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APOLLO 7 MISSION REPORT
COMMUNICATIONS SYSTEM PERFORMANCE

Prepared by
LOCKHEED ELECTRONICS COMPANY

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Supplement 3

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PREPARED BY

Lockheed Electronics Company

APPROVED BY

George M. Low

George M. Low, Manager
Apollo Spacecraft Program

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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Prepared By: Carl Gentry Date 3-6-69
Engineer

Approved By: Louis J. Ammann Date 3-7-69
Section Supervisor

PREFACE

This document presents a supplemental report on the communications system performance during the Apollo 7 mission. It has been prepared for the Information Systems Division of the NASA's Manned Spacecraft Center under contract NAS 9-5191. The information contained herein should not be regarded as representing a firm position of the NASA's Manned Spacecraft Center, nor does it obligate or commit the Center in any way.

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1.0 INTRODUCTION

This report presents the results of an evaluation of the communications system performance during the Apollo 7 mission. The report includes, in addition to a communications system performance evaluation presented previously (Reference 1 of Appendix A), a supplemental evaluation of additional data.

1.1 EVALUATION

The communications system performance was evaluated by analyzing both the command service module communications as an entity and the operation of the command service module communications system and the Manned Space Flight Network (MSFN) communications equipment as an integrated system. A functional diagram of the communications system utilized during the mission is presented Figure 3-1.

The evaluation of the communications system was principally directed to; the launch phase, Service Propulsion System (SPS) burns, the re-entry phase, command service module and S-IVB formation flying, communications system signal combination checks, and problem areas.

An S-band PM down-link problem, which developed during the mission from 65:13:58 until 72:36:32, is noted in the telemetry and down-voice channel evaluation. The problem was characterized by:

a. Drop in the ground-received PM signal strength

b. Loss of PM subcarriers on the secondary S-band transponder

c. Lower than expected transponder-received signal strength

The only components within the S-band system which could have failed and caused all these symptoms are the panel switch for selecting the primary or secondary transponder and the wiring which controls this function. Postflight tests of the switch and transponder revealed no abnormalities.

When the select switch is changed from one transponder to the other, a momentary hesitation in the OFF position is required to allow latching relays to reset. Switching without this hesitation can cause both transponders to be ON and will create all the symptoms of the failure.

The transponder select switch, directly above the antenna select switch, may have been inadvertently thrown during one of the frequent antenna switchings, and both transponders may have been activated. Although the crewmember on duty cannot remember inadvertently throwing the wrong switch, he does not discount the possibility.

The S-band omni-antenna management during the mission was less than optimum resulting in several periods of marginal performance of the S-band system. The position of the spacecraft omni-antenna switch was unknown during the majority of the mission.

2.0 SUMMARY

The communications system satisfactorily supported the mission, and the applicable mission objectives were achieved. The S-band and VHF links provided good quality voice except during the launch phase, when the crew failed to receive certain uplink transmissions and the down-voice was garbled because of improper procedures and/or malfunctioning equipment at the ground stations. The quality of the dumped voice ranged from poor to good. The performance of the real-time and dumped telemetry channels was consistent with the received signal strengths. The quality of television pictures during the seven broadcasts ranged from fair to excellent. More than 93 percent of the commands transmitted were verified by the spacecraft updata link equipment; and in each instance, the unverified commands had been transmitted during a period of weak signal strength.

The S-band carrier phase modulation by voice and telemetry subcarriers was interrupted at 65:13:58, and real-time telemetry was then transmitted on the S-band FM link. Full S-band communications capability was restored at 72:36:32 when the crew selected the alternate S-band transponder. All of the scheduled communication checks were performed.

3.0 COMMUNICATION SYSTEMS PERFORMANCE

3.1 S-Band Communications System Performance

3.1.1 Radio Frequency System

Highlights of the S-band RF system performance during the Apollo 7 mission are presented in Table 3-1 and Figures 3-2 through 3-43. The tabular data is time phased, related to significant events from launch through re-entry. Delineated within the tables are MSFN sites, events, periods of coverage and summaries of the performance of the passes evaluated. The RF up-link and down-link received signal characteristics are illustrated graphically. Pre-mission predictions obtained from the Apollo 7 Coverage Analysis (Reference 2 Appendix A) have been compared to MSFN received carrier power levels during the launch phase, and selected passes up to and including the first Service Propulsion System (SPS) burn. These comparisons were found to be generally in very good agreement. Post mission predictions, based on spacecraft trajectory and attitude data have been added to those received signal power plots for time periods during which guidance and navigation spacecraft attitude data were available. Post-mission predictions were computed for each of the four omni antennas. Best fit comparisons were necessarily performed between the predicted and measured received carrier powers for each of the omni's due to lack of data relative to the active antenna during the pass. Reasonably good correlation between predicted and measured values was obtained for the majority of the passes evaluated.

The general performance of the S-band RF system was good and compared favorably with pre-mission planning and predicted performance. Communications detailed test objectives involving selected signal combination mode checks were satisfactorily executed with good results. The RF system adequately supported the Apollo 7 mission in both the PM and FM modes of operation.

3.1.2 PCM Telemetry Channel

As discussed previously, a loss of the down-link telemetry and voice subcarriers occurred at approximately 65:13:58, while operating with the secondary transponder. Real-time telemetry and television were then time-shared on the backup S-band FM channel until full communications capability was restored by switching to the primary S-band transponder at approximately 72:36:32.

The S-band telemetry performance was evaluated from telemetry frame synchronization bit errors and post mission data processor in-synchronization/out-of-synchronization conditions. These data were correlated with received carrier power levels for selected station passes. Frame synchronization bit errors were accumulated and indicated for one second intervals. Bit errors of greater than three per prime frame are indicated as an out-of-sync condition.

The results of the telemetry channel performance, referenced to down-link received carrier power, are shown graphically in Figures 3-2 through 3-43. The data indicates satisfactory telemetry performance generally existed when the down-link received carrier power was above system threshold for the appropriate PCM bit-rate. Nominal telemetry performance was observed during the mission while observing the telemetry data display monitors.

3.1.3 Up-Data Channel

The S-band up-data channel was used throughout the mission for transmission of guidance computer updata information, central timing equipment updating, and real-time commands. The post-mission analysis and evaluation indicated satisfactory performance of the S-band up-data channel existed throughout the mission. A total of 3,796 commands were transmitted during the flight, including 55 guidance and navigation computer loads. Of the 3,796 transmitted commands, there were 241 spacecraft rejects and 91 ground station rejects. All spacecraft rejects occurred during periods of weak signal strength with the majority being near AOS or LOS.

3.1.4 Up-Voice Channel

The S-band up-voice channel performance was nominal throughout the mission. The Apollo 7 crew reported good S-band up-voice performance during all periods of utilization.

3.1.5 Down-Voice Channel

The S-band down-voice channel performance was good during the mission with the exception of the time period between approximately 65:13:58 and 72:36:32. As discussed previously, there was a loss of the down-voice and telemetry subcarriers while utilizing the secondary transponder during the above time period. The S-band down-voice channel operation was restored to normal when the primary transponder was activated. Detailed analysis and evaluation of the down-voice quality and intelligibility from MSFN site recordings is not possible in many cases due, apparently, to improper recordings techniques. Real-time mission support monitoring of the S-band down-voice indicated good to excellent voice quality and intelligibility existed throughout the mission.

3.1.6 Frequency Modulation Channel

3.1.6.1 PCM Telemetry

The S-band FM telemetry channel performance was satisfactory throughout the mission. At approximately 65:13:58, the FM telemetry channel was utilized on a time-shared basis between real-time telemetry and television due to the loss of the telemetry subcarrier on the PM secondary transponder (see previous discussion). At approximately 72:36:32, the FM channel was switched back to its normal mode when the alternate transponder was activated.

3.1.6.2 Stored Telemetry and Voice Dumps

With the exception of the above 7 hours and 22 minutes, the FM mode was used principally for Data Storage Equipment (DSE) stored telemetry data and voice dumps, and television telecasts. The majority of the DSE data dumps were 32:1, although a 1:1 dump was performed over several stations. Evaluation of the FM mode performance for the DSE telemetry data and voice dumps indicated nominal performance.

3.1.6.3 Television

The S-band FM television channel performance was good. Seven television telecasts were conducted during the mission. The Texas and Merritt Island MSFN sites provided coverage for these telecasts. Magnetic tape recordings were made at the sites for use in post-mission television performance evaluation. A detailed evaluation of the Texas and Merritt Island revolution 45 and 60 passes was made and is discussed in Table 3-1.

3.2 VHF/AM Communications System Performance

The VHF/AM voice communications system generally performed satisfactorily throughout the mission. The VHF voice duplex "B" mode was prime for the launch phase with communications being adequate during the count-down and the launch phase up to about 7 minutes into the flight, when voice quality became garbled on the down-link receivers. During the same time period, the flight crew reported difficulty in receiving certain up-link transmissions from the sites. This condition continued until the simplex "A" mode was selected over the Canary Islands tracking station at approximately 00:19:17. The operation of the duplex "B" mode was successfully re-verified over Guam at approximately 7 hours and 30 minutes into the mission.

A voice communications time-line chart is shown in Figure 3-44 for the launch phase of the mission. As shown in the chart, both Grand Bahama Island and Bermuda Island sites were transmitting voice to the spacecraft on the VHF link from 00:07:06 to 00:08:05. Voice transmissions to the spacecraft from the Bermuda site via VHF were terminated at 00:09:50 and were not resumed until 00:11:57. The "MODE IV MARK", which the crew did not hear, was transmitted on S-band only. The results of a qualitative evaluation of the ground voice receiver outputs are also presented in the chart although the received VHF signal power at Bermuda was sufficient to support good voice communications, the receiver output was garbled, from acquisition to 00:09:50. The output of the receiver cleared up after it was removed from NETWORK 1. The garbled voice at the output of the Bermuda VHF receiver also degraded the outputs of the S-band and VHF receivers at Grand Bahama during the time that the two sites were simultaneously connected to NETWORK 1.

The output of the VHF receiver at the Canary Island site was also garbled until the simplex-A mode was selected at 00:19:17. The failure of the crew to receive certain uplink transmissions resulted from improper procedures at the ground station, and the garbled voice resulted from improper procedures and/or malfunctioning receivers at the Bermuda and Canary Island sites.

