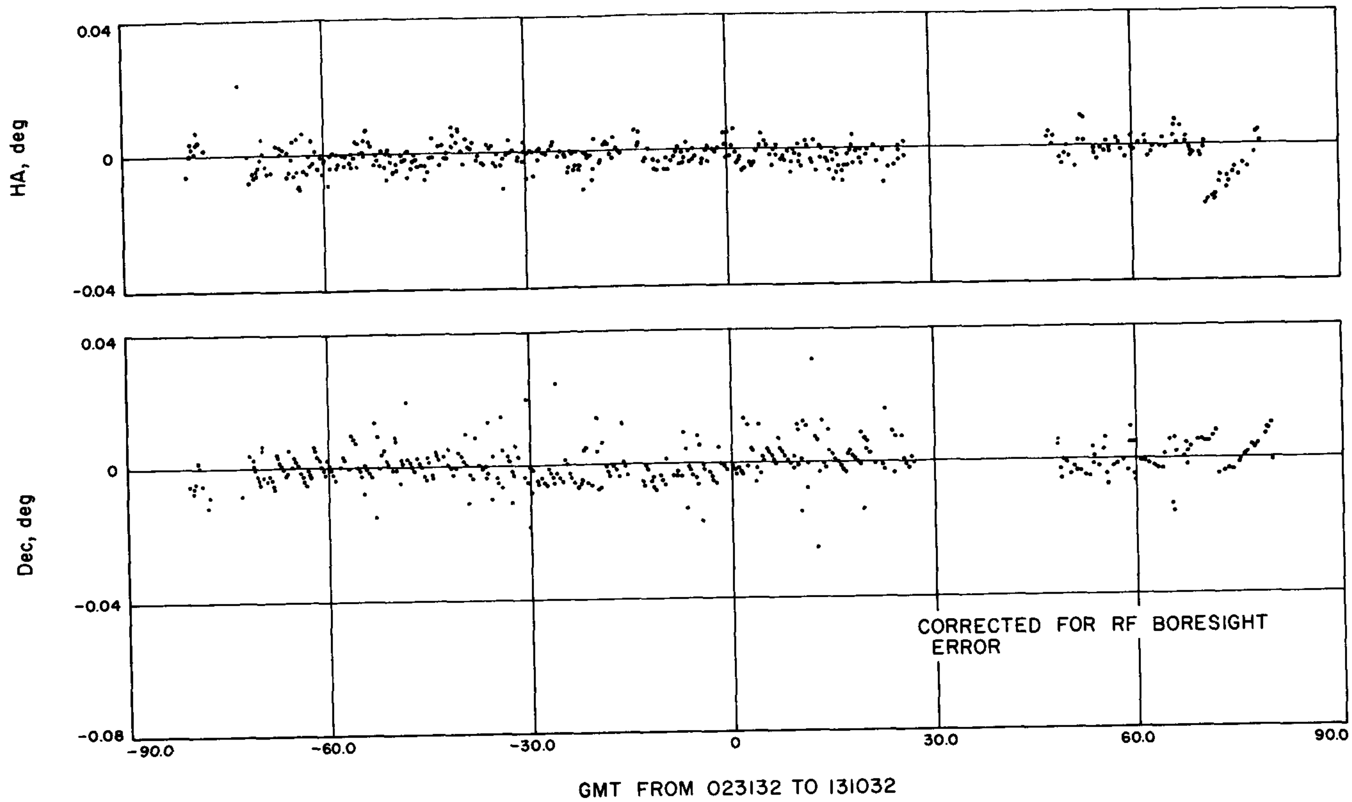

Fig. 21. DSIF-4 Dec and HA residuals vs time (pass No. 2)

Table 10. Total angular error coefficients

HA	Dec
$A_{00} = 8.0146025 \times 10^{-2}$	$B_{00} = 9.0860527 \times 10^{-2}$
$A_{01} = +5.45289422 \times 10^{-1}$	$B_{01} = +1.34214922 \times 10^{-4}$
$A_{02} = +2.48249580 \times 10^{-6}$	$B_{02} = -1.41108901 \times 10^{-5}$
$A_{03} = +2.24555914 \times 10^{-7}$	$B_{03} = 0.0$
$A_{10} = 6.4243077 \times 10^{-4}$	$B_{10} = -3.8345691 \times 10^{-4}$
$A_{11} = +8.69584098 \times 10^{-6}$	$B_{11} = +3.34771543 \times 10^{-6}$
$A_{12} = -6.52074417 \times 10^{-7}$	$B_{12} = +1.01895206 \times 10^{-7}$
$A_{13} = -1.59490382 \times 10^{-8}$	$B_{13} = 0.0$
$A_{20} = -3.3956128 \times 10^{-7}$	$B_{20} = -8.5070846 \times 10^{-6}$
$A_{21} = -7.89511508 \times 10^{-8}$	$B_{21} = +4.53942058 \times 10^{-9}$
$A_{22} = -7.04116079 \times 10^{-9}$	$B_{22} = +2.09578021 \times 10^{-9}$
$A_{23} = -1.23595449 \times 10^{-10}$	$B_{23} = 0.0$
$A_{30} = -6.3636126 \times 10^{-8}$	$B_{30} = -5.5657391 \times 10^{-9}$
$A_{31} = +1.90513748 \times 10^{-9}$	$B_{31} = 0.0$
$A_{32} = +3.95248319 \times 10^{-10}$	$B_{32} = 0.0$
$A_{33} = +9.57751208 \times 10^{-12}$	$B_{33} = 0.0$

Preflight calibration tests indicated a bias of 0.05 deg between the optical axis and the RF axis in both HA and Dec (Table 11). Biases observed during tracking were approximately 0.06 deg in HA and 0.07 deg in Dec when using optical calibration coefficients only. The discrepancy between preflight and inflight is attributed to the change in declination as the declination of the collimation tower is 47 deg and the nominal inflight declination was 350 deg. However, the close agreement between the preflight and inflight RF axis biases indicates that the preflight B/P test may be used as a calibration tool. Additional investigation of the effectiveness of the B/P test as an angular calibration test should be conducted for all stations on all missions.

The SD of the HA residuals increased from 0.013 to 0.033 deg between passes 4 and 5. The mean error also changed from −0.006 to −0.063 deg. Investigation of the residual plots revealed that the residuals contained a sinusoid of 0.050 deg peak-to-peak and frequency of 8 cps/hr. The amplitude of this sinusoid increased on subsequent passes to 0.130 deg peak-to-peak just prior to Earth acquisition and changeover to the high gain antenna at 0529 on 3 September (Fig. 22). After changeover to the high gain antenna, the HA residuals no longer

Table 11. DSIF-4 table of boresight shifts

Day of year	HA					Dec				
	TV boresight 1	RF boresight 2	Diff 2–1	Optical boresight 3	Diff 2–3	TV boresight 4	RF boresight 5	Diff 5–4	Optical boresight 6	Diff 5–6
239 Pre	317.224	317.255	0.031	317.220	0.035	46.878	46.924	0.046	46.870	0.054
239 Post	.208	.358	0.050	.206	0.052	.852	.876	0.024	.846	0.030
240 Pre	.232	.254	0.022	.206	0.048	.856	.914	0.042	.848	0.066
241 Pre	.230	.253	0.023	.218	0.035	.856	.902	0.046	.848	0.054
242 Pre	.234	.248	0.014	.212	0.036	.856	.907	0.053	.850	0.057
242 Post	.208	.264	0.056	.210	0.054	.858	.898	0.040	.852	0.046
243 Pre	.228	.250	0.032	.210	0.040	.854	.905	0.051	.852	0.053
243 Post	.212	.256	0.044	.204	0.052	.856	.898	0.042	.850	0.048
244 Pre	—	—	—	—	—	—	—	—	—	—
244 Post	.206	.244	0.038	.210	0.034	.864	.898	0.034	.854	0.044
245 Pre	.218	.256	0.038	.208	0.048	.873	.907	0.034	.870	0.037
245 Post	.218	.362	0.044	.208	0.054	.859	.908	0.049	.858	0.050
246 Pre	.212	.230	0.018	.202	0.028	.867	.908	0.041	.866	0.042
246 Post	.212	.237	0.025	.208	0.029	.866	.898	0.032	.858	0.040
247 Pre	.230	.258	0.028	.218	0.040	.881	.937	0.056	.884	0.053
247 Post	.208	.240	0.032	.200	0.040	.846	.892	0.046	.846	0.046
248 Pre	.214	.250	0.036	.202	0.048	.848	.900	0.052	.844	0.056
248 Post	.212	.257	0.045	.206	0.051	.854	.914	0.060	.850	0.064
249 Pre	.228	.265	0.037	.210	0.055	.848	.911	0.063	.846	0.065
249 Post	.212	.269	0.057	.212	0.057	.854	.910	0.056	.848	0.062
250 Pre	.232	.261	0.029	.206	0.055	.848	.908	0.060	.848	0.060
250 Post	.218	.239	0.021	.206	0.033	.852	.906	0.054	.848	0.058
251 Pre	.230	.270	0.040	.204	0.066	.848	.907	0.059	.848	0.059
251 Post	.212	.249	0.037	.204	0.045	.856	.904	0.048	.848	0.056
252 Pre	.208	.254	0.046	.196	0.058	.862	.916	0.054	.860	0.056
252 Post	.216	.258	0.042	.212	0.046	.856	.900	0.044	.850	0.050

indicated the sinusoid, and the SD decreased from 0.047 to 0.006 deg. The HA RF error channel on the CEC recording indicated the same periodic function and became stable after Earth acquisition. This sinusoidal error is attributed to the instability of the servo system when the received signal strength is < -135 dbm and varying.

The C-2 doppler for DSIF-4 was normal for passes 1 and 2, but the SD of the residuals exceeded those of DSIF-5 by a factor of 2 for passes 3 and 4. The increase in SD is attributed partly to the limited transmitting power of 50 w. Additional contribution is due to the unstable transmitter VCO used at DSIF-4. The transmitter

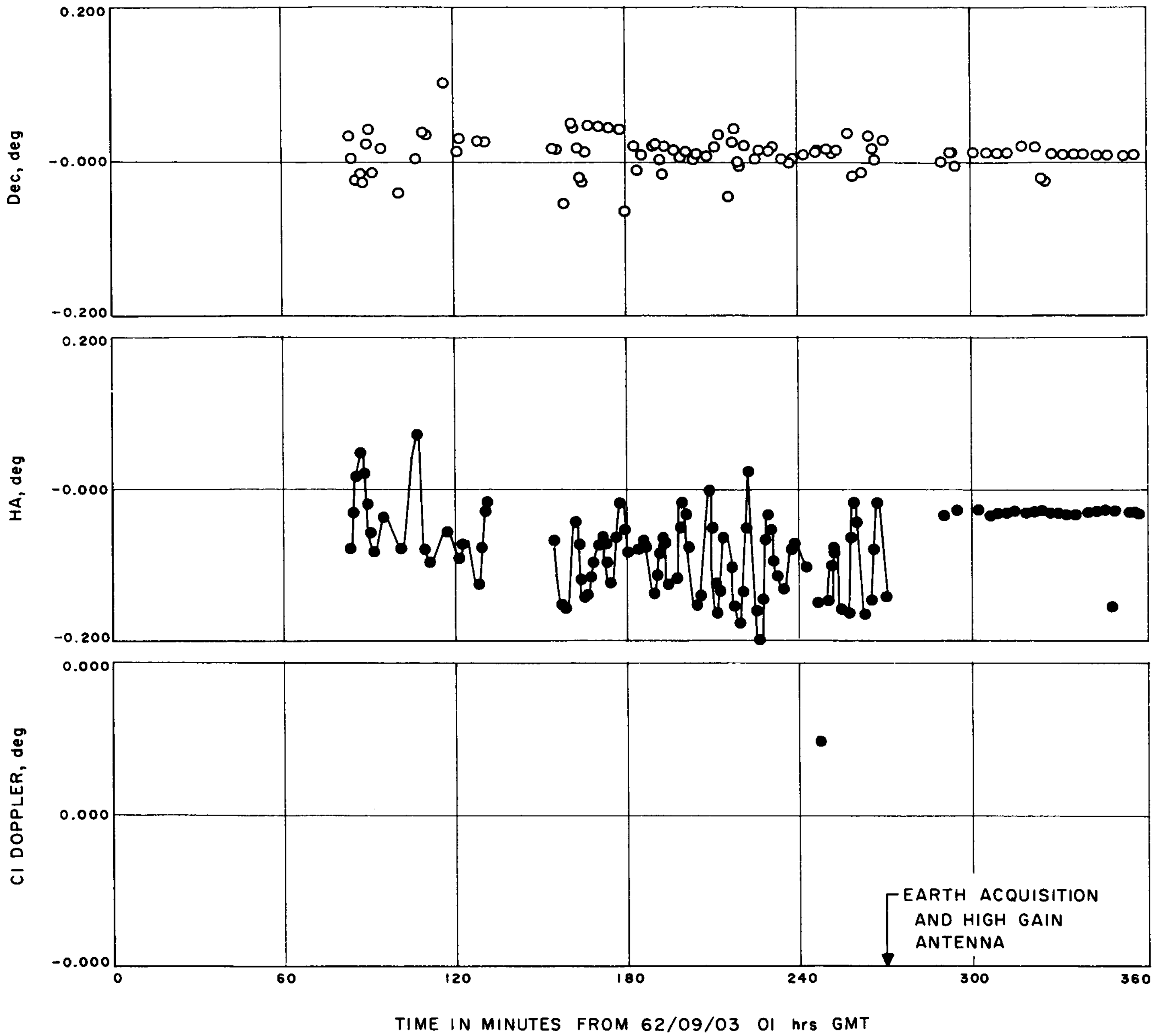

Fig. 22. DSIF-4 C-1 doppler, HA and Dec residuals vs time (pass No. 5)

VCO frequency drift exceeded specifications of 1 part in 10^8/15 min for over 25% of two-way doppler tracking. Plots of typical transmitter VCO frequencies are presented as Fig. 23 and 24.Two-way doppler tracking was discontinued after pass 4 on instructions from DSIF net control.

*c. **Postmidcourse.*** Tracking data statistics, as determined from the ODP, are presented in Table 12.

Biases were observed in the pseudo two-way doppler when DSIF-3 transmitter was using the ultra stable frequency standard. The bias was 4.43 cps on 29 September 1962 increasing at approximately 0.26 cps/day to 16.0 cps on 6 October 1962 (Fig. 25). The bias then changed to −8.95 cps on 14 October 1962 and varied systematically thru encounter.

Investigation of frequency standard setting errors revealed a setting error of approximately 0.9 ms/day and

Table 12. DSIF-4 postmidcourse tracking statistics

Date	Pass	Day of year	Data type	No. of data points	Mean	Standard deviation
					deg	deg
5 Sept	10	248	HA	561	0.054[a]	0.014
6	11	249		586	0.062[a]	0.016
7	12	250		493	0.068[a]	0.012
8	13	251		570	0.064[a]	0.013
9	14	252		251	0.059[a]	0.009
13	18	256		595	0.076[a]	0.015
16	21	259		603	0.076[a]	0.014
17	22	260		305	0.072[a]	0.012
24	29	267		441	0.059[a]	0.020
28	33	271		356	0.081[a]	0.013
30	35	273		485	0.066[a]	0.018
5 Oct	40	278		481	0.005	0.007
6	41	279		495	−0.006	0.004
13	48	286		419	0.008	0.009
14	49	287		514	0.006	0.007
23	58	296		1983	−0.003	0.011
24	59	297				
26	61	299				
27	62	300				
31	66	304		441	−0.008	0.009
5 Nov	71	309		500	−0.023	0.012
8	74	312		416	0.005	0.007
9	75	313		492	0.012	0.009
10	76	314		522	0.007	0.010
16	82	320		495	0.003	0.009
17	83	321		470	0.000	0.011
25	91	329		521	0.005	0.016
26	92	330		437	−0.027	0.024
30	96	334		490	0.026	0.020
5 Sept	10	248	Dec	561	0.107[a]	0.009
6	11	249		586	0.088[a]	0.008
7	12	250		493	0.082[a]	0.007
8	13	251		570	0.090[a]	0.011
9	14	252		251	0.088[a]	0.006
13	18	256		595	0.070[a]	0.010
16	21	259		603	0.076[a]	0.014
17	22	260		305	0.073[a]	0.010
24	29	267		441	0.081[a]	0.014
28	33	271		356	0.052[a]	0.009
30	35	273		485	0.072[a]	0.012
5 Oct	40	278		481	0.005	0.007
6	41	279		495	−0.006	0.005
13	48	286		419	−0.036	0.014
14	49	287		514	−0.043	0.009

[a]Corrected for OPE only.

Date	Pass	Day of year	Data type	No. of data points	Mean	Standard deviation	Transponder frequency
					deg	deg	
23	58	296	Dec	1983	−0.017	0.030	—
24	59	297					
26	61	299					
27	62	300					
31	66	304		441	−0.027	0.010	—
5 Nov	71	309		500	0.039	0.029	—
8	74	312		416	−0.003	0.012	—
9	75	313		492	−0.046	0.012	—
10	76	314		522	−0.041	0.011	—
16	82	320		495	−0.019	0.013	—
17	83	321		470	−0.021	0.013	—
25	91	329		521	−0.043	0.015	—
26	92	330		437	−0.034	0.021	—
30	96	334		490	0.008	0.031	—
					cps	cps	
6 Sept	11	249	C-3	434	− 15.4[b]	155.0[b]	—
7	12	250		350	971.0[b]	6600.0[b]	—
8	13	251		420	−114.0[b]	565.0[b]	—
9	14	252		114	7.51	0.445	—
24	29	267		136	12.3	0.573	—
30	35	273		172	14.0	0.223	—
6 Oct	41	279		156	16.0	0.055	—
15	50	288		61	− 8.95	0.031	—
1 Dec	97	335		9	− 8.25	12.6	—
7 Dec	103	341		61	− 2.96	0.025	—
8	104	342		161	− 2.86	0.030	—
12	108	346		216	− 1.91	0.509	—
13	109	347		152	− 0.78	0.431	—
14	110	348		58	− 28.5	22.6	—
16	112	350		151	− 43.3	0.446	—
16 Sept	21	259	C-1	679	174.0	3.38	960.036751
17	22	260		301	193.0	1.32	.036851
24	29	267		306	339.0	2.04	.036751
28	33	271		358	410.0	2.23	.036751
30	35	273		295	461.0	2.31	.036751
6 Oct	41	279		480	−197.0	1.82	.035964
7	42	280		313	−172.0	1.09	.035964
31	66	304		79	297.0	7.36	.036244
1 Nov	67	305		363	267.0	22.2	.036244
8	74	312		55	415.0	3.95	.036244
10	76	314		337	324.0	5.18	.036244
11	77	315		299	277.0	5.26	.036244
16	82	320		137	735.0	1.94	.036980
17	83	321		357	726.0	3.85	.036980
18	84	322		303	679.0	5.78	.036980

[b]Includes C-3 doppler data for DSIF-3 and -5 as transmitter stations.

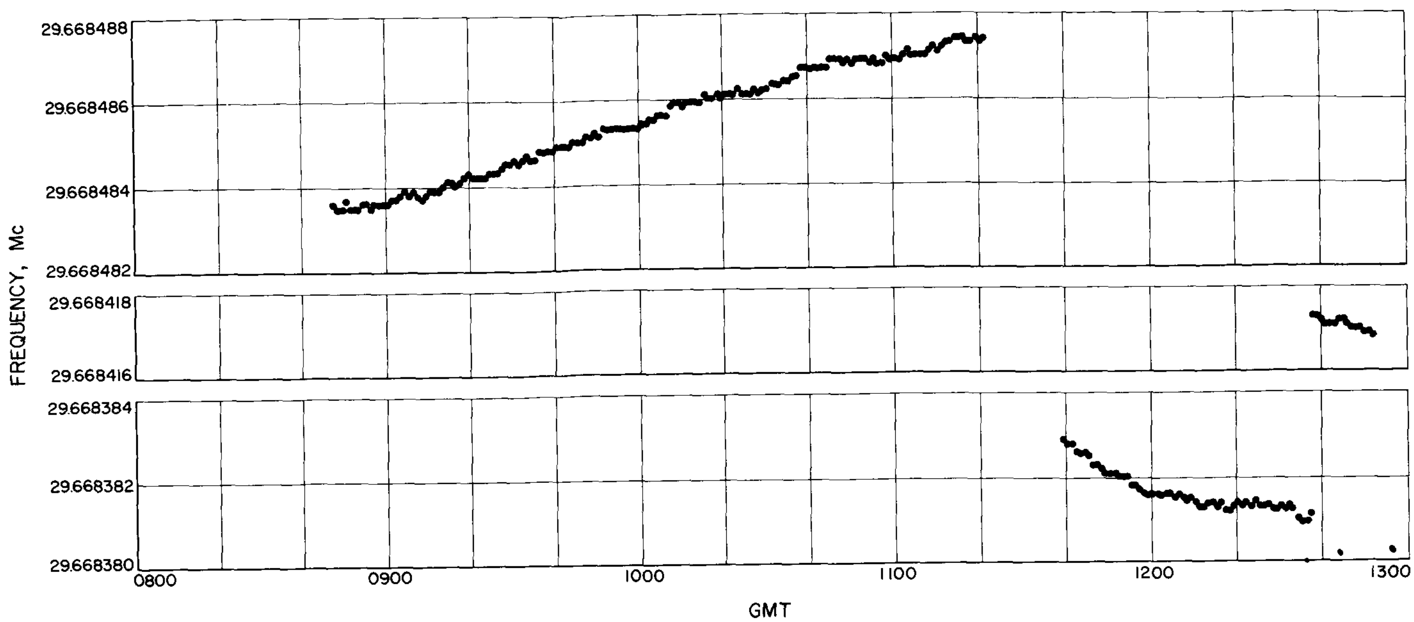

Fig. 23. DSIF-4 transmitter VCO frequency vs time, 27 Aug 1962

a frequency standard drift error of 0.025 ms/day. The error (Δf_3) in doppler due to the frequency standard is computed as follows:

$$\Delta f_3 = (30)\,(31/32)\,(96/89)\left(1 - \frac{\dot{r}_i + \dot{r}_q}{c}\right) fq \,\frac{\Delta f_s}{f_s}$$

Where

$\dot{r}_i$ = Spacecraft velocity relative to receiving station

$\dot{r}_q$ = Spacecraft velocity relative to transmitting station

f_q = Transmitted frequency (nominal 29.668212 Mc)

$\frac{\Delta f_s}{f_s}$ = Station standard set error (nominal <1 part in 10^8)

Station standard frequency setting errors of 1 ms/day is equivalent to 9.3 cps bias in C-3 doppler data. Figure 26 presents the station standard history during *Mariner II*. Figure 27 presents the error in C-3 doppler due to the error in the station standard. As can be seen in Fig. 27, the station standard error is responsible for approximately 50% of the bias observed during *Mariner II*. Possible sources of the remaining bias are: (1) the ODP or (2) the setting of the station reference oscillator. C-3 data during *Mariner II* were not considered primary; however, for future missions [when the rubidium standard is Goldstone duplicate standard (GSDS)] detailed investigation of error sources should be conducted so that C-3 data may be used as reliable secondary data.

C-1 data were spot checked during the mission to determine the spacecraft transponder stability and also compare C-1 doppler during periods of mutual coverage. Table 12 compares C-1 residuals from the ODP during periods of station mutual coverage. Figure 27 presents a history of mean pass transponder frequency versus day number.

Hour angle and declination angular data were investigated each week after midcourse maneuver to determine the adequacy of the total error coefficients. Examination of the HA and Dec residuals from the ODP indicates that the HA bias was <0.02 deg and declination bias was <0.05 deg. The inconsistency of the declination bias is due to the tracking procedure of locking in declination at the maximum signal strength with an estimated resolution of ≈ 0.07 deg. A plot of HA and Dec mean error versus pass number is presented in Fig. 28. A plot of HA and Dec residual standard deviation versus signal strength is presented as Fig. 29. This plot also contains points from the preflight B/P tests.