Figure 3-45 presents plots of the average total received signal power at the Merritt Island and Bermuda Island tracking stations during launch and injection phases and are indicative of the levels during the first 20 minutes of the flight. The spacecraft VHF/AM system transmits only when keyed. The down-link received signal power plots show actual measured ground station signal levels during the time periods of voice transmission. Intervals between voice transmissions are indicated by dashed lines. Based upon the available data, the analysis indicates that the received signal power-to-noise margins should have provided nominal voice quality and intelligibility during the launch phase. Table 3-2 presents highlights of the VHF/AM voice communications.

STATION	REV.	EVENT	AOS	LOS	COMMENTS
MIL	0/1	Launch	Pre-launch	00:09:55	The S-band communications system performance during the Merritt Island site coverage of the Apollo 7 launch was nominal. As shown in Figure 3-2, the received carrier power compares favorably with the pre-mission predictions. The telemetry, range code acquisition, and voice quality were good for the majority of the Merritt Island coverage of the launch.
GBM	1	Launch	00:01:21	00:10:08	The Grand Bahama site acquired the CM S-band transponder in handover from Merritt Island, without interruption in communications. Telemetry and range code acquisition performance were nominal. The actual received carrier power compares favorably with the pre-mission predictions as shown in Figure 3-3. The S-band voice recording level at the site was too low to permit an evaluation of quality or intelligibility.
BDA	1	Launch	00:04:01	00:12:58	The Bermuda site acquired the spacecraft in handover from GBM without interruption of communications. Telemetry, range code acquisition, and voice performance were nominal. As shown in Figure 3-4, the received carrier power compares favorably with pre-mission pred-ctions. The voice quality and intelligibility were good during the BDA coverage except for a 9 second period from 00:10:26 to 00:10:35 when the site received carrier power momentarily dropped to about -122 dBm with a resultant voice degradation.
VAN	1	Orbital Phase	00:10:15	00:17:23	As shown in Figure 3-5, the U.S.N.S. Vanguard experienced some difficulty in completing the handover from BDA when approximately 1 minute of interruption in the S-band communication occurred. Except for this delay the RF and telemetry performance were nominal during the Vanguard coverage. No voice was received at MCC from the Vanguard from approximately 00:13:00 to 00:17:00. Postmission voice analysis revealed no voice recorded by the Vanguard. Therefore, voice analysis was not possible.
CYI	1	Orbital Phase	00:17:06	00:25:25	The Canary Island site acquired the spacecraft in Handover from the Vanguard. As shown in Figure 3-6, the actual received carrier power and the pre-mission predictions compare favorably. The magnetic tape recording of the PCM telemetry was noisy, which prohibited evaluation of the telemetry performance. Real-time telemetry range code acquisition and command performance were nominal. Three commands were transmitted and verified by Message Acceptance Patterns (MAP's).
MIL	1/2	DSE 32:1 Data Dump	01:36:31	00:44:50	The first Data Storage Equipment (DSE) dump of the Apollo 7 mission was conducted during the Merritt Island revolution 1/2 pass. The dump was performed on the FM channel at 32:1 while real-time telemetry was transmitted on the PM channel. As shown in Figures 3-7 and 3-8, both real-time and stored PCM telemetry performance were nominal. The stored speech quality and intelligibility ranged from poor to good. Most of the speech interference was due to the scientific data subcarriers. The voice was recorded at the output of the 500 kHz TV filter instead of the output of the voice filter. Command performance and range code acquisition were nominal. The received carrier power levels for the PM channel compare favorably with predictions.
TEX	14	PIPA Check	22:21:59	22:26:19	The Texas site acquired the spacecraft after exit from keyhole at approximately 22:21:59, as shown in Figure 3-9. Active coverage was provided by Texas during the pass, which included the PIPA check. No detectable degradation of the S-band system performance was evident during the check. Command, telemetry, and range code acquisition performance were nominal. The S-band down voice recording level at the MSFN was too low to permit a voice evaluation.

TABLE 3-1: S-BAND SYSTEM PERFORMANCE SUMMARY

STATION	REV.	EVENT	AOS	LOS	COMMENTS
CRO	17	SPS Burn #1	26:23:03	26:31:03	The first Service Propulsion System burn was conducted during the 17th revolution over the Carnarvon site. No detectable degradation of the S-band system performance was evident during the burn. As shown in Figure 3-10, the received carrier power and pre-mission predictions compare favorably. Command, telemetry and range code acquisition performance were nominal. The S-band down-voice recording level at the MSFN was too low to permit a voice evaluation.
CRO	18	SPS Burn #2	27:57:37	28:06:04	The Carnarvon MSFN site provided active coverage of the second Service Propulsion System burn. As shown in Figure 3-11, the average S-band down-link received carrier power during the burn period was -78 dBm. There was no detectable system performance degradation during the burn. Command, telemetry, range code acquisition, and voice channel performance were nominal. The recorded S-band down-voice speech-to-noise ratio was + 11.0 dB. The voice quality and intelligibility were good.
GDS	19	Formation Flying	30:09:36	30:13:36	The Goldstone site passive coverage of the formation flying was limited to approximately 4 minutes, as shown in Figure 3-12. Insufficient telemetry data due to frequent switching of the PCM bit rate prevented a conclusive evaluation of the telemetry performance. S-band down-link voice was not recorded during GDS coverage.
TEX	19	Formation Flying	30:12:55	30:19:17	The Texas site provided approximately 6 minutes of coverage during the formation flying. As shown in Figure 3-13, the received carrier power level was near the telemetry threshold for the majority of the pass. The omni antenna was switched during the pass, providing approximately 40 dB improvement in received carrier power. Shortly after switching antennas, the look angle between the spacecraft and MSFN passed through a null in the antenna pattern, reducing the received carrier power level to near threshold again. General performance of the S-band system during the Texas pass was nominal. The voice recording level was apparently too low at the site to permit an evaluation.
GWM	24	S-Band Signal Combination Check	37:41:32	37:48:48	S-Band Signal Combination Check: Up-Link: Ranging, Up-Data, Voice Down-Link: Ranging, Voice, LBR TLM. Guam provided active coverage for the above S-band signal combination check during revolution 24. As shown in Figure 3-14, Low Bit Rate (LBR) telemetry was checked during the initial portion of the pass until the switch to High Bit Rate (HBR) at 37:44:02. PCM telemetry was intermittent after the switch to HBR until a switch of omni antennas at approximately 37:46:10, due to fluctuations of the down-link received carrier power. Telemetry frame synchronization was maintained after the omni antenna switch until a switch back to LBR telemetry at 37:47:52, although a large number of bit errors were present. Range code acquisition and voice were not recorded during the pass. Two commands were verified as having been accepted by the spacecraft, and two commands were rejected due to low signal strength near AOS.

TABLE 3-1: S-BAND SYSTEM PERFORMANCE SUMMARY (CONTINUED)

STATION	REV.	EVENT	AOS	LOS	COMMENTS
GWM	25	DSE 32:1 Dump Voice Evaluation	39:17:12	39:23:43	A DSE (32:1) dump was performed during the Guam coverage of revolution 25. The average speech-to-noise ratio of the site recorded dump voice was + 4.5 dB. Speech quality and intelligibility, as recorded at the site, was poor to fair. A low amplitude 1-2 kHz tone was present on the tape.
TEX	33	S-Band Signal Combination Check	52:31:41	52:39:06	S-Band Signal Combination Check: Up-Link: Voice, Up-data Down-Link: Backup Voice, LBR Telemetry During approximately 8 minutes of coverage provided by Texas, the above S-band communications signal combination check was conducted. As shown in Figure 3-15, the test period included received carrier power levels both well above and approaching telemetry threshold. As anticipated, some telemetry performance degradation occurred due to interference from the direct voice modulation of the carrier caused by use of the 700 Hz bandwidth of the ground receiver tracking loop. The 700 Hz bandwidth was required for the Apollo 7 mission to accommodate the high doppler rates expected with near earth orbits. Lunar missions will not experience this interference when the 50 Hz bandwidth is used after trans-lunar injection. Overall system performance was nominal. The backup down-voice quality and intelligibility were fair to good. Three commands were transmitted and verified by MAP's.
HAW	35	DSE 32:1 Dump Voice Evaluation	55:27:32	55:34:39	A DSE (32:1) dump was performed during the Hawaii coverage of revolution 35. The average speech-to-noise ratio of the site recorded dump voice was + 11.9 dB. Speech quality and intelligibility, as recorded at the site, was fair to good.
HAW	36	S-Band Signal Combination Check	57:01:27	57:10:03	S-Band Signal Combination Check: Up-Link: Voice, Up-data Down-Link: Voice, HBR TLM. During approximately 6 minutes and 45 seconds of coverage by Hawaii, the above S-band signal combination check was performed. As shown in Figure 3-16 , there was no detectable system performance degradation during the pass. Command, telemetry, and voice channel performance were nominal. The recorded S-band down-voice speech-to-noise ratio averaged + 24.1 dB. The voice quality and intelligibility were good.
RED	41	Loss of PM Subcarriers	65:10:57	65:19:56	The U.S.N.S. Redstone initially acquired the spacecraft at approximately 65:10:57. Intermittent tracking occurred until after the omni antenna was switched for the first time during the pass at approximately 65:14:00. As shown in Figure 3-17, the down-link received carrier power varied between -120 dBm and threshold prior to 65:14:00. The PCM telemetry was intermittent due to the signal level flucuations. The spacecraft was re-acquired by Redstone shortly after the initial omni antenna switching. From the time of re-acquisition until final LOS, the Redstone was unable to detect the presence of either the telemetry subcarrier or the voice subcarrier. The RF received carrier power level was adequate during the majority of the time period from the initial omni antenna switch to LOS to have provided nominal telemetry and voice channel performance.

TABLE 3-1: S-BAND SYSTEM PERFORMANCE SUMMARY (CONTINUED)

STATION	REV.	EVENT	AOS	LOS	COMMENTS
CRO	43	CMC Up-Date Not Verified By MAP	67:50:34	67:59:25	During the Carnarvon site active coverage of revolution 43, the following CMC updates were not verified by MAP's: 67:53:31 "AGC Verb" ----- Due to low signal strength 67:55:22 "AGC ER Reset" ----- LOS at 67:55:16 67:57:36 "AGC ER Reset" ----- No indication of up-link lock.
CYI	45	Early LOS			At approximately 70:29:16 the Canary Island site experienced an early LOS. From 70:28:30 to 70:29:07, the MSFN received carrier power had been decreasing steadily from approximately -100 dBm to -136 dBm, until the signal strength was too low to continue valid track. Receiver No. 2 was on the FM link, rather than the acquisition antenna, due to the problem with the secondary transponder. Therefore, re-acquisition was not possible.
TEX	45	TV	71:41:14	71:48:40	Texas provided coverage for the first live telecast from an Apollo spacecraft. A graphic plot of the PM channel is shown in Figure 3-18. The FM channel was switched from the real-time HBR telemetry mode to the television mode during this period. Texas television quality ranged from fair to good, being somewhat limited by weak signal strength. The secondary transponder anomaly prevented the transmission of normal down-link PM modulation. Up-link transponder functions were apparently not degraded, permitting full up-voice and command capability.
MIL	45/46	TV	71:44:53	71:52:48	The Merritt Island coverage during this pass was limited to time sharing of real-time telemetry and television on the FM link due to the secondary transponder anomaly. Graphic plots of the PM and FM channels are shown in Figures 3-19 and 3-20 respectively. The television picture quality ranged from fair to good during this pass.
CRO	46	Switch Transponder Secondary To Primary	72:35:05	72:44:21	Carnarvon acquired the spacecraft secondary S-band transponder signal shortly before switching to the primary transponder. As shown in Figure 3-21, the transponder transfer was accomplished at approximately 72:36:38. After acquisition of the primary transponder, the S-band system performance was nominal. The site bit synchronizer output indicated a drop-out of telemetry from 72:37:15 to 72:38:15.
CRO	48	SPS Burn #3	75:44:58	75:50:19	Carnarvon provided coverage of the third Service Propulsion System burn. As shown in Figure 3-22, there was no degradation of the S-band system performance related to the event. Nominal system performance continued during the pass. Carnarvon did not transfer receiver two from acquisition antenna to main antenna. The S-band down-voice recording level at the site was too low to permit a qualitative evaluation.

TABLE 3-1: S-BAND SYSTEM PERFORMANCE SUMMARY (CONTINUED)

STATION	REV.	EVENT	AOS	LOS	COMMENTS
HAW	51	S-Band Signal Combination Check	80:53:27	81:00:26	S-Band Signal Combination Check: Up-Link: Voice, Up-data Down-Link: Voice, LBR TLM The above S-band signal combination check was conducted during the active coverage by the Hawaii site of revolution 51. As shown in Figure 3-23, the test period included received carrier power levels both well above and approaching telemetry threshold. Overall system performance was nominal. Voice transmissions, during this pass, occurred near LOS where the site recorded down-link received carrier power was averaging -120 dBm. The average site recorded speech-to-noise ratio was + 6.9 dB. The down-voice quality was fair, and the intelligibility was good. Eight commands were transmitted and verified by MAP's.
TEX	60	TV	95:25:27	95:33:12	Texas provided normal S-band system capability in addition to television during the pass. Command, telemetry, and voice communication were nominal. The S-band PM down-link received carrier power on receiver one averaged -85 dBm during the pass. As shown in Figure 3-24, receiver two remained on the acquisition antenna throughout the pass. The television coverage utilizing the S-band FM down-link provided good picture quality.
MIL	60/61	TV	95:30:02	95:36:35	Merritt Island provided normal S-band system capability including television during this pass. Graphic plots of the PM and FM channels are shown in Figures 3-25, and 3-26, respectively. The command, telemetry, and voice communications were nominal. Television coverage began at hand-over from the Texas site. As shown in Figure 3-26, the total FM received power level averaged approximately -75 dBm, resulting in an average video signal-to-noise ratio of greater than + 16.2 dB. Photographs of TV monitor displays made from the site television magnetic tape recording are also shown in Figure 3-26.
HAW	63	S-Band Signal Combination Check	99:53:57	99:57:04	S-Band Signal Combination Check: Up-Link: Voice, Up-data Down-Link: Voice The Hawaii MSFN site provided coverage for the S-band down-link, voice-only mode evaluation (Figure 3-27). The speech-to-noise ratio averaged +22.9 dB during the mode check. The voice quality and intelligibility were good. Seven commands were transmitted; two no-MAP's were attributed to weak ground received carrier power near LOS.
TEX	76	SPS Burn #4	120:42:30	120:47:55	Texas provided active coverage during the fourth Service Propulsion System burn. As shown in Figure 3-28, the average S-band down-link received carrier power was -83 dBm during the pass. There was no detectable S-band performance degradation during the SPS burn. Command, telemetry, and range code acquisition were nominal during the pass. The MSFN station recording level was apparently too low to permit an S-band down voice evaluation.

TABLE 3-1: S-BAND SYSTEM PERFORMANCE SUMMARY (CONTINUED)

STATION	REV.	EVENT	AOS	LOS	COMMENTS
GDS	91	DSE 1:1 Dump Voice Evaluation			A DSE (1:1) dump was performed during the Goldstone coverage of revolution 91. The average speech-to-noise ratio of the site recorded dump voice was + 9.9 dB. Speech quality and intelligibility, as recorded at the site, was fair to good.
TEX	91	Omni Antenna Call-out	144:22:25	144:29:50	Texas acquired the spacecraft at handover from GYM, with an approximate 20 second delay in obtaining two-way lock. As shown in Figure 3-29, the down-link received carrier power at the Texas handover was -98 dBm. Two minutes after handover the spacecraft look angle appears to have changed, resulting in a reduction of the received carrier power. The antenna was switched to omni "A", resulting in a received carrier power of -80 dBm. The overall performance during this pass was nominal. Four commands were transmitted and verified by MAP's.
TEX	104	SPS Burn #5	164:54:28	165:01:35	Texas provided passive coverage of the fifth Service Propulsion System burn after handover to Merritt Island near LOS. As shown in Figure 3-30, down-link received carrier power at the Texas S-band receiver two was approximately 10 dB below receiver one with both receivers on the main antenna. This appears to have been caused by site operation. The overall system performance was nominal. The average speech-to-noise ratio was +23.8 dB. The voice quality and intelligibility during the pass were good.
MIL	104/105	SPS Burn #5	164:59:10	165:05:02	Merritt Island provided prime coverage of the fifth Service Propulsion System burn. As shown in Figure 3-31, Merritt Island acquired the spacecraft at handover from Texas. The received carrier power plot shows fluctuations as large as 15 dB during the burn period, possibly due to spacecraft look angles. The overall S-band system performance was nominal during the pass. Three commands were transmitted and verified by MAP's.
TEX	105	DSE 1:1 Dump Voice Evaluation	166:30:27	166:37:59	A DSE (1:1) dump was performed during the Texas coverage of revolution 105. The average speech-to-noise ratio of the site recorded dump voice was + 14.2 dB. Speech quality and intelligibility, as recorded at the site, was fair to good.
GDS	107	DSE 32:1 Dump Voice Evaluation			A DSE (32:1) dump was performed during the Goldstone coverage of revolution 107. The average speech-to-noise ratio of the site recorded dump voice was + 21.3 dB. Speech quality, as recorded at the site, was excellent, and speech intelligibility was fair to good.
TEX	107	DSE 32:1 Dump Voice Evaluation	169:42:15	169:47:55	A DSE (32:1) dump was performed during the Texas coverage of revolution 107. The average speech-to-noise ratio of the site recorded dump voice was + 12.6 dB. Speech quality and intelligibility, as recorded at the site, was fair to good.
CYI	118	S-Band Signal Combination Check	186:11:38	186:18:56	S-Band Signal Combination Check: Up-Link: Backup Voice Down-Link: Voice, LBR TLM The Canary Islands site provided coverage for the above S-band signal combination check during revolution 118. The crew confirmed receipt of very clear voice during the check.

TABLE 3-1: S-BAND SYSTEM PERFORMANCE SUMMARY (CONTINUED)

STATION	REV.	EVENT	AOS	LOS	COMMENTS
CRO	119	Voice Relay USB-Up VHF-Down	188:21:15	188:32:10	The Carnarvon site provided active coverage during revolution 119 for a simulated voice relay check. Voice was transmitted to the spacecraft via S-band, and relayed back to the MSFN site via VHF. Speech quality and intelligibility, as recorded at the site, was fair to good.
GDS	120	S-Band Signal Combination Check	190:36:06	190:43:01	S-Band Signal Combination Check: Up-Link: Voice, Up-data Down-Link: Key The Goldstone site provided coverage of the S-band emergency key communications check. As shown in Figure 3-32, the check was conducted just prior to LOS with down-link received carrier power levels between -100 and -120 dBm. The check, as monitored at MSC, provided a clear, audible 1 kHz tone of the code words "THIS IS A TEST OF EMERGENCY KEY". Each character of the code was also discernable, on the site strip-chart recorder, as carrier suppression by the 512 kHz subcarrier when keyed. The overall system performance during the GDS pass was nominal.
GYM	121	Voice Relay VHF-Up USB-Down	192:13:01	192:19:50	The Guaymas site provided coverage during revolution 121 for a simulated voice relay check (Figure 3-33). The check of the voice relay capability was conducted between 192:15:41 and 192:16:18 by relaying the voice output of the spacecraft VHF receiver to the Guaymas site on the S-band link. The quality of the relayed voice varied from fair to good.
TEX	132	SPS Burn #6	210:02:08	210:09:25	Texas provided passive coverage of the sixth Service Propulsion System burn. No degradation in system performance was noted during this burn. As shown in Figure 3-34, the telemetry performance was good. Evaluation of the voice channel established a speech-to-noise ratio of +22.4 dB with good quality and intelligibility.
MIL	132/133	SPS Burn #6	210:04:15	210:13:29	Merritt Island provided active coverage of the sixth Service Propulsion System burn. Overall system performance was nominal during the pass. Three commands were transmitted and verified by MAP's. The voice quality and intelligibility were fair at AOS, and good during the remainder of the pass. As shown in Figure 3-35, S-band down-link received carrier power during the burn was approximately -82 dBm with no detectable degradation of system performance.
ACN	142	S-Band Signal Combination Check	224:48:17	224:58:33	S-Band Signal Combination Check: Up-Link: Ranging, Voice, Up-Data Down-Link: Ranging, Backup Voice, LBR TLM The Ascension MSFN site provided support for the above S-band PM signal combination check. As seen in Figure 3-36, receiver No. 2 remained on the acquisition antenna throughout the pass. The command, telemetry and range code acquisition performance were nominal. The backup voice transmissions recorded at the site from approximately 224:47:57 until 224:52:50 had an average speech-to-noise ratio of + 10.2 dB. The speech quality and intelligibility were good.