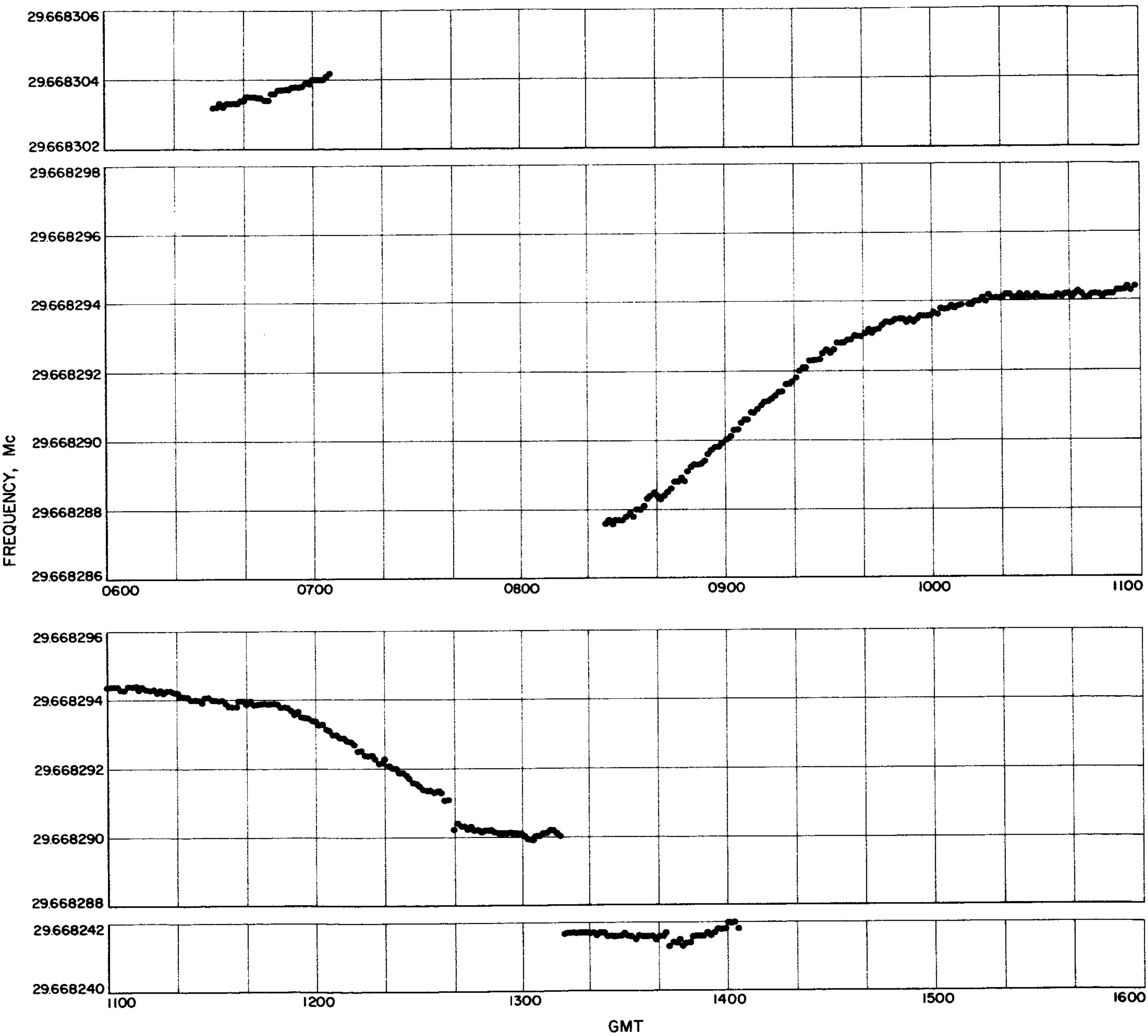

Fig. 24. DSIF-4 transmitter VCO frequency vs time, 29 Aug 1962

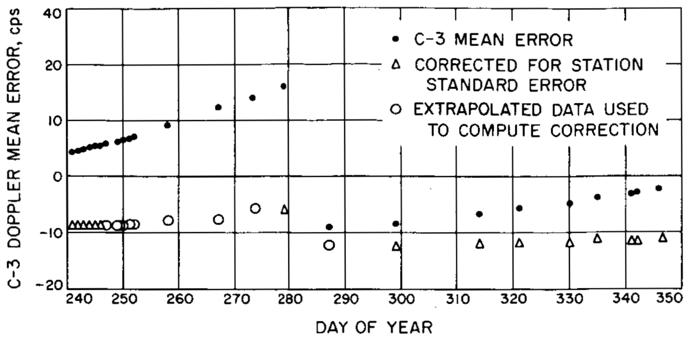

Fig. 25. DSIF-4 C-3 doppler mean error vs day of year

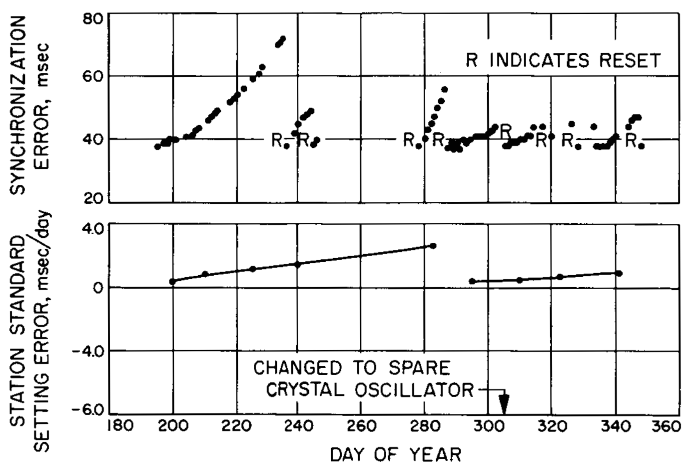

Fig. 26. DSIF-4 synchronization error and computed setting error vs day of year

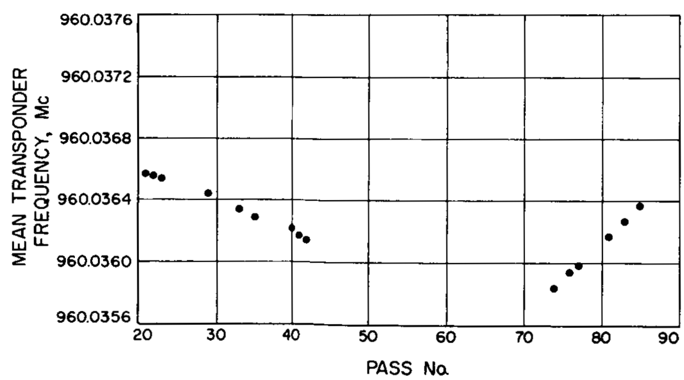

Fig. 27. Mean transponder frequency vs pass No.

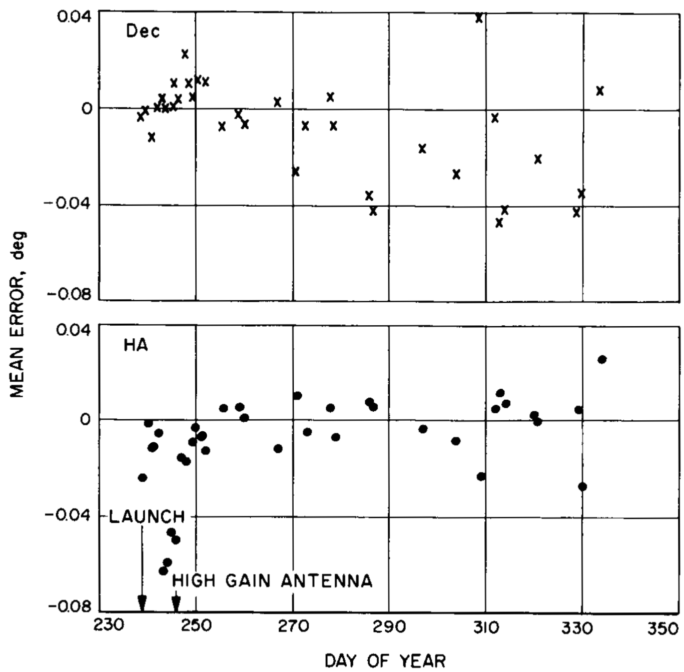

Fig. 28. DSIF-4 HA and Dec mean error vs day of year

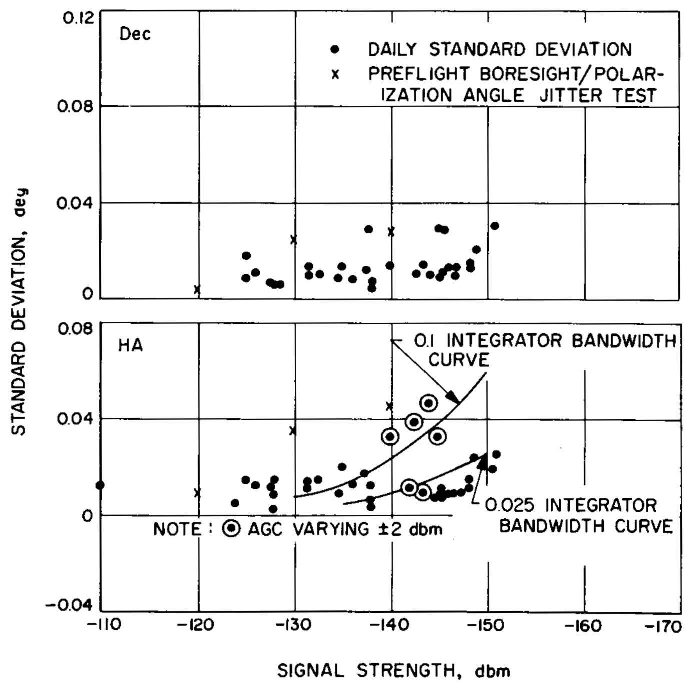

Fig. 29. DSIF-4 HA and Dec standard deviation vs signal strength

5. DSIF-5

a. Acquisition. DSIF-5 acquired the spacecraft at 072158 GMT with the receiver going in and out of lock several times until 075357. The transmitter was turned on from 081200 to 083900 in an unsuccessful effort to obtain two-way doppler lock. Reacquisition in GM-3 was established at 083942 and remained in GM-3 until 100000 when the transmitter was again turned on and two-way lock established at 100220.

Table 13. DSIF-5 orbit determination program statistics

Date	Pass	Day of year	Data type	No. of data points	Mean	Standard deviation
					deg	deg
27 Aug	1	239	HA	664	0.0020	0.0168
28	2	240		510	0.0012	0.0063
29	3	241		483	0.0008	0.0080
30	4	242		349	0.0057	0.0091
31	5	243		397	0.0067	0.0105
27	1	239	Dec	664	0.0277	0.0147
28	2	240		511	0.0293	0.0109
29	3	241		483	0.0301	0.0052
30	4	242		349	0.0321	0.0076
31	5	243		397	0.0374	0.0136
					cps	cps
27	1	239	C-2	375	0.112	0.497
28	2	240		481	0.102	0.247
29	3	241		393	0.111	0.228
30	4	242		32	0.100	0.188
31	5	243		378	0.145	0.313
1 Sept	6	244		114	0.108	0.237
2	7	245		72	0.156	0.269
3	8	246		76	−0.053	0.339
4	9	247		369	0.050	0.312
27 Aug	1	239	C-3	104	11.2	31.8
28	2	240		21	1.71	0.02
29	3	241		47	−7.97	4.42
1 Sept	6	244		13	1.95	0.11
2	7	245		5	1.97	0.02

The transmitter VCO frequency was not recorded while attempting two-way doppler lock from 081200 to 083900 rendering it impossible to determine if the search procedure was proper. The spacecraft AGC indicated two-way lock from 083300 to 083800.

b. Premidcourse. Tracking data statistics as determined by the ODP are presented in Table 13. The tracking feed was removed at DSIF-5 after the pass on day 243; therefore, HA and Dec statistics are available only thru pass 5.

Several large positive two-way doppler residuals were noted during each pass at approximately 15-min intervals. Since DSIF-5 was using the same doppler loop monitoring procedure as DSIF-2, the large residuals are attributed to the same problem discussed earlier. The fix made at DSIF-2 during *Mariner II* tracking was made at DSIF-5.

The stability of the transmitter VCO frequency was well within specifications for all passes during which two-way doppler was taken. Plots indicating typical transmitter VCO frequency stability are presented as Fig. 30 and 31.

Angular data at DSIF-5 were taken in the automatic tracking mode for passes 1 thru 5. The angular error coefficients obtained from star tracks during 1961–1962 were used to correct the optical pointing error. The error remaining is attributed to RF boresight error,