TABLE 3-1: S-BAND SYSTEM PERFORMANCE SUMMARY (CONTINUED)

STATION	REV.	EVENT	AOS	LOS	COMMENTS
ANG	151	SPS Burn #7	239:04:24	239:10:24	Antigua Island MSFN provided active coverage during the seventh Service Propulsion System burn. As shown in Figure 3-37, there was no detectable S-band system performance degradation during the burn period. The command, telemetry, and range code acquisition performance were nominal. Three commands were transmitted and verified by MAP's. The average speech-to-noise ratio was + 13.7 dB. The USB down-voice evaluation indicated that the voice quality and intelligibility were fair to good.
HTV	163	SPS Burn #8 and Re-entry	259:38:21	259:45:23	The U.S.N.S. Huntsville provided passive coverage during the eighth Service Propulsion System burn. Handover from Hawaii to the Huntsville was completed at 259:41:09. An unexplained LOS occurred at 259:42:50. The Huntsville re-acquired two-way lock again at approximately 259:43:59. Huntsville experienced LOS 7 seconds prior to the planned handover time of 259:45:30. The data does not indicate any RF carrier power degradation coincident with the SPS burn. CM/SM separation occurred during the period of unexplained low signal levels. As shown in Figure 3-38, the average S-band down-link received carrier power during the Huntsville pass was -92 dBm.
GYM	163	Re-entry	259:45:05	259:52:32	As shown in Figure 3-39, the Guaymas MSFN site provided approximately 4 minutes of active coverage during re-entry of the Command Module. GYN experienced a temporary LOS just prior to handover to Texas. The S-band down-link was re-acquired after the handover, with good passive coverage for an additional 2.5 minutes. The command, telemetry, and range code acquisition performance were nominal during the Texas pass. The average S-band down-link received carrier power was approximately -88 dBm during the pass.
TEX	163	Re-entry	259:48:25	259:55:01	The Texas MSFN site provided approximately 6.5 minutes of coverage during re-entry. As shown in Figure 3-40, the S-band system performance was nominal during the Texas pass. The command, telemetry, range code acquisition, and voice quality and intelligibility were good.
A/RIA 5	164/164	Re-entry	259:50:15	259:56:32	The A/RIA No. 5 provided passive coverage during revolution 163/164. As seen in Figure 3-41, the average down-link received carrier power, as recorded on the A/RIA, was approximately -110 dBm during the pass. Telemetry performance during the pass was nominal.
MIL	163/164	Re-entry	259:52:55	259:54:49	The Merritt Island site acquired the spacecraft carrier with handover from Texas. As shown in Figure 3-42, the average S-band down-link received carrier power during the pass prior to communications blackout was -92 dBm. A 2 second LOS occurred at 259:54:10. The spacecraft entered S-band blackout during the Merritt Island pass at 259:54:58. The average speech-to-noise ratio was + 4.1 dB. The recorded voice quality was poor to fair, and intelligibility was fair to good.
BDA	164	Re-entry	260:00:00	260:02:13	The Bermuda MSFN site acquired S-band two-way lock at 260:00:00 at the end of the communications blackout. As shown in Figure 3-43, the down-link received carrier power increased rapidly to -76 dBm within 15 seconds after acquisition. The spacecraft trajectory entered the Bermuda keyhole at approximately 260:00:40. Bermuda coverage continued through the keyhole, reaching threshold at 260:01:10. The telemetry, range code acquisition, and voice channel performance were nominal. The voice evaluation indicated that the speech quality and intelligibility were good.

TABLE 3-1: S-BAND SYSTEM PERFORMANCE SUMMARY (CONCLUDED)

STATION	REV.	EVENT	COMMENTS
MIL	0/1	Launch	The Merritt Island site VHF received signal strength during the launch phase maintained a positive signal margin of 20 dB or greater than the level required to maintain a 90% word intelligibility. LOS of the VHF 259.7 MHz signal occurred at approximately 00:09:30. The pre-mission predictions agree favorably with measured signal levels. The voice quality and intelligibility were good. Figure 3-45A (Merritt Island Launch) shows the VHF AM received signal power plot of voice groups between liftoff and loss of signal (LOS).
GBM	1	Launch	The Grand Bahama Island site provided VHF/AM voice coverage during the launch phase. An evaluation of the VHF/AM down-voice site recording was made. The average speech-to-noise ratio was +4.5 dB. Voice quality was rated poor, and intelligibility fair to good. The site magnetic tape recording contained a very strong 60 Hz background component.
BDA	1	Launch	The VHF received signal strength recorded during the launch phase maintained a positive signal margin of 20 dB or greater than the level required to maintain a 90% word intelligibility. The measured and pre-mission predicted signal levels compare favorably. The down-voice was garbled between AOS and 00:09:50 due to a site procedural problem and/or equipment malfunction. From 00:09:50 until LOS, at approximately 00:13:45, the voice quality and intelligibility were good. Figure 3-45 B (Bermuda Launch) shows the VHF/AM received signal power plot of voice groups during the Bermuda site coverage.
CYI	1	Orbital Phase	The Canary Island site provided prime coverage of the VHF/AM voice communications during this pass. The spacecraft VHF system was switched by the crew from Duplex "B" to Simplex "A" at approximately 00:19:17. The voice recording from the site contained garbled voice between 00:17:07 and 00:19:17. The average speech-to-noise ratio for the Simplex "A" mode was +21.3 dB. After switching to Simplex "A", the voice quality and intelligibility were good.
GWM	5	VHF Duplex "B" Check	The Guam site conducted a VHF/AM Duplex "B" voice check during this pass. The site tape recording contained transmissions in both Simplex "A" and Duplex "B" modes. In both modes, voice was fair to good, but slightly garbled. The speech-to-noise ratio averaged +20 dB. Intelligibility was good for both modes.
HAW	7	VHF Duplex "A" Check	The Hawaii site conducted a VHF/AM Duplex "A" voice check during this pass. The average speech-to-noise ratio was +21.7 dB. The site recording of the down-voice quality and intelligibility was fair to good.
ACN	9	VHF Simplex "B" Check	The Ascension site conducted a VHF/AM Simplex "B" voice check during this pass. The site recording tape contained a 2.8 kHz tone that shifted in frequency when information was recorded. The noise level was high, but intelligibility was generally fair to good. Although the received signal strength was adequate, the average speech-to-noise ratio was +2.5 dB. The speech quality was poor.

TABLE 3-2: VHF SYSTEM PERFORMANCE SUMMARY

STATION	REV.	EVENT	COMMENTS
TEX	14	PIPA Check	The Texas site provided VHF/AM voice coverage during the PIPA check. The average speech-to-noise ratio of the site recorded VHF voice transmissions was +16.5 dB. Voice quality and intelligibility were good.
CRO	17	SPS Burn #1	The Carnarvon site provided VHF/AM voice coverage during SPS burn No. 1. The site recorded VHF voice had a considerable amount of noise and "popping" present until approximately 26:24:52, and intelligibility was very poor. The average signal-to-noise ratio improved during the balance of the pass (+12.9 dB), and the voice quality and intelligibility was fair.
CRO	18	SPS Burn #2	The Carnarvon site provided VHF/AM voice coverage during SPS burn No. 2. The average speech-to-noise ratio of the site recorded voice varied from +4.5 dB to +12.3 dB. Voice quality and intelligibility were good during most of the pass. Near AOS and LOS, voice quality and intelligibility were poor due to weak down-link received VHF carrier power.
TEX	19	Formation Flying	The Texas site provided VHF/AM voice coverage during the formation flying period. The average speech-to-noise ratio of the site recorded VHF voice was +14.7 dB. Voice quality and intelligibility were good during this period.
CRO	48	SPS Burn #3	The Carnarvon site provided VHF/AM voice coverage during SPS burn No.3. The average speech-to-noise ratio of the site recorded VHF voice was +18.6 dB. Voice quality was good during this period, and intelligibility was fair to poor.
TEX	76	SPS Burn #4	The Texas site provided VHF/AM voice coverage during SPS burn No. 4. The average speech-to-noise ratio of the site recorded VHF voice was +21.7 dB. Voice quality and intelligibility were poor to fair during this period.
TEX	104	SPS Burn #5 VHF Simplex "A" Check	The Texas site conducted a VHF/AM Simplex "A" voice check during this pass. The received signal power was nominal during transmission from the spacecraft. The average speech-to-noise ratio was +22 dB. Voice quality and intelligibility were good.
MIL	104/105	SPS Burn #5 VHF Simplex "A" Check	The Merritt Island site conducted a VHF/AM Simplex "A" voice check during this pass. The average speech-to-noise ratio was +2.7 dB. The VHF down-link recorded voice quality and intelligibility were poor. The noise spectrum of the recorded voice contained a large 400 Hz component.
TEX	132	SPS Burn #6	The Texas site provided VHF/AM voice coverage during SPS burn No. 6. The average speech-to-noise ratio of the site recorded VHF voice was +23.8 dB. The voice quality was good during this period, and the intelligibility was generally fair.
MIL	132/133	SPS Burn #6	The Merritt Island site also provided VHF/AM voice coverage during SPS burn No. 6. The average speech-to-noise ratio of the site recorded VHF voice was +9.1 dB. Voice quality and intelligibility were fair during this period.
ANG	151	SPS Burn #7	The Antigua site provided VHF/AM voice coverage during SPS burn No. 7. The average speech-to-noise ratio of the site recorded VHF voice was +15.2 dB. Voice quality was fair to good during this period, and intelligibility was fair.

TABLE 3-2: VHF SYSTEM PERFORMANCE SUMMARY (CONCLUDED) 3-16

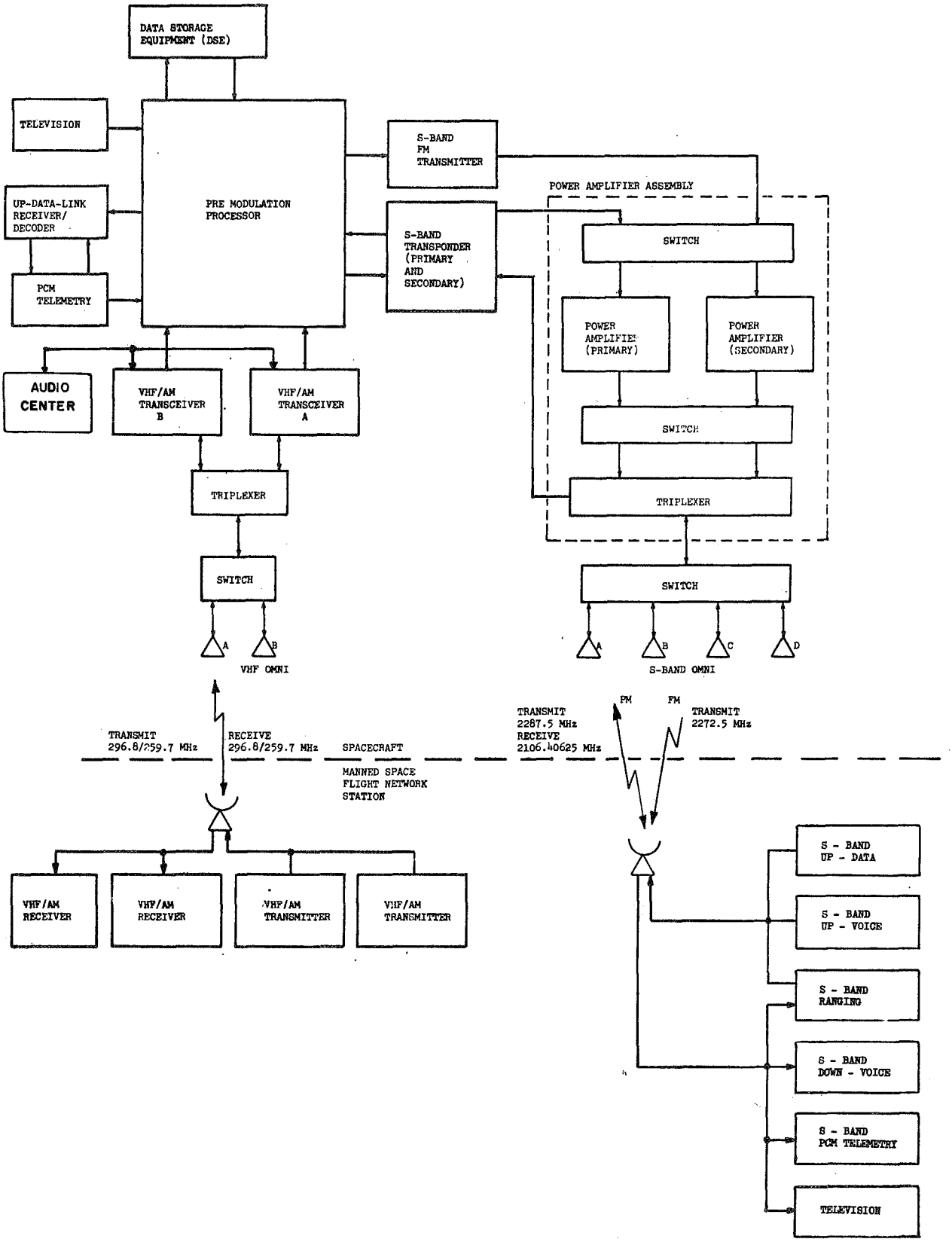

FIGURE 3-1. COMMUNICATIONS SYSTEM CONFIGURATION

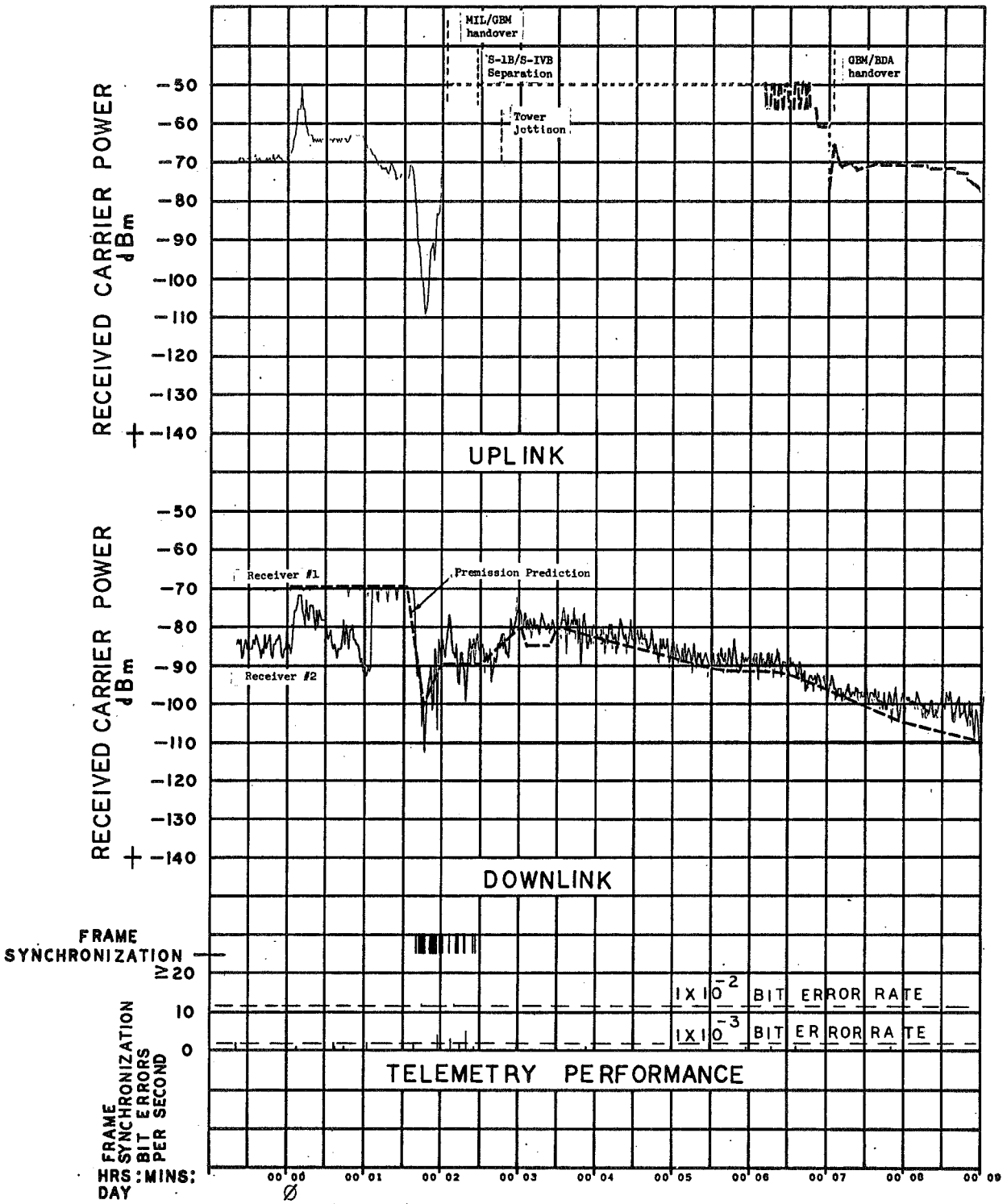

FIGURE 3-2 RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, MERRITT ISLAND, LAUNCH

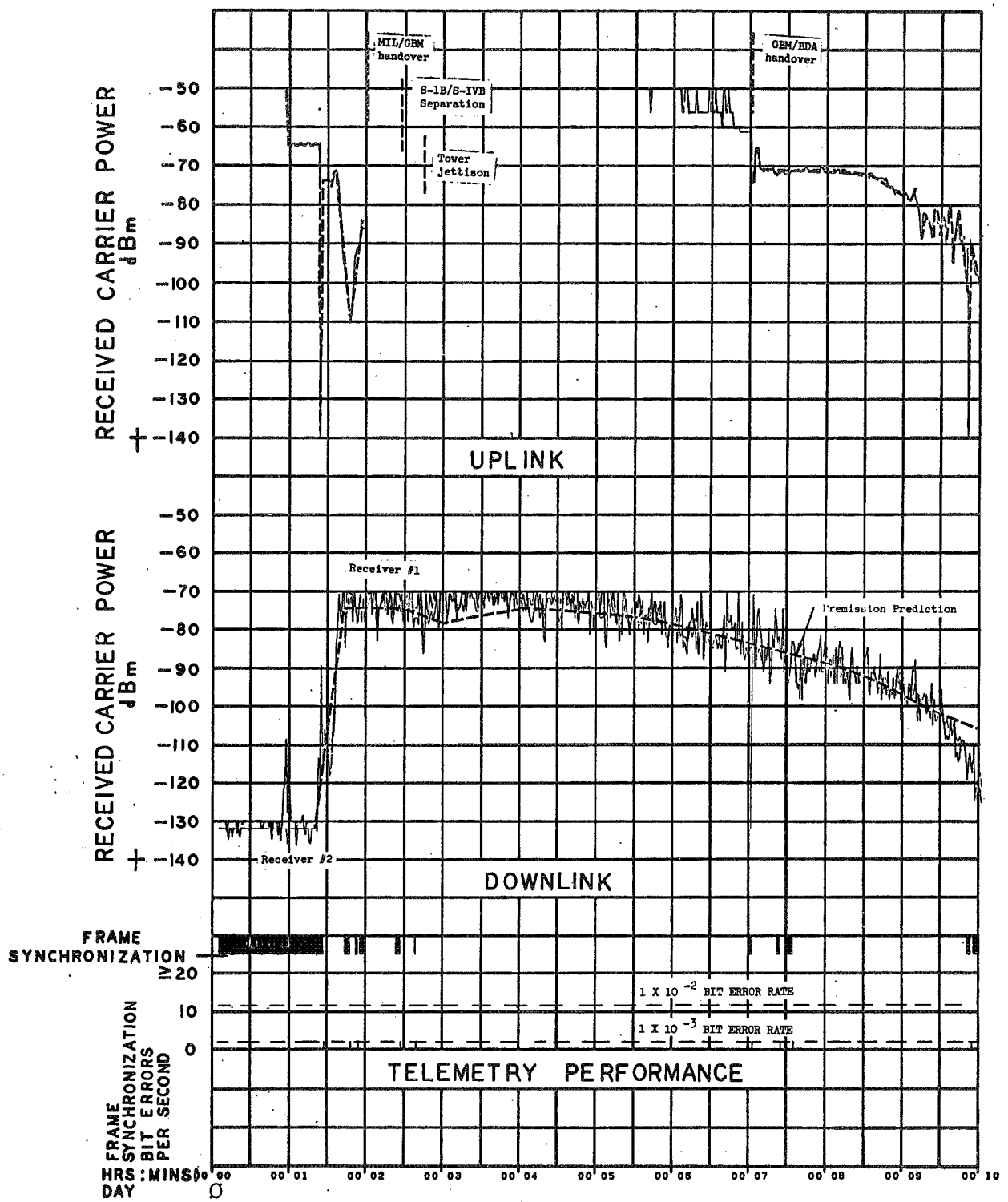

FIGURE 3-3 RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, GRAND BAHAMA, LAUNCH