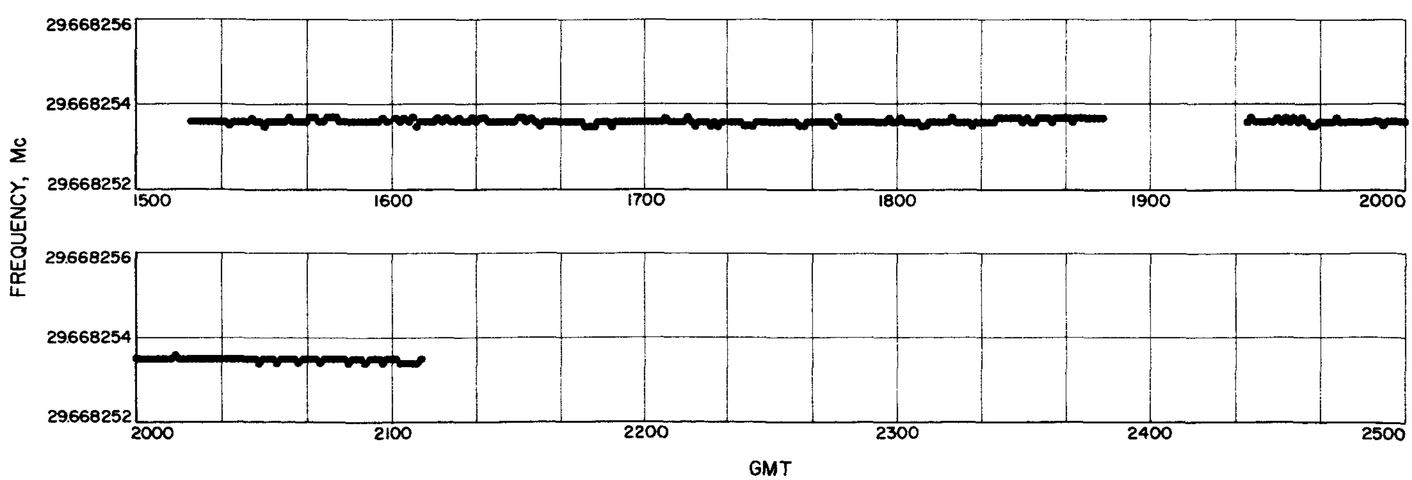

Fig. 30. DSIF-5 transmitter VCO frequency vs time, 30 Aug 1962

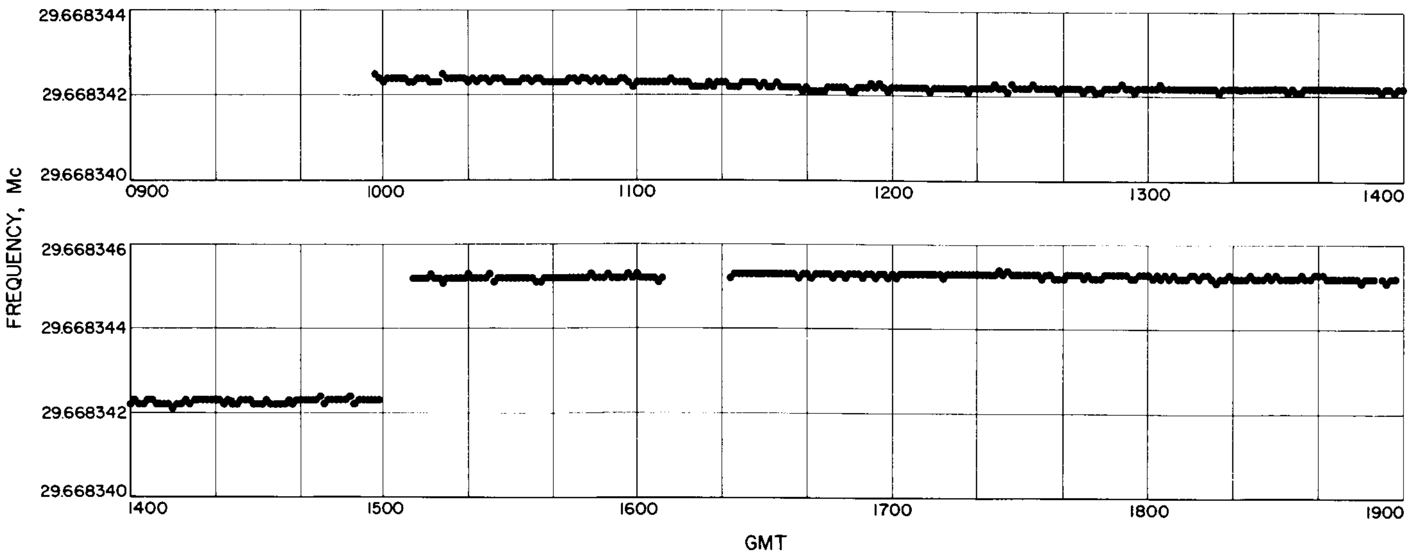

Fig. 31. DSIF-5 transmitter VCO frequency vs time, 31 Aug 1962

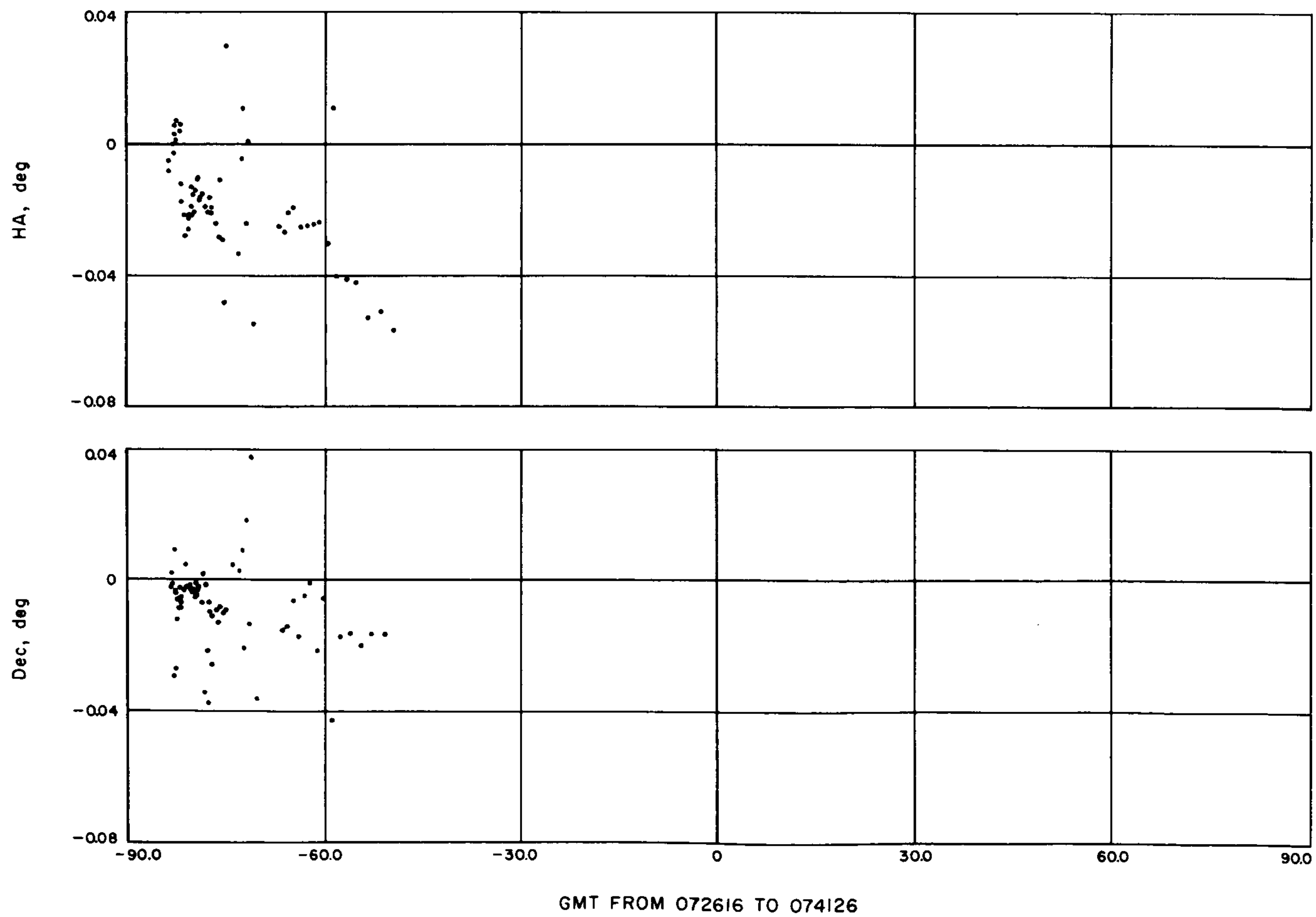

Fig. 32. DSIF-5 HA and Dec residuals vs time (pass No. 1)

thermal deflections, uncompensated refraction correction and additional deflections due to gravity (Fig. 32–34). There was a shift of approximately 0.01 deg in the Dec residual at 350 deg HA on each pass. The discontinuity is most probably due to bearing shift due to change in loading. A similar discontinuity was noted during pass 2 at DSIF-2 at an HA of 8 deg during *Ranger IV* tracking.

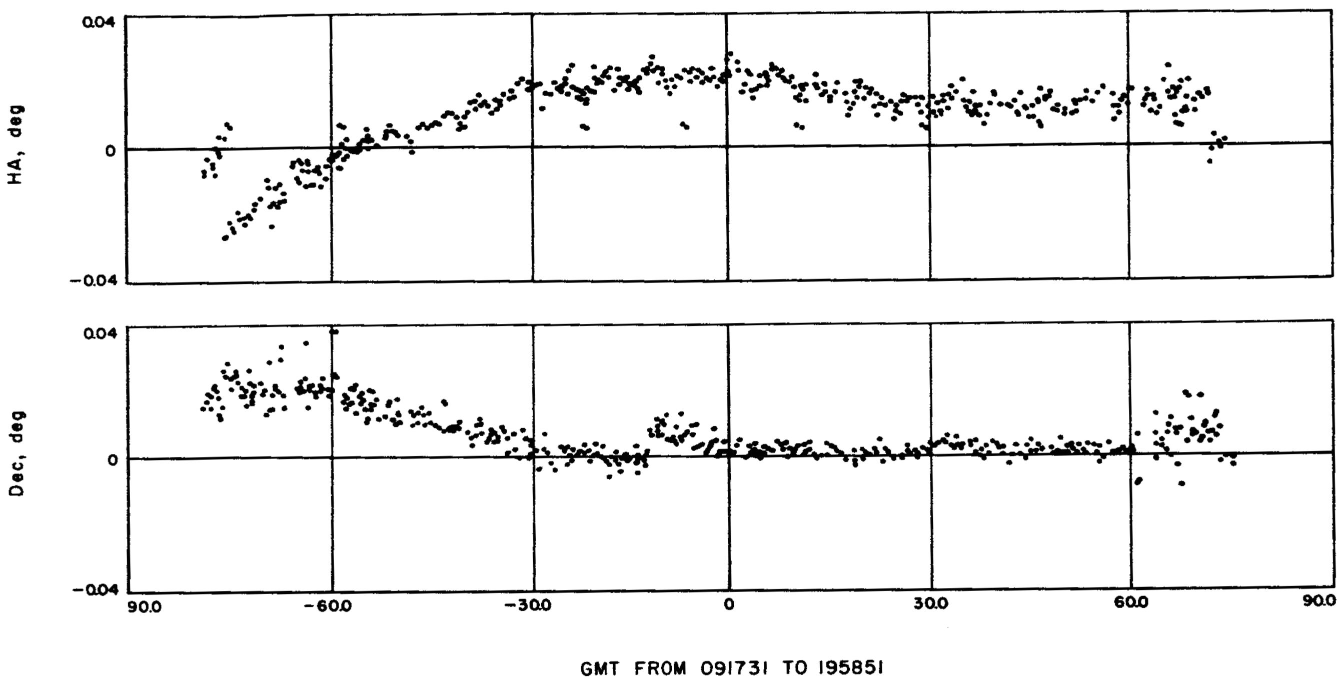

Fig. 33. DSIF-5 HA and Dec residuals vs time (pass No. 1A)

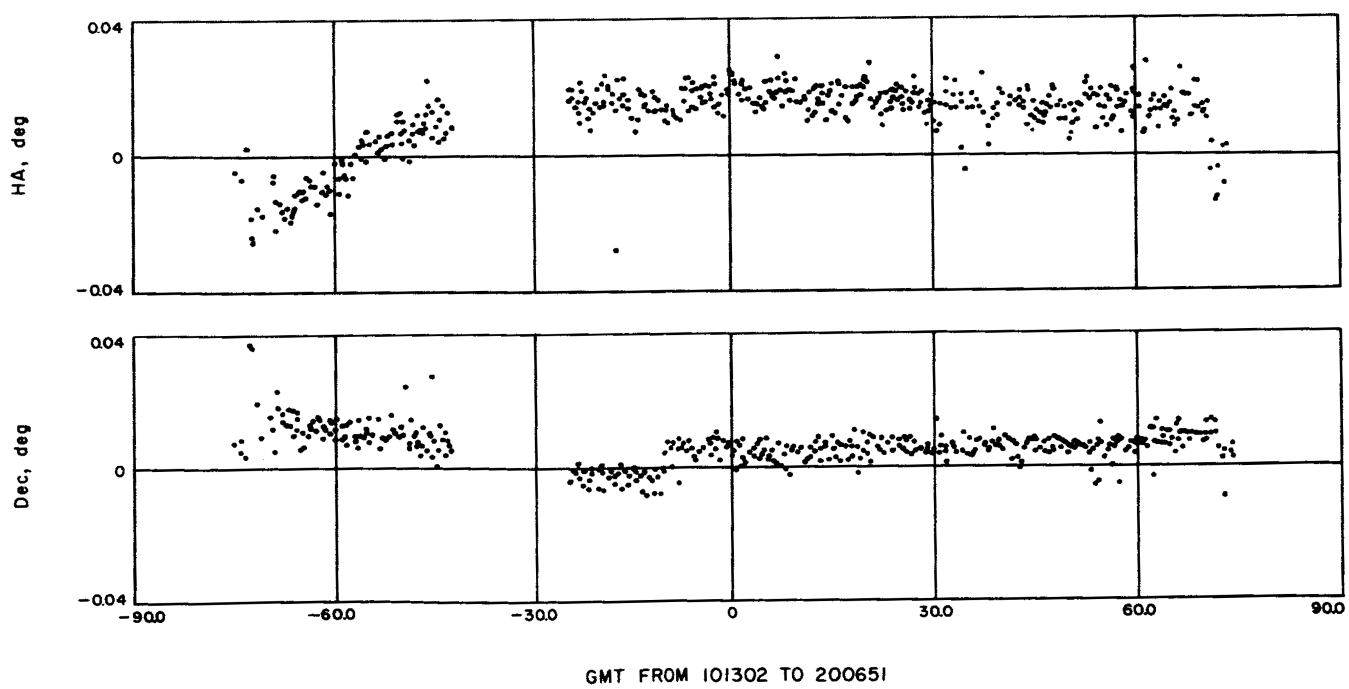

Fig. 34. DSIF-5 HA and Dec residuals vs time (pass No. 2)

There is a discontinuity of approximately 0.02 deg in the HA residuals at HA corresponding to approximately 18-deg elevation angle. The method for refraction correction is changed at this elevation angle and results in this discontinuity.