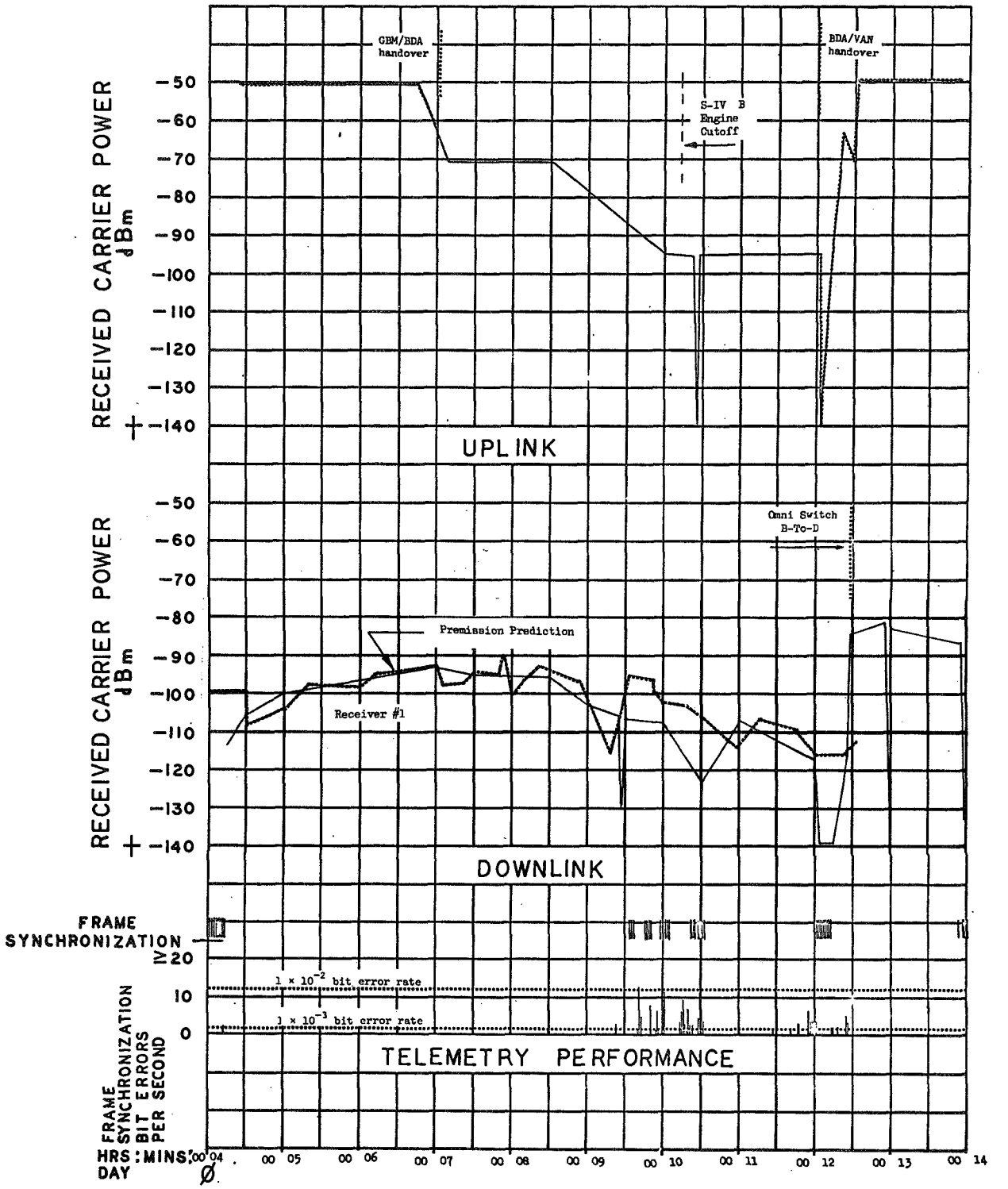

FIGURE 3-4 RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, BERMUDA, LAUNCH

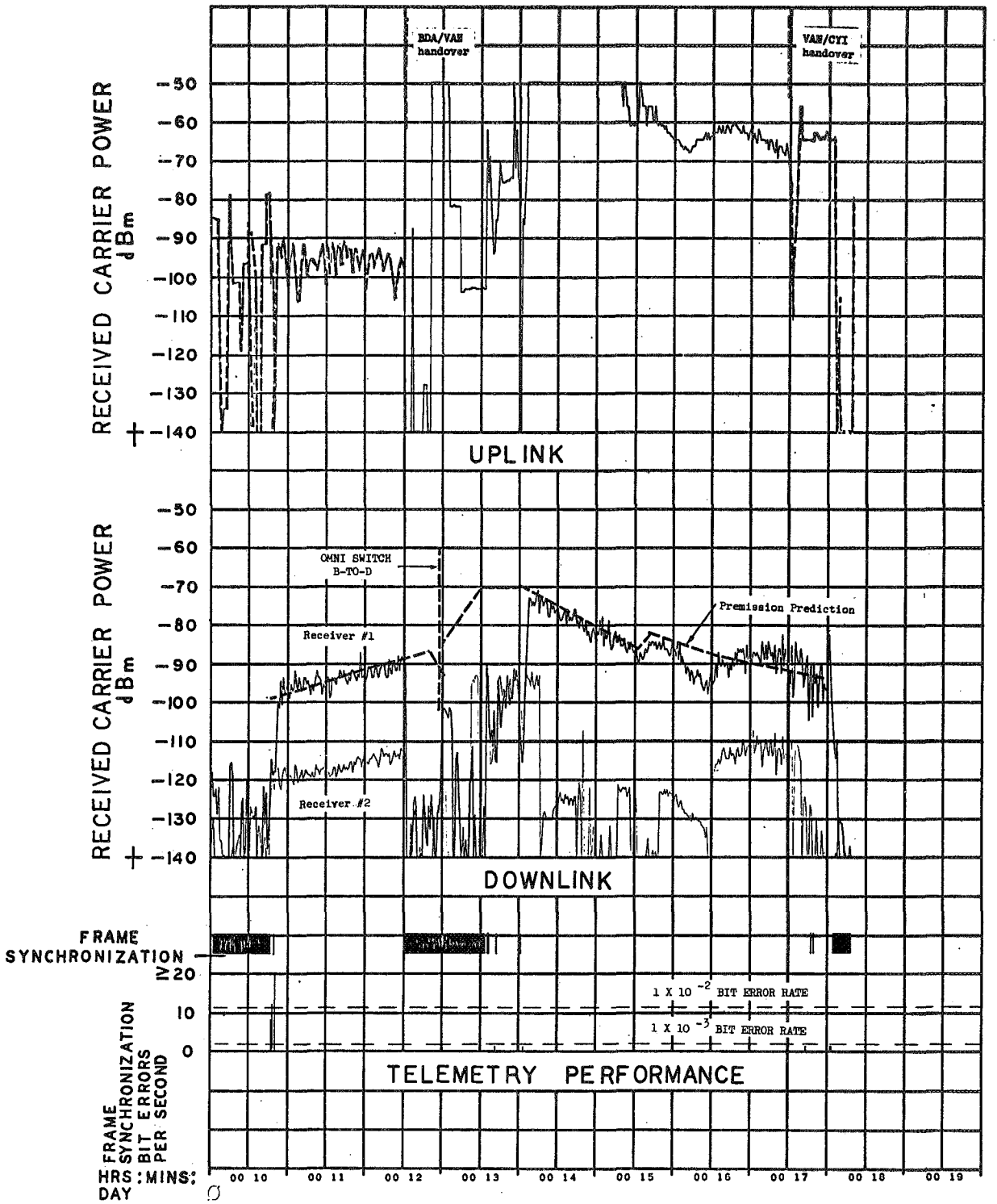

FIGURE 3-5 RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, U.S.N.S. VANGUARD, REVOLUTION 1

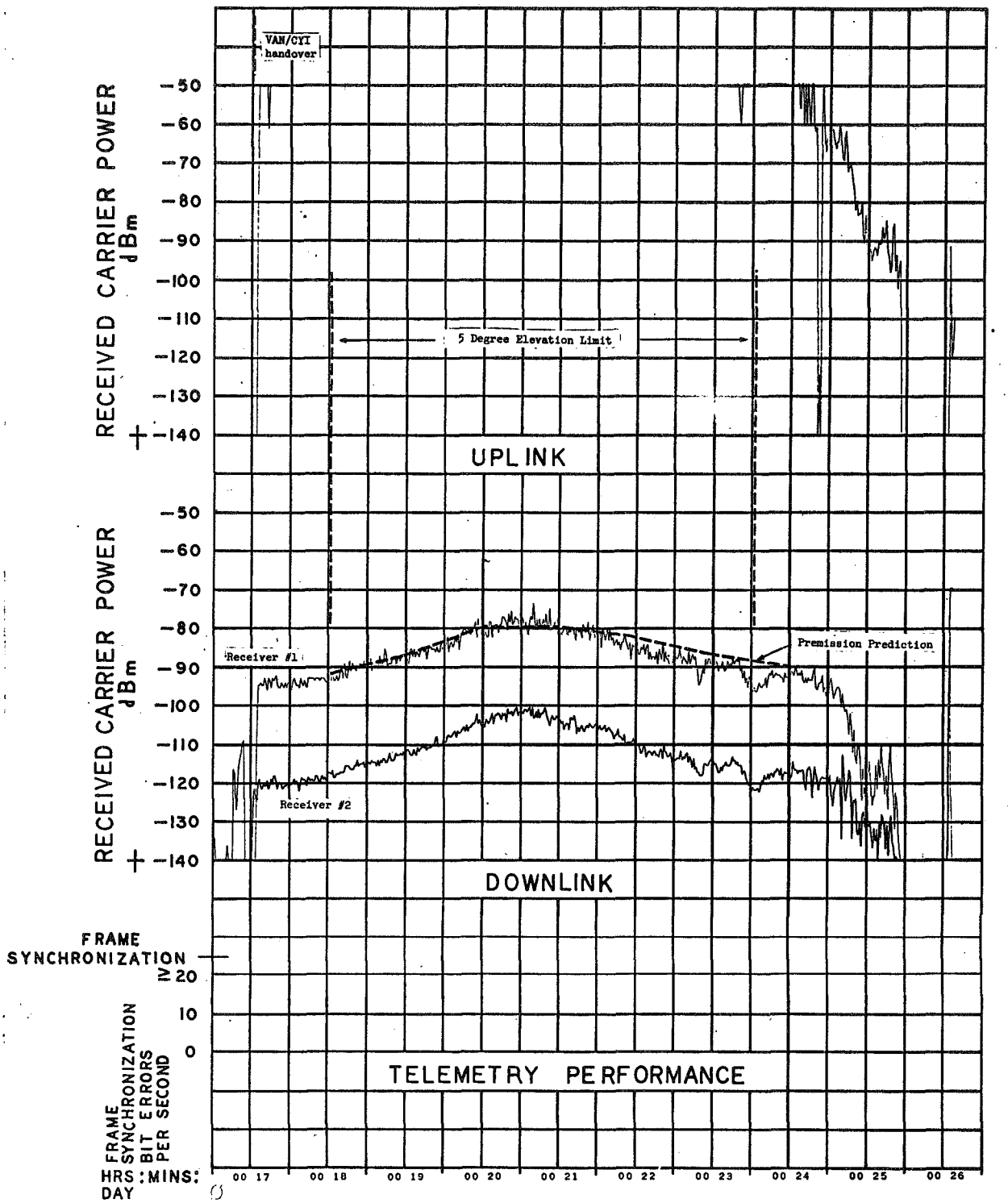

FIGURE 3-6 RECEIVED S-BAND CARRIER POWER CANARY ISLANDS, REVOLUTION 1

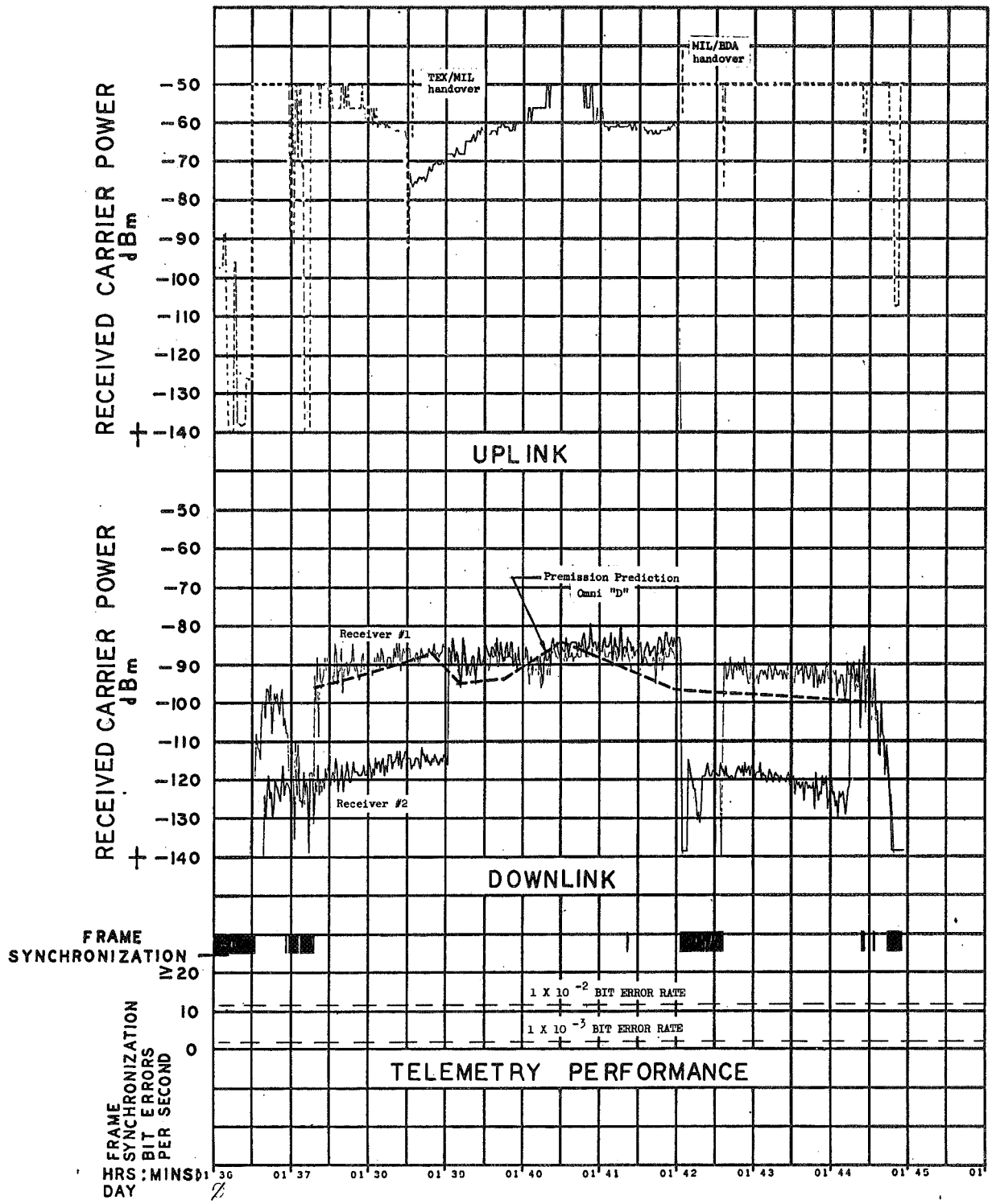

FIGURE 3-7 RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, MERRITT ISLAND, REVOLUTION 1/2.

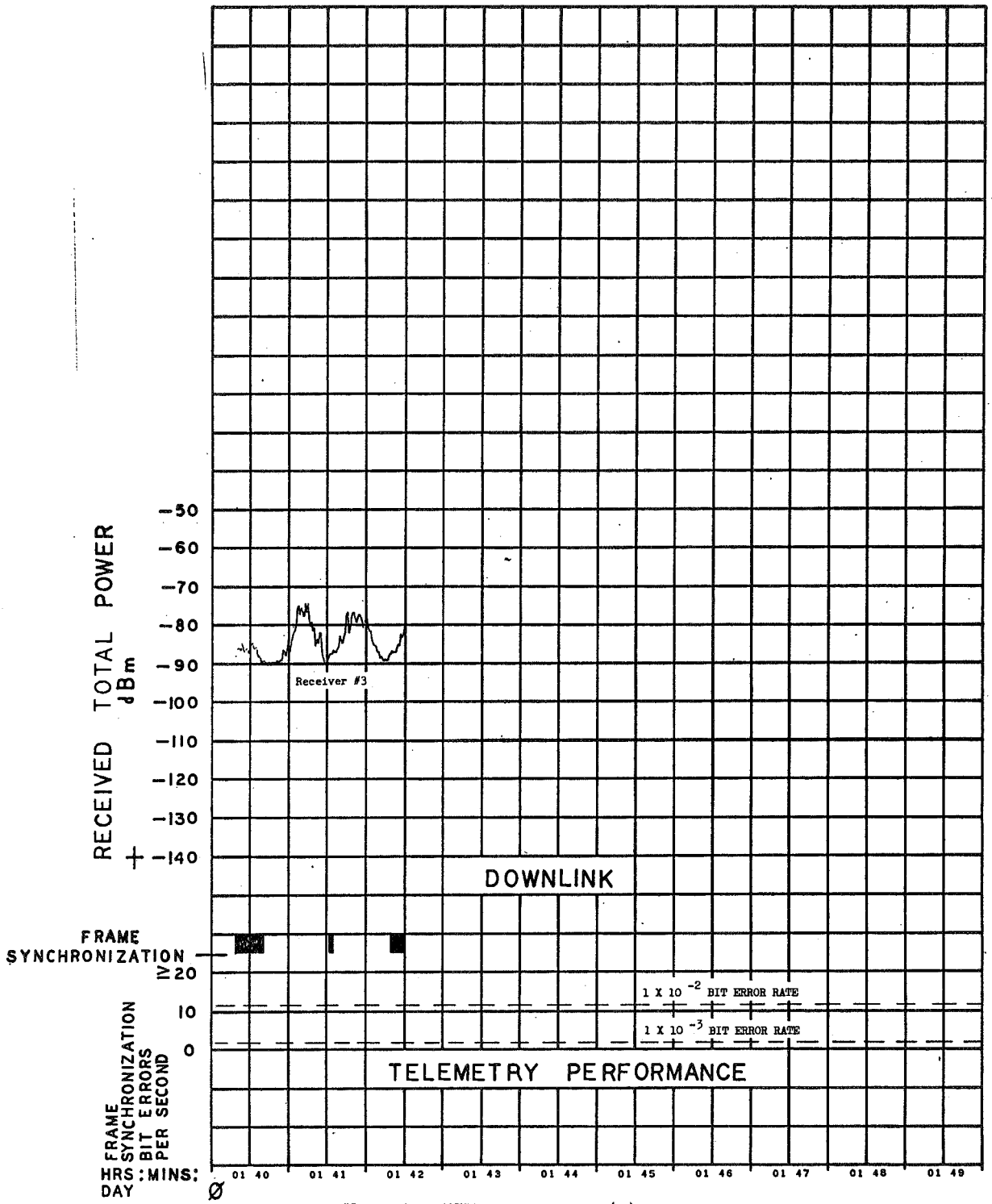

FIGURE 3-8. RECEIVED S-BAND TOTAL POWER (FM) AND TELEMETRY PERFORMANCE, MERRITT ISLAND, REVOLUTION 1/2.