In order to better represent the total pointing error (optical + RF), the HA and Dec residuals (corrected for optical error only) from pass 2 were each fitted to a polynomial by a linear least squares. The combined angular error coefficients were then used to correct the

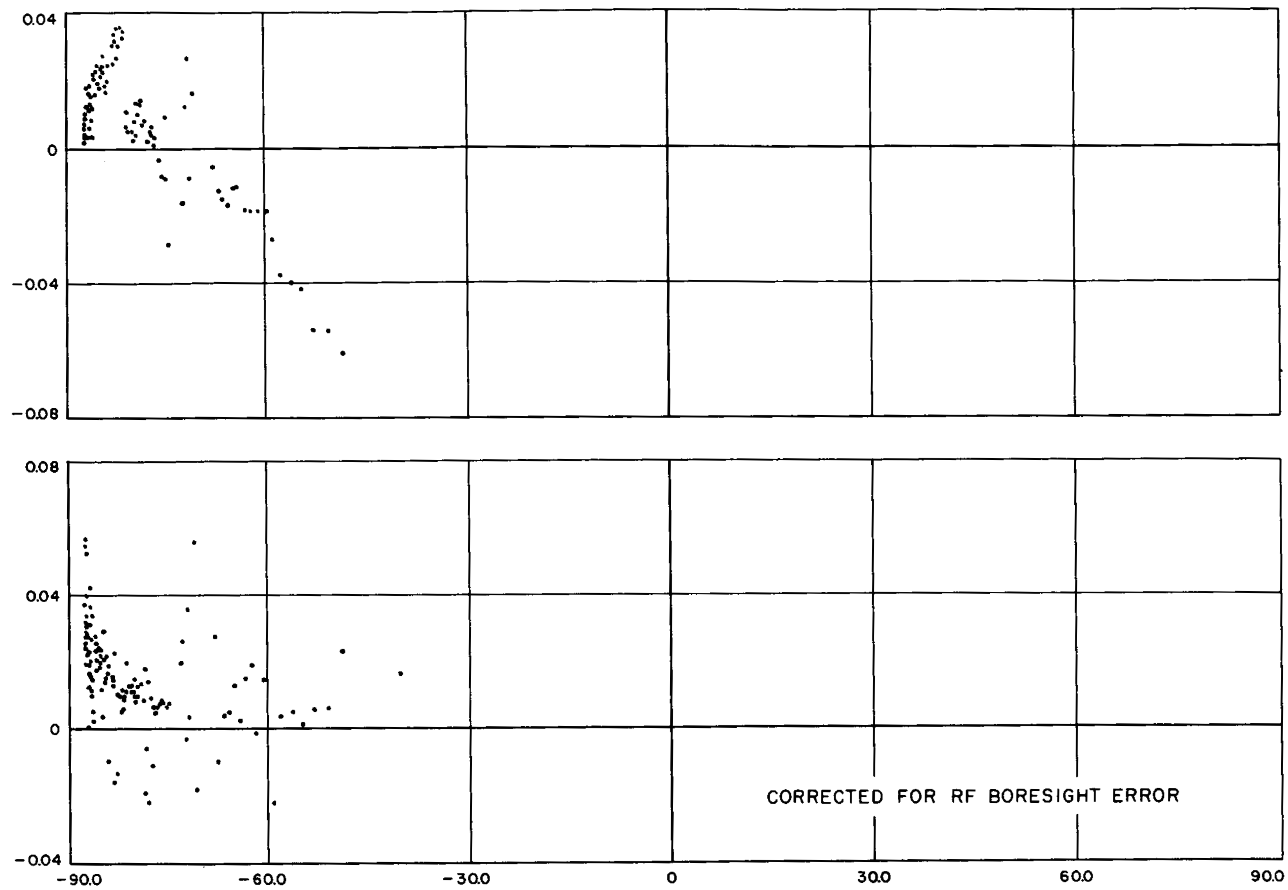

Fig. 35. DSIF-5 HA and Dec residuals vs time (pass No. 1)

Table 14. DSIF-4 preflight RF boresight errors

Day of year	HA					Dec				
	TV boresight 1	RF boresight 2	Diff 2–1	Optical boresight 3	Diff 2–3	TV boresight 4	RF boresight 5	Diff 5–4	Optical boresight 6	Diff 5–6
239 Pre	315.184	315.174	−0.010	315.188	−0.014	48.378	48.378	0.0	48.374	+0.004
240	.196	.170	−0.026	.202	−0.032	.386	.374	−0.012	.380	−0.006
241	.178	.134	−0.044	.174	−0.040	.390	.380	−0.010	.390	−0.010
242	.180	.166	−0.014	.180	−0.014	.384	.380	−0.004	.382	−0.002
243	.178	.172	−0.006	.174	−0.002	.392	.400	0.008	.388	0.011

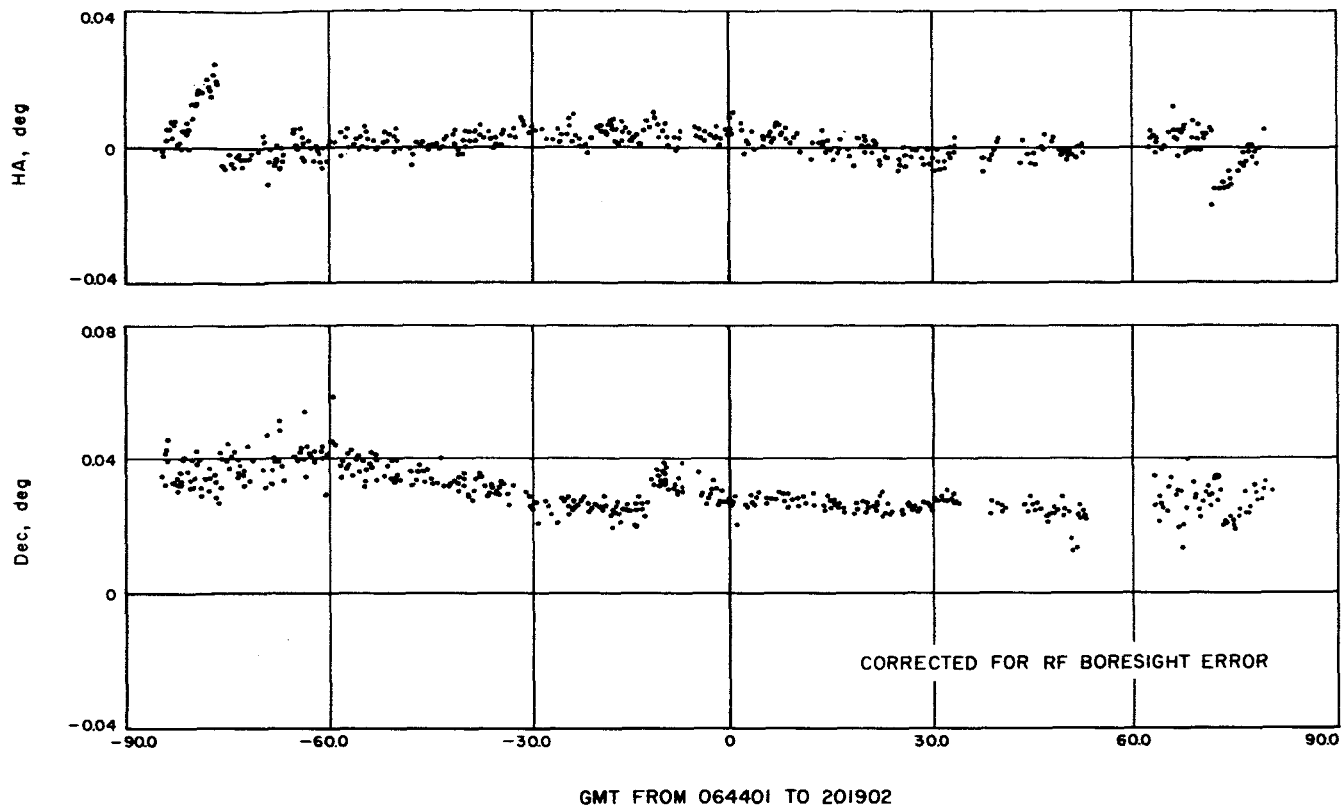

Fig. 36. DSIF-5 HA and Dec residuals vs time (pass No. 1A)

angular data during pass 1. HA and Dec residuals from the ODP are presented in Fig. 35–37. Table 14 contains a record of preflight RF boresight errors at the collimation tower.

The HA and Dec error during high tracking rates before effective turnaround (Δ HA changing from − to +) could not be entirely corrected by the angular error coefficients. It is believed that this error may be caused by lag in the servo system due to angular acceleration. Investigation of the servo loop transfer function to determine the error due to angular acceleration has been instigated.

Another possible source of error may be the change in RF pointing error as a function of declination as there is a change in declination from 318 deg at acquisition to 335 deg at effective turnaround. After turnaround declination remains nearly constant. Tests[3] conducted at DSIF-5 during Spring 1962 to determine quadripod deflection due to gravity indicated that an error of <0.008 deg could be expected in HA.

[3] Investigation of the DSIF 85-foot Antenna Structural Deflections Caused by Dead Load and Terminal Inputs, Floyd Stoller, August 7, 1962.

Table 15. DSIF-5 total angular error coefficients

HA	Dec
$A_{00} = 2.7012712 \times 10^{-2}$	$B_{00} = 3.0964575 \times 10^{-2}$
$A_{01} = 1.5852843 \times 10^{-4}$	$B_{01} = 1.0443459 \times 10^{-4}$
$A_{02} = 6.2453096 \times 10^{-6}$	$B_{02} = 3.6495579 \times 10^{-6}$
$A_{03} = 3.4384273 \times 10^{-7}$	$B_{03} = 2.0183882 \times 10^{-7}$
$A_{10} = 4.1445643 \times 10^{-4}$	$B_{10} = -5.0429648 \times 10^{-5}$
$A_{11} = 9.3636995 \times 10^{-6}$	$B_{11} = 4.5503798 \times 10^{-6}$
$A_{12} = -3.4191398 \times 10^{-7}$	$B_{12} = -9.4572764 \times 10^{-8}$
$A_{13} = -3.7665906 \times 10^{-9}$	$B_{13} = -7.1265086 \times 10^{-9}$
$A_{20} = 4.5531603 \times 10^{-7}$	$B_{20} = -7.9892838 \times 10^{-6}$
$A_{21} = -1.0353745 \times 10^{-8}$	$B_{21} = 5.8977874 \times 10^{-8}$
$A_{22} = -3.0418727 \times 10^{-9}$	$B_{22} = 3.6280184 \times 10^{-9}$
$A_{23} = -1.5236838 \times 10^{-11}$	$B_{23} = -5.1657298 \times 10^{-11}$
$A_{30} = -1.3219781 \times 10^{-8}$	$B_{30} = -1.0465099 \times 10^{-8}$
$A_{31} = 6.2245085 \times 10^{-10}$	$B_{31} = 0.0$
$A_{32} = 1.7992403 \times 10^{-10}$	$B_{32} = 0.0$
$A_{33} = 3.3140295 \times 10^{-12}$	$B_{33} = 0.0$

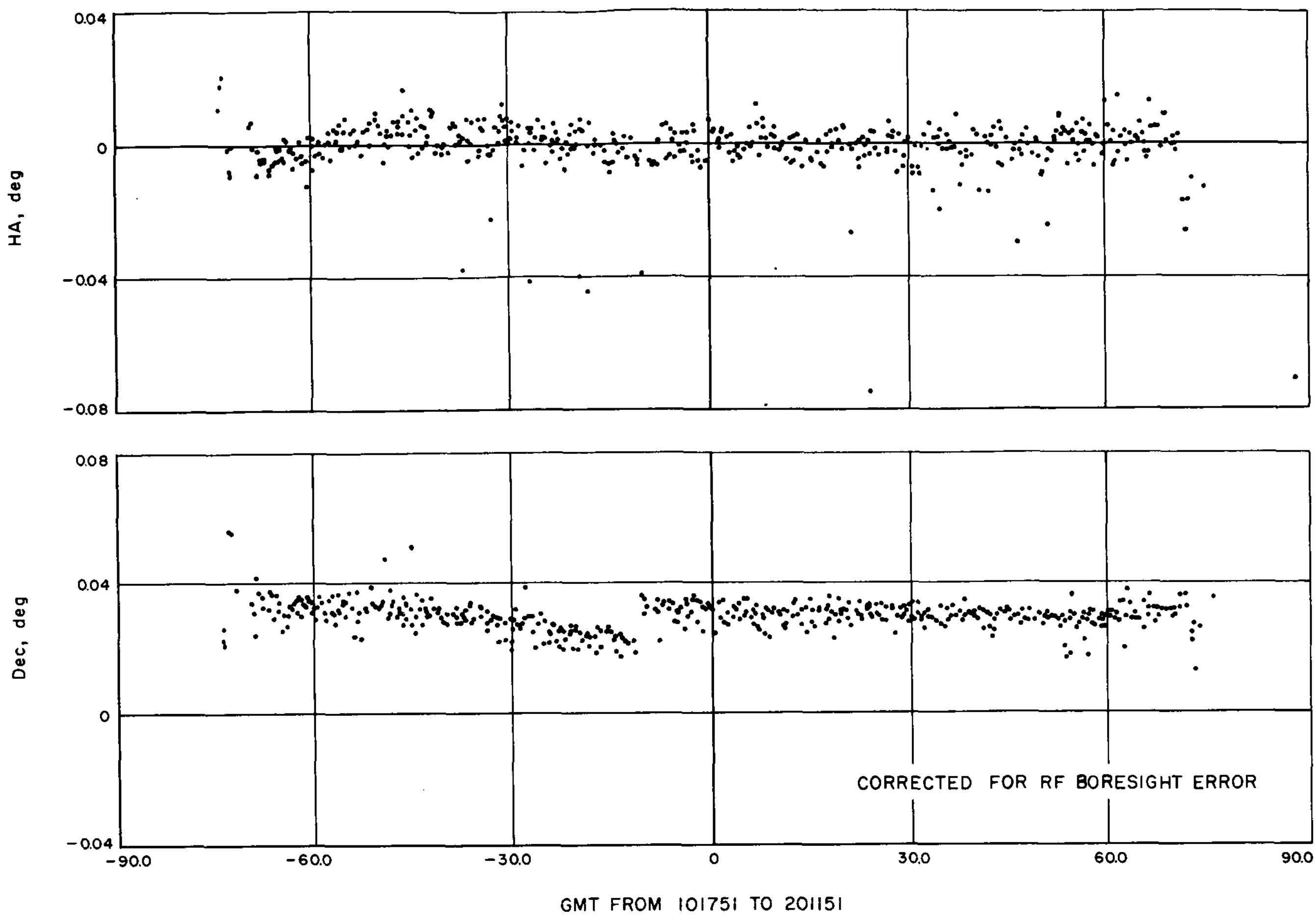

Fig. 37. DSIF-5 HA and Dec residuals vs time (pass No. 2)

Final angular error coefficients representing total pointing error are presented in Table 15.

c. Postmidcourse. DSIF-5 continued to track in the two-way doppler mode thru pass 13 on 8 September 1962. Two-way doppler tracking was discontinued after pass 13 on instructions by DSIF net control; however, tracking in the C-1 and C-2 modes was continued as scheduled until the end of mission, 4 January 1963.

Table 16 presents the statistics for all postmidcourse tracking as determined from the ODP.

A plot of two-way doppler SD versus range is presented as Fig. 38. There is a definite increase in the SD, and it is attributed to the transmitter VCO frequency instability and increased delay time between transmitting and receiving.

C-3 doppler with DSIF-3 transmitting and using the ultra stable frequency standard contained a bias of 1.73 cps on the 28 August 1962 pass. The bias increased on subsequent passes at the rate of 0.04 cps/day reaching a maximum of 2.87 cps on 30 September 1962. (Fig. 39). Between 30 September and 10 November the bias changed from 2.87 to −7.36 cps. A similar shift in the C-3 bias was noted between 6 and 14 October at DSIF-4. History of station standard checks were not available from DSIF-51. Biases observed in the C-3 doppler at DSIF-5 were within station time standard capability. Improved station standards will be available in the near future.

C-1 doppler was checked periodically during the mission to check the stability of the spacecraft transponder and to compare the station doppler during periods of mutual coverage. Table 17 presents the comparison of C-1 residuals during mutual coverage.

Table 16. DSIF-5 postmidcourse ODP statistics

Date	Pass	Day	Data type	No. of data points	Mean	Standard deviation	Transponder frequency	Date	Pass	Day	Data type	No. of data points	Mean	Standard deviation	Transponder frequency
					cps	cps		8	104	339	↓	41	− 5.89	0.039	
5 Sept	10	245	C-2	234	0.0923	0.306	Not applicable (N/A)	11	107	342		19	− 5.51	0.012	
6	11	246	↓	374	0.0319	0.364		12	108	343		22	− 4.54	3.93	
7	12	247		471	0.0747	0.350		13	109	344		50	− 4.79	0.405	
8	13	248		512	0.0532	0.269		16	112	347	↓	39	− 49.3	0.074	
7	12	247	C-3	91	2.26	0.352		5 Sept	10	245	C-1	26	338.0	8.88	960.036751
8	13	248	↓	37	2.28	0.545		7	12	247	↓	27	− 58.4	0.382	.036751
14	19	254		80	2.53	0.337		8	13	248		19	− 15.8	12.6	.036751
23	28	263		30	2.94	0.430		14	19	254		68	132.0	2.42	.036751
29	34	269		80	2.87	0.263		14 Oct	49	284		423	− 82.5	1.43	.036751
6 Oct	41	276		4	10.5	12.4		27 Nov	93	328		442	− 34.7	12.3	.036980
7 Dec	103	338	↓	13	− 5.92	0.015		9 Dec	105	340	↓	418	−116.	12.7	.036980

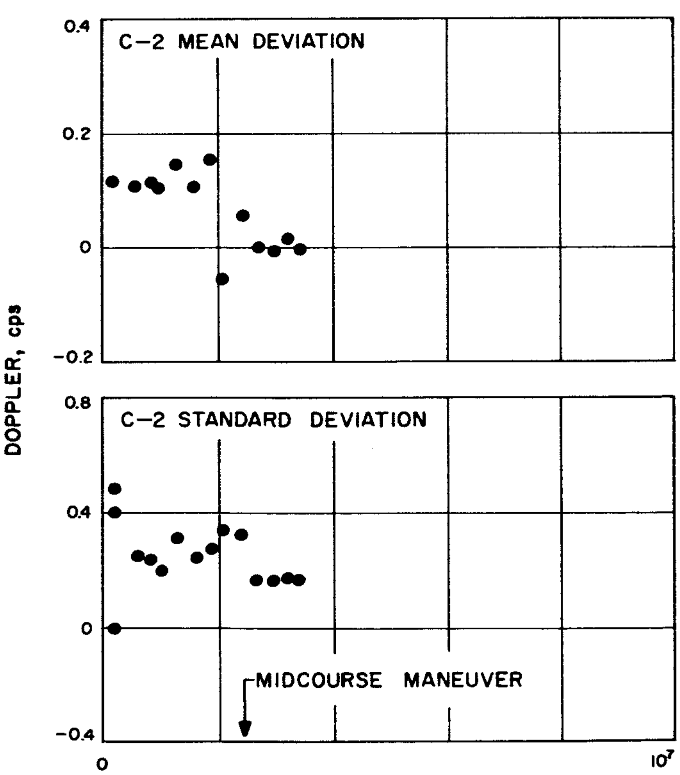

Fig. 38. DSIF-5 C-2 doppler mean and standard deviation vs range

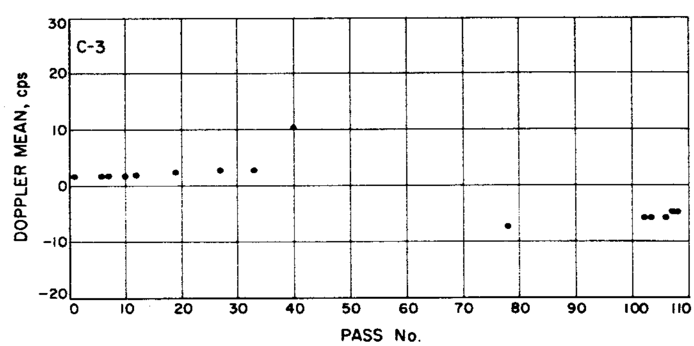

Fig. 39. DSIF-5 C-3 doppler mean vs pass No.

Table 17. C-1 mutual coverage comparison

Date	Pass	Day of year	C-1 ODP residuals, cps			
			GMT	DSIF-2	DSIF-4	DSIF-5
6 Oct	41	280	0120	−235.0	−199.0	N/A
6 Oct	41	280	0920	N/A	−195.0	−208.0
9 Nov	75	314	0600	N/A	411.0	410.0

IV. ORBIT DETERMINATION

A. Prior to Encounter

The *Mariner II* premidcourse orbit was determined on the basis of data received from DSIF tracking stations in Johannesburg, South Africa, Woomera, Australia, and Goldstone, California. The data used for determining the premidcourse orbit are shown in Table 18. The primary data types are coherent pseudo-two way doppler from Goldstone and two-way doppler from the other two stations. Angle data is also used for the first 15 hr of flight.

Table 18. Tracking data used in premidcourse orbits

Tracking station	Number of two-way or coherent three-way doppler data points	Number of angle data points	
		HA	Dec
DSIF-2 and -3 combination (Goldstone)	2539	None	None
DSIF-4 (Woomera)	730	308	308
DSIF-5 (Johannesburg)	1920	476	476

The *Mariner II* postmidcourse orbits were determined on the basis of data received from DSIF tracking stations in Johannesburg, South Africa and Goldstone, California. Two-way Doppler from DSIF-5 and -3, and coherent, pseudo-two-way doppler from DSIF-2 were used. Table 19 gives the approximate time distribution of the doppler observations. After 9 September the DSIF normally tracked one day per week. No angle data were used in the postmidcourse orbit determination.

The target parameters corresponding to the converged conditions of the premidcourse orbit and to various solutions of the postmidcourse orbit are given in Table 20. The postmidcourse orbit target parameters changed with the addition of each weekly pass of data. However, the changes were small and are explained by the fact that the effects of inaccuracies in station locations and the astronomical unit were not considered in arriving at the result.

Table 19. Tracking data used in postmidcourse orbits[a]

Date	DSIF-2 coherent 3-way doppler points	DSIF-3 2-way doppler points	Johannesburg 2-way doppler points
9/5–9/9	2600	0	1600
9/15	625	↓	0
9/22–9/24	1121		↓
10/7	1172		
10/15	588		
10/25	504	70	
10/28	547	0	
11/5	510	↓	
11/11	545		
11/17	623		
11/26	555		
12/1	466		
12/7	496		
12/8	408		
12/11	552		
12/12	433		
12/13	174		
12/14	404		
12/15	296		
12/16	469		
12/17	369		
12/19	277		
12/20	410		
12/28	209		
12/30	164		
TOTAL	14515	70	1600

[a]After 9 September, the DSIF normally tracked one pass per week.

B. During Encounter

Data covering the period 7 December to the end of the mission shows that the encounter parameters were

$$B \cdot T = -41489 \text{ km}$$

Table 20. Target parameters (Venus)

Description	$\bar{B}$, km	$\bar{B} \cdot \bar{T}$, km	$\bar{B} \cdot \bar{R}$, km	Radius of closest approach (RCA), km	Time of closest approach (12/14)
No advance information[a] on premidcourse orbits epoch 62/08/27 07 hr 19 min 19 sec	394293	291715	−265272	384180	
Postmidcourse orbits, advance information[a] epoch 62/09/05 at 0 hr 23 min 32 sec					
Data used from epoch to					
9 Sept	53139	−42655	31725	43314	193146
15	49921	−39768	30176	40153	191259
24	49850	−39722	30120	40083	191447
7 Oct	50839	−41473	29404	41042	194705
15	50869	−41590	29291	41071	195035
25	50690	−41581	28992	40895	195512
28	50549	−41549	28798	40756	195650
5 Nov	50177	−41351	28420	40392	195918
11	50050	−41282	28298	40269	195953
17	49931	−41189	28223	40152	200005
26	49712	−41068	28012	39938	200032
1 Dec	49709	−41066	28009	39935	200032

[a]The advance information consisted of a covariance matrix corresponding to a set of nominal position and velocity components at epoch. This matrix expresses the uncertainty assumed to exist in the premidcourse orbit solution and in the knowledge of the midcourse maneuver.

$B \cdot R = 29231$ km

$B = 59753$ km

$RCA = 40953$ km

$TCA =$ 19 hr 59 min 28 sec 14 December 1962

The Space Flight Operations Memorandum, dated 28 February 1963, contains a detailed discussion of the orbit, trajectory, and midcourse maneuver.

APPENDIX

Tables A-1 through A-3 contain the results of preflight calibration tests conducted by DSIF-1, -4 and -5 and represent the evaluation of pertinent DSIF observables.

Results of the B/P tests are listed in Table A-1. The mean error and SD in degrees were computed for all polarization angles at each signal strength.

The angular error coefficients determined from star tracks conducted during 1961–1962 at DSIF-4 and -5 are presented in Tables A-2 and A-3, respectively. These angular error coefficients represent the best estimate of the OPE and were first used to correct *Mariner II* angular data for the ODP. *Aij* refers to the hour angle correction coefficients and *Bij* refers to the declination correction coefficients.

Table A-1. B/P test results

DSIF station	Signal, deg	Signal strength, dbm		
		−120	−130	−140
1	Az Mean	0.229	—	0.205
	Az SD	0.224	—	0.165
	El Mean	−0.070	—	0.080
	El SD	−0.096	—	0.124
4	HA Mean	0.052	0.016	0.046
	HA SD	0.010	0.035	0.045
	Dec Mean	0.046	0.068	0.047
	Dec SD	0.004	0.025	0.028
5	HA Mean	−0.024	−0.028	−0.033
	HA SD	0.016	0.016	0.017
	Dec Mean	−0.003	−0.006	−0.033
	Dec SD	0.005	0.004	0.006

Table A-2. DSIF-4 angular error coefficients determined from star tracks

A_{ij}	B_{ij}
$A_{00} = 8.55001840 \times 10^{-3}$	$B_{00} = 1.34214922 \times 10^{-4}$
$A_{01} = 5.45289422 \times 10^{-4}$	$B_{01} = -1.41108901 \times 10^{-5}$
$A_{02} = 2.48239580 \times 10^{-6}$	$B_{02} = 0.0$
$A_{03} = 2.24566914 \times 10^{-7}$	$B_{03} = -4.31028233 \times 10^{-4}$
$A_{10} = 4.27133878 \times 10^{-4}$	$B_{10} = 3.34771543 \times 10^{-6}$
$A_{11} = 8.69584098 \times 10^{-6}$	$B_{11} = 1.01895206 \times 10^{-7}$
$A_{12} = -6.52074417 \times 10^{-7}$	$B_{12} = 0.0$
$A_{13} = -1.59490382 \times 10^{-8}$	$B_{13} = -9.56363999 \times 10^{-6}$
$A_{20} = 2.53268802 \times 10^{-6}$	$B_{20} = 4.53942058 \times 10^{-9}$
$A_{21} = -7.89511508 \times 10^{-8}$	$B_{21} = 2.09578021 \times 10^{-9}$
$A_{22} = -7.04116079 \times 10^{-9}$	$B_{22} = 0.0$
$A_{23} = -1.23595449 \times 10^{-10}$	$B_{23} = 0.0$
$A_{30} = -8.38262784 \times 10^{-8}$	$B_{30} = 0.0$
$A_{31} = 1.90513748 \times 10^{-9}$	$B_{31} = 0.0$
$A_{32} = 3.95248319 \times 10^{-10}$	$B_{32} = 0.0$
$A_{33} = 9.57751208 \times 10^{-12}$	$B_{33} = 0.0$

Table A-3. DSIF-5 angular error coefficients determined from star tracks

A_{ij}	B_{ij}	A_{ij}	B_{ij}
$A_{00} = 9.14878200 \times 10^{-3}$	$B_{00} = 2.98696570 \times 10^{-2}$	$A_{20} = 4.31922333 \times 10^{-6}$	$B_{20} = -9.21918567 \times 10^{-6}$
$A_{01} = 1.58528433 \times 10^{-4}$	$B_{01} = 1.04434590 \times 10^{-4}$	$A_{21} = -1.03537453 \times 10^{-8}$	$B_{21} = 5.89778738 \times 10^{-8}$
$A_{02} = 6.24530962 \times 10^{-6}$	$B_{02} = -3.64955790 \times 10^{-6}$	$A_{22} = -3.04187273 \times 10^{-9}$	$B_{22} = 3.62801844 \times 10^{-9}$
$A_{03} = 3.43842729 \times 10^{-7}$	$B_{03} = 2.01838820 \times 10^{-7}$	$A_{23} = -1.52368379 \times 10^{-11}$	$B_{23} = -5.16572982 \times 10^{-11}$
$A_{10} = 3.95889511 \times 10^{-4}$	$B_{10} = -7.39376711 \times 10^{-5}$	$A_{30} = -4.82682978 \times 10^{-8}$	$B_{30} = 0.0$
$A_{11} = 9.36369950 \times 10^{-6}$	$B_{11} = 4.55037975 \times 10^{-6}$	$A_{31} = 6.22450846 \times 10^{-10}$	$B_{31} = 0.0$
$A_{12} = -3.41913978 \times 10^{-7}$	$B_{12} = -9.45727640 \times 10^{-8}$	$A_{32} = 1.79924034 \times 10^{-10}$	$B_{32} = 0.0$
$A_{13} = -3.76659061 \times 10^{-9}$	$B_{13} = -7.12650861 \times 10^{-9}$	$A_{33} = 3.31402952 \times 10^{-10}$	$B_{33} = 0.0$

Table A-4. Premidcourse doppler data

DSIF station	Day of year	Pass	GMT		Sample interval	Count duration, sec	Doppler type
			From	To			
1	239	1	074551	074801	10 sec	1	C-2
2	239/240	1	201951	024351	1 min	50	Cc-3
	240/241	2	194051	195951			C-3
	240/241	2	202751	060851			Cc-3
	241/242	3	194351	195951			C-3
	241/242	3	201551	054751			Cc-3
	241/242	3	055851	062551			C-3
	242/243	4	193651	210051			C-3
	242/243	4	210751	213151			Cc-3
	242/243	4	214051	215051			C-1
	242/243	4	215202	224802		cont	C-1
	242/243	4	225351	062651		50	Cc-3
	243/244	5	193851	061851			Cc-3
	244/245	6	192451	061951			Cc-3
	245/246	7	192451	061451			Cc-3
	246/247	8	193551	061251			Cc-3
	247/248	9	191751	225251			Cc-3
	247/248	9	230002	002202		cont	C-1
	247/248	9	002204	002301	1 sec		C-1
4	239	1	074426	075006	10 sec	5	C-3
		1	075006	081206			C-1
		1	084951	095951	1 min	50	C-2
		1	100551	104151			C-3
		1	104751	113051		cont	C-3
		1	114051	131551		50	C-2
	240	2	020002	024402		cont	C-3
		2	030749	093951		50	C-2
		2	110502	135202		cont	C-3
	241	3	020802	060902			C-3
		3	063451	114151		50	C-2
		3	115502	135002		cont	C-3
	242	4	015802	054802			C-3
		4	061851	130651		50	C-2
		4	133402	135202		cont	C-3
	243	5	022002	062702			C-3
		5	063202	093202			C-1
		5	093802	134701			C-3
	244	6	015702	034302			C-3
		6	034702	043602			C-1
		6	044402	051702			C-3
		6	053102	054502			C-1
		6	054602	062002			C-3
		6	063402	134602			C-1
	245	7	015402	062002			C-3
		7	062702	120102			C-1
		7	120402	134102			C-3
	246	8	014602	061502			C-3
		8	061802	132702			C-1
	247	9	011001	061502			C-3
		9	061802	091702			C-1
		9	092102	133502			C-3

Table A-4. (Cont'd)

DSIF station	Day of year	Pass	GMT		Sample interval	Count duration, sec	Doppler type
			From	To			
5	239	1	072246	073116	10 sec	5	C-1
		1	073156	074806			C-3
		1	074856	075806			C-1
		1	084401	095201	1 min	cont	C-1
		1	085401	095601			C-3
		1	100251	112951		50	C-2
		1	114001	130202		cont	C-3
		1	130751	201451		50	C-2
		1	201901	210402		cont	C-3
	240	2	093802	101302			C-1
		2	101751	200151		50	C-2
		2	204502	210702		cont	C-3
	241	3	093702	095002			C-1
		3	095302	113802			C-3
		3	114251	201451		50	C-2
		3	203102	210602			C-3
	242	4	094502	101702		cont	C-1
		4	101802	130302			C-3
		4	130402	131802			C-1
		4	140802	145002			C-2
		4	145551	210051		50	C-2
	243	5	093651	160351			C-2
		5	160751	161751			C-1
		5	162051	185651			C-2
		5	190251	210051			C-1
	244	6	093802	163902		cont	C-1
		6	164251	191151		50	C-2
		6	192002	195302		cont	C-1
		6	195402	205502			C-3
	245	7	120951	133451		50	C-2
		7	134251	190951		cont	C-1
	246	8	134902	143302			C-1
		8	145151	195951		50	C-2
		8	200851	205051			C-3
	247	9	093851	094951			C-1
		9	095651	190351			C-2
		9	190702	204702		cont	C-1

Table A-5. Postmidcourse doppler data

DSIF station	Day of year	Pass	GMT From	GMT To	Sample interval	Count duration, sec	Doppler type
2	248	9	011551	055951	1 min	50	Cc-3
	248/249	10	192551	055951			
	249/250	11	190551	055851			
	250/251	12	190251	055451			
	251/252	13	190151	055451			
	254/255	16	183902	054802		cont	C-1
	256/257	18	183102	054002			
	257/258	19	183951	051951		50	Cc-3
	259/260	21	182002	031502		cont	C-1
	260/261	22	182302	040002			
	261/262	23	183002	030002			
	262/263	24	181002	030002			
	263/264	25	181102	024502			
	264/265	26	181502	030002			
	265/266	27	180851	044551			Cc-3
	266/267	28	175851	043251		50	
	267/268	29	180002	023002		cont	C-1
	268/269	30	174102	030002			
	270/271	32	173002	030002			
	271/272	33	180702	024502			
	272/273	34	172351	040051		50	Cc-3
	273/274	35	171402	023002		cont	C-1
	274/275	36	170902	023002			
	275/276	37	170502	021502			
	276/277	38	165902	021502			
	277/278	39	171402	020002			
	278/279	40	165102	020002			
	279/280	41	172751	032951		50	Cc-3
	280/281	42	165102	020002		cont	C-1
	281/282	43	163502	014502			
	282/283	44	162602	014502			
	283	45	162802	231502			
	284/285	46	162602	013002			
	285/286	47	161702	013002			
	286	48	163402	231202			
	287/288	49	162551	025951		50	Cc-3
	288/289	50	155502	013002		cont	C-1
	289/290	51	155102	013002			
	290/291	52	160402	011702			
	291/292	53	153802	024002			
	292/293	54	163302	023402			
	293/294	55	167020	023302			
	294/295	56	205402	022602			
	295/296	57	152602	010002			
	296/297	58	152102	010002			
	297/298	59	152202	015002			Cc-3
	298/299	60	145902	002702			C-1
	299/300	61	145702	001502			C-1
	300/301	62	145502	013202			Cc-3
	301	63	144702	231002			C-1
	302	64	144202	240002			
	303	65	143502	235902			
	304	66	144702	195102			

Table A-5. (Cont'd)

DSIF station	Day of year	Pass	GMT		Sample interval	Count duration, sec	Doppler type
			From	To			
2	304	66	200002	204202	1 min	cont	Cc-3
	304	66	204402	234502			C-1
	305	67	143400	234500			
	306/307	68	142300	011300			
	307/308	69	141700	010800			
	308	70	141200	233000			
	309/310	71	143800	003200			Cc-3[a]
	310	72	140300	231500			C-1
	311	73	140300	230000			
	312	74	135400	204500			
	312	74	204700	223300			Cc-3[a]
	312	74	223400	230000			C-1
	314/315	76	134900	003200			Cc-3[a]
	315	77	134000	224500			C-1
	316	78	133600	223000			
	317	79	133300	223000			
	318	80	132800	223000			
	319	81	132400	223000			
	320	82	133200	215500			
	321	83	132100	235900			Cc-3[a]
	322	84	131400	221500			C-1
	323	85	131500	221500			
	324	86	131300	220000			
	325	87	130900	220000			
	326	88	125800	220000			
	327	89	125700	214500			
	328	90	125600	214500			
	329	91	125500	214500			
	330	92	124600	131300			
	330	92	133100	231100			Cc-3[a]
	330	93	124500	214500			C-1
	335	97	124100	205500			Cc-3
	336	98	123600	213000			C-1
	337	99	123000	213000			
	338	100	123700	323000			
	339	101	124100	213000			
	340	102	123000	213000			
	341	103	122700	213000			Cc-3
	342	104	122600	153600			
	342	104	174800	223100			
	343	105	122000	213000			C-1
	344	106	121800	223000			
	345	107	122500	222600			Cc-3
	346	108	131200	222200			
	347	109	121800	130100			
	347	109	194700	221400			
	347	109	131100	192900			C-1
	348	110	123500	135500			Cc-3
	348	110	141000	214900			
	349	111	133900	145500			

[a]During periods of Cc-3 doppler, Station 3 was counting Station 2's doppler at 1 min sample interval and 50 sec count duraton.

Table A-5. (Cont'd)

DSIF station	Day of year	Pass	GMT		Sample interval	Count duration, sec	Doppler type
			From	To			
2	349	111	150200	175300	1 min	cont	Cc-3
	349	111	180600	185300			
	349	111	192500	221000			
	350	112	124100	175000			
	350	112	180200	185700			
	350	112	185800	214900			
	351	113	121200	215400			
	352	114	173900	215100			
	353	115	121100	214400			
	354	116	123300	151900			
	354	116	153200	173600			
	354	116	174500	215000			
	362	124	125900	174200			
	362	124	175200	212900			
3	287/288	49	173651	024951		50	C-2
	297	59	152651	165651			
	331	94	124400	214500		cont	C-1
	332	95	123200	214600			
	333	96	122400	214000			
4	248	10	014002	060002			C-3
	248	10	061302	095502			C-1
	248	10	102302	133102			C-3
	249	11	022002	060002			
	249	11	060302	092202			C-1
	249	11	092502	132802			C-3
	250	12	012702	060002			
	250	12	060402	093302			C-1
	250	12	094202	132402			C-3
	251	13	014302	055502			
	251	13	060402	092802			C-1
	251	13	093202	132102			C-3
	252	14	040002	055502			Cc-3
	252	14	055102	100002			C-1
	254	16	011102	131502			
	256	18	010602	130502			
	258	20	012802	052002			C-3
	258	20	052302	090002			C-1
	259	21	005202	124602			
	260	22	024202	110002			
	261	23	034302	123002			
	262	24	023302	110002			
	263	25	024102	110002			
	264	26	021402	104502			
	265	27	022002	104502			
	267	29	015902	043002			C-3
	267	29	043402	095602			C-1
	268	30	020202	103002			
	269	31	020402	102902			
	270	32	020902	102902			
	271	33	015002	101502			
	272	34	014302	101402			
	273	35	000602	040102			C-3
	273	35	040402	100002			C-1

Table A-5. (Cont'd)

DSIF station	Day of year	Pass	GMT		Sample interval	Count duration, sec	Doppler type
			From	To			
4	274	36	013002	100002	1 min	cont	C-1
	275	37	014302	094402			
	276	38	011602	094502			
	277	39	011902	094502			
	278	40	010302	092902			
	279	41	010602	093002			
	280	42	004502	040002			C-3
	280	42	040102	091402			C-1
	281	43	004602	091502			
	282	44	002902	090002			
	283	45	005202	090002			
	283/284	46	230702	081502			
	285	47	002802	090002			
	286	48	001702	084502			
	286/287	49	224602	083002			
	287/288	50	222502	025102			C-3
	288	50	025402	083002			C-1
	289	51	003402	083202			
	290	52	004802	090002			
	291	53	001902	084402			
	292	54	043902	095802			
	294	56	040202	094702			
	295	57	034702	094102			
	296	58	000202	082902			
	296/297	59	234302	081502			
	297/298	60	225902	015502			C-3
	298	60	015702	081102			C-1
	299	61	030902	074502			
	299/300	62	232802	074502			
	300/301	63	223102	013202			C-3
	301	63	013802	073002			C-1
	301/302	64	225002	073002			
	303/304	66	230302	073002			
	304/305	67	223500	030200			
	305	67	031600	033100		50	C-2
	305	67	033500	071500		cont	C-1
	305/306	68	224400	065300			
	307	69	011000	071500			
	308	70	011200	070000			
	308/309	71	214600	070000			
	309/310	72	213000	003200			C-3
	310	72	003900	073200			C-1
	310/311	73	220700	063000			
	311/312	74	214000	062900			
	312/313	75	225500	063000			
	313/314	76	211600	063000			
	314/315	77	204800	003400			C-3
	315	77	004000	061400			C-1
	315/316	78	212900	060000			
	316/317	79	211000	055900			
	317/318	80	212200	060000			
	318/319	81	212700	055900			
	319/320	82	212100	065900			
	320/321	83	213500	060000			

Table A-5. (Cont'd)

DSIF station	Day of year	Pass	GMT		Sample interval	Count duration, sec	Doppler type
			From	To			
4	321/322	84	212100	000200	1 min	cont	C-3
	322	84	000600	054500			C-1
	322/323	85	211300	054600			
	323/324	86	211900	054500			
	324/325	87	210300	053100			
	325/326	88	204000	065600			
	326/327	89	210100	053000			
	327/328	90	204600	051300			
	328/329	91	204000	050100			
	329/330	92	201600	051500			
	330	93	205600	231100			C-3
	330/331	93	231900	051500			C-1
	331/332	94	201300	051500			
	332/333	95	203900	065100			
	333/334	96	202700	051500			
	334/335	97	203900	051500			
	335/336	98	202300	214900			C-3
	335/336	98	215000	064200			C-1
	336/337	99	195700	050000			
	337/338	100	203000	053000			C-1
	338/339	101	195300	053000			
	339/340	102	200100	050000			
	340/341	103	201700	050000			
	341/342	104	202800	213500			C-3
	341/342	104	213800	053000			C-1
	342/343	105	194400	223500			C-3
	342/343	105	223600	051000			C-1
	343/344	106	193800	050000			
	344/345	107	221500	044500			
	345/346	108	182800	222600			C-3
	345/346	108	222900	050000			C-1
	346/347	109	183200	222700			C-3
	346/347	109	222700	050000			C-1
	347/348	110	182900	193600			
	347/348	110	193700	221600			C-3
	347/348	110	221600	050000			C-1
	348/349	111	181000	221800			C-3
	348/349	111	221800	050000			C-1
	349/350	112	182900	221000			C-3
	349/350	112	221000	043000			C-1
	350/351	113	191800	215600			C-3
	350/351	113	221000	040000			C-1
	356/357	119	193000	050000			
	357/358	120	185900	050000			
	360/361	123	190300	050100			
	361/362	124	185900	053000			
	363/364	126	180400	020000			
	365/001	128	231500	020000			
5	248	10	092702	093802			
	248	10	095751	182251		50	C-2
	249	11	091051	184951			
	250	12	093551	184951			
	250	12	185602	203602		cont	C-3

Table A-5. (Cont'd)

DSIF station	Day of year	Pass	GMT From	GMT To	Sample interval	Count duration, sec	Doppler type
5	251	13	094151	184451	1 min	50	C-2
	251	13	185502	195002		cont	C-3
	253	15	085202	202602			C-1
	255	17	090402	201302			
	257	19	182002	200602			
	258	20	083902	200102			
	261	23	115902	190002			
	262	24	103402	190002			
	264	26	200902	184602			
	265	27	101702	184502			
	266	28	101302	185702			
	268	30	095802	183002			
	270	32	094702	181502			
	271	33	095002	181402			
	272	34	170302	184502			C-3
	273	35	092802	180002			C-1
	274	36	093402	175902			
	276	38	090702	174502			
	277	39	090002	173002			
	278	40	090002	173002			
	279	41	095202	171502			
	279	41	171602	173002			C-3
	280	42	084502	171502			C-1
	282	44	085102	170002			
	283	45	090102	161502			
	284	46	080702	170102			
	285	47	081102	170202			
	286	48	081902	161502			
	287	49	080902	163002			
	288	50	075902	165002			
	289	51	082602	164502			
	290	52	080002	163002			
	291	53	081202	153002			
	292	54	112002	155002			
	293	55	110902	170302			
	294	56	110202	165902			
	295	57	082602	165402			
	296	58	080002	163002			
	297	59	074502	151502			
	297	59	151602	164202			C-3
	298	60	065302	160002			C-1
	299	61	064902	154502			
	300	62	064902	144702			
	300	62	144902	161502			C-3
	301	63	062202	153002			C-1
	302	64	062702	153002			
	303	65	063002	153002			
	304	66	062002	153002			
	305	67	062000	151500			
	306	68	062000	151500			
	307	69	061000	151500			
	309	71	061000	135000			
	309	71	135300	153000			C-3
	310	72	054000	144500			C-1

Table A-5. (Cont'd)

DSIF station	Day of year	Pass	GMT From	GMT To	Sample interval	Count duration, sec	Doppler type
5	312	74	052300	143000	1 min	cont	C-1
	313	75	053100	152000			
	314	76	052900	134000			
	314	76	134800	142900			
	315	77	051400	141500			
	316	78	051000	141500			
	317	79	050000	140000			
	318	80	050400	140000			
	319	81	045500	140000			
	321	83	050000	131200			
	321	83	131900	144000			C-3
	322	84	045200	134500			C-1
	323	85	045100	134500			
	324	86	044900	134500			
	325	87	043700	133000			
	327	89	043500	133000			
	330	92	041700	123600			
	330	92	124900	140000			C-3
	331	93	041000	131500			C-1
	333	95	054900	131500			
	334	96	041100	131500			
	335	97	042200	122900			
	335	97	130400	134500			C-3
	336	98	052800	130000			C-1
	337	99	035600	130000			
	338	100	035600	130000			
	339	101	035500	130000			
	340	102	034800	130000			
	341	103	040700	121300			
	341	103	122200	130000			C-3
	342	104	044500	120500			C-1
	342	104	121400	130000			C-3
	343	105	035000	130000			C-1
	344	106	034700	130000			
	345	107	034500	120000			
	345	107	120000	130000			C-3
	346	108	034600	123100			C-1
	346	108	123400	132800			C-3
	347	109	034900	120600			C-1
	347	109	121200	133100			C-3
	348	110	013600	122600			C-1
	348	110	122700	133100			C-3
	349	111	013700	120800			C-1
	349	111	121100	132700			C-3
	350	112	030000	123300			C-1
	350	112	124100	132600			C-3
	355	117	020900	120000			C-1
	356	118	020600	120000			
	360	122	015400	120000			
	363	125	044100	080000			
	365	127	024500	120000			
	002	129	095100	130200			

Table A-6. Premidcourse transmitter "on" times and VCO frequency

DSIF station	Day of year	GMT	Minutes from epoch	Xmtr status	VCO freq., cps
3	239	201215	0	On	29668400
	240	200200	2202.7		300
	241	200000	3640.7		200
	241	214000	3740.7	Change	300
	242	203500	5155.7	On	200
	242	210000	5180.7		200
	243	195500	6555.7		200
	244	044000	7075.7		200
	244	191800	7958.7		200
	244	221700	8137.7		200
	245	192000	9560.7		200
	246	194300	10863.7		100
	247	000500	11125.7	Change	200
	247	190700	12267.7	On	100
	247	201300	12333.7	Change	181
4	239	084432	0	On	29668484
	239	113700	257.7		383
	239	123700	322.7	Change	417
	239	125600	336.7		396
	240	030100	1181.9	On	303
	241	082000	2940.7	Change	290
	241	092000	3000.7		294
	242	060100	4315.7	On	274
	242	073514	4336.0	Change	207
	242	093518	4456.0		226
5	239	100220	0	On	29668330
	239	101500	175.7	Change	498
	239	130600	346.9	On	319
	239	133900	379.5	Change	473
	239	190400	704.6		481
	240	101600	1616.6	On	199
	240	150100	2186.6	Change	422
	241	114000	3140.6	On	246
	241	153703	3377.8	Change	277
	242	151200	4792.8	On	254
	243	093415	5900.4		162
	243	095742	5917.8	Change	342
	243	150647	6227.0		245
	244	164908	7770.0	On	200
	245	120612	8927.0		182
	246	145506	10536.0		215
	247	095444	11675.0		203
	247	140827	11944.0	Change	227
	247	164827	12089.0		238

Table A-7. Postmidcourse transmitter "on" times and VCO frequency

DSIF station	Day of year	GMT	Xmtr status	VCO freq, cps
3	248	010900	On	29.668200
	248	192342		100
	248	211600	Change	200
	249	193007	On	200
	250	190040		200
	251	185900		200
	257	183828		100
	257	225643	Change	200
	265	181127	On	200
	266	175634		100
	272	170430		100
	279	172453		29668100.0
	287	161135		100.0
	297	152400		100.0
	300	151745		100.0
	300	210804	Change	200.0
	304	195755	On	200.0
	309	135500		200.0
	309/310	192100	Change	300.0
	311	204500	On	315.0[a]
	314	134300		300.0
	314/315	234100	Change	400.0
	321	131000	On	500.0
	330	132500		600.0
	330	212300	Change	700.0
	335	122500	On	700.0
	341	121400		900.0
	342	121200		900.0
	345	120800		900.0
3	346	123600	On	29669000.0
	346	130200	Change	29668900.0
	346	161900		29669000.0
	347	120400	On	000.0
	348	140100		000.0
	348	164300	Change	100.0
	348	204500		200.0
	349	170700	On	100.0
	349	191700	Change	200.0
	350	120100	On	200.0
	350	123300	Change	100.0
	350	185800		200.0
	351	120200	On	100.0
	351	160300	Change	200.0
	352	173400	On	180.0[a]
	352	174800	Change	190.0[a]
	352	192300		170.0[a]
	353	115900	On	100.0
	353	164100	Change	200.0
	354	115800	On	100.0
	354	173600	Change	200.0
	362	173900	On	200.0
5	248	101700		29.668151
	248	153500	Change	200
	248	181200		238
	249	092300	On	129
	249	102500	Change	157
	249	131300		186
	250	095600	On	172
	250	121900	Change	065
	251	103100	On	154
	251	120700	Change	157

[a]VCO frequency only for these passes. Synthesizer on and frequency changes for all other passes.