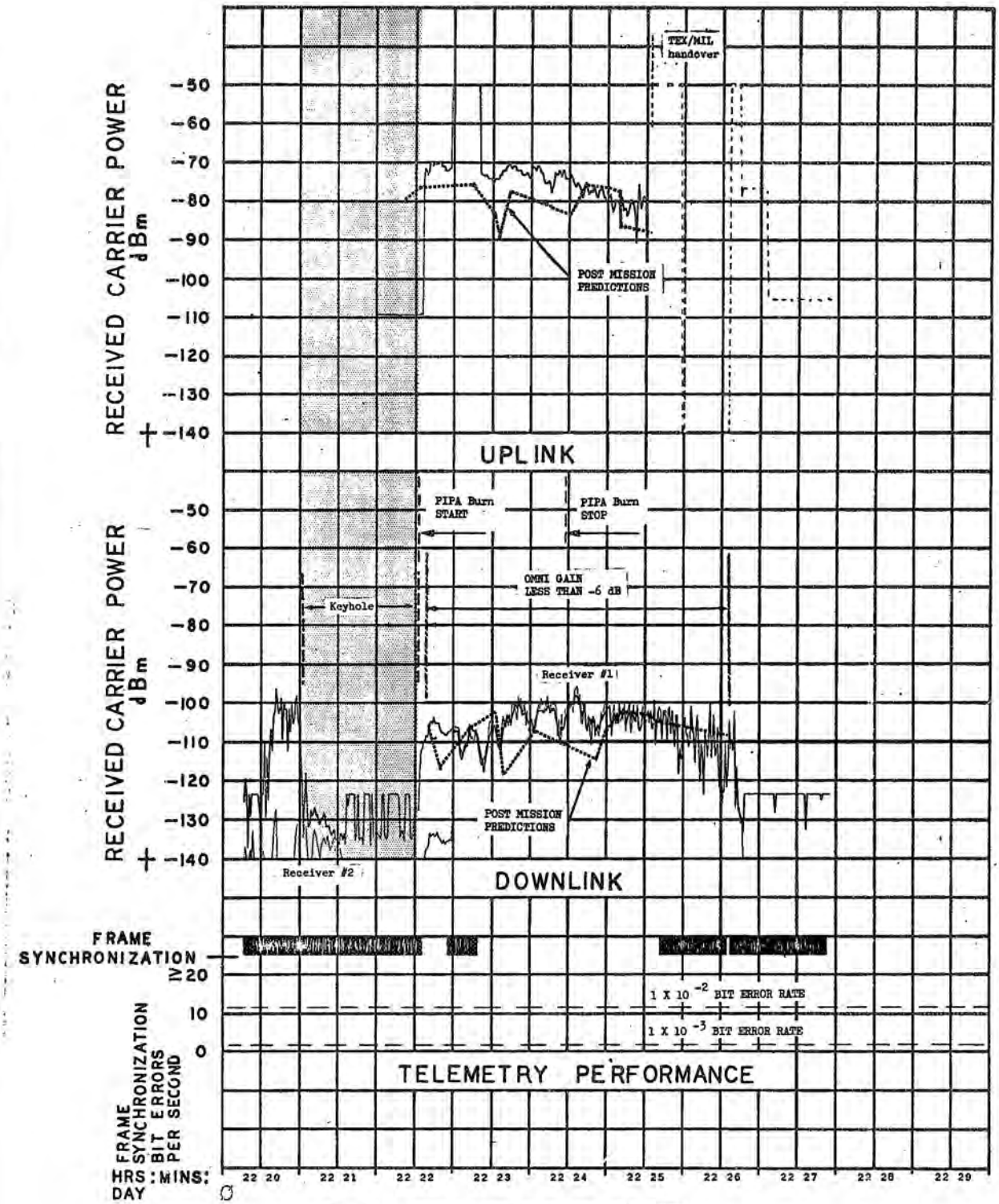

FIGURE 3-9. RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, TEXAS, REVOLUTION 14.

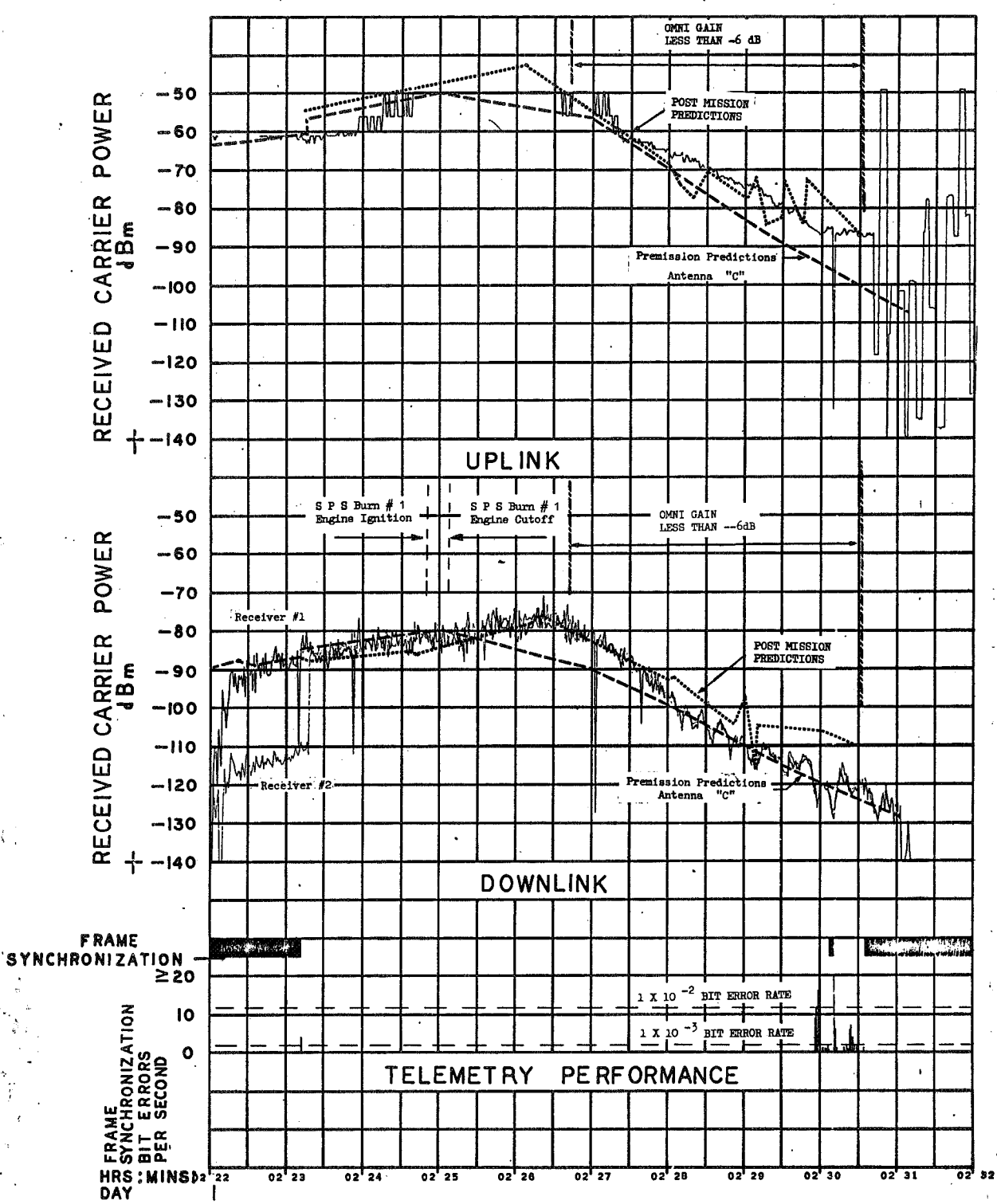

FIGURE 3-10. RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, CARNARVON, REVOLUTION 17.

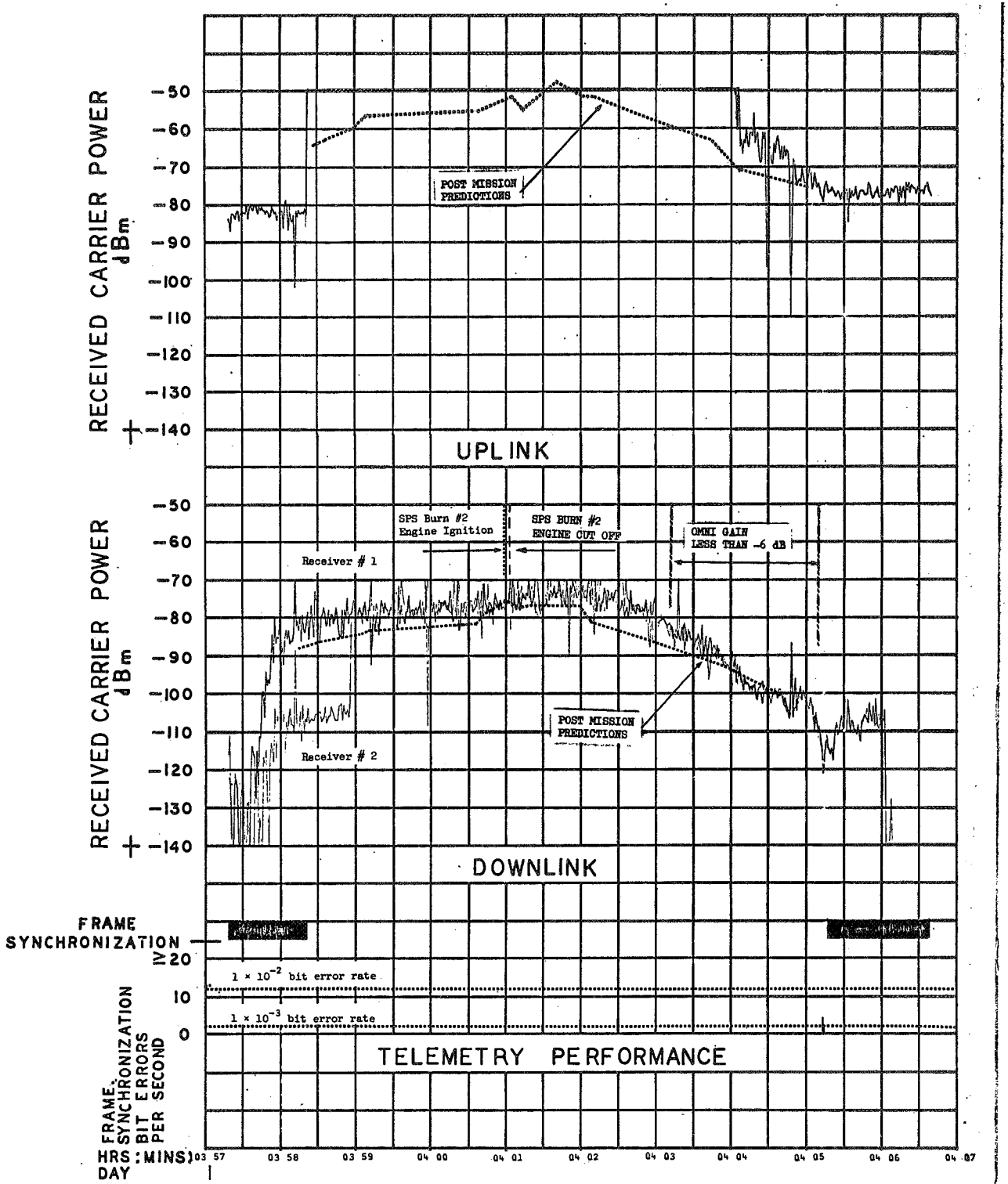

FIGURE 3-11. RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, CARNARVON, REVOLUTION 18.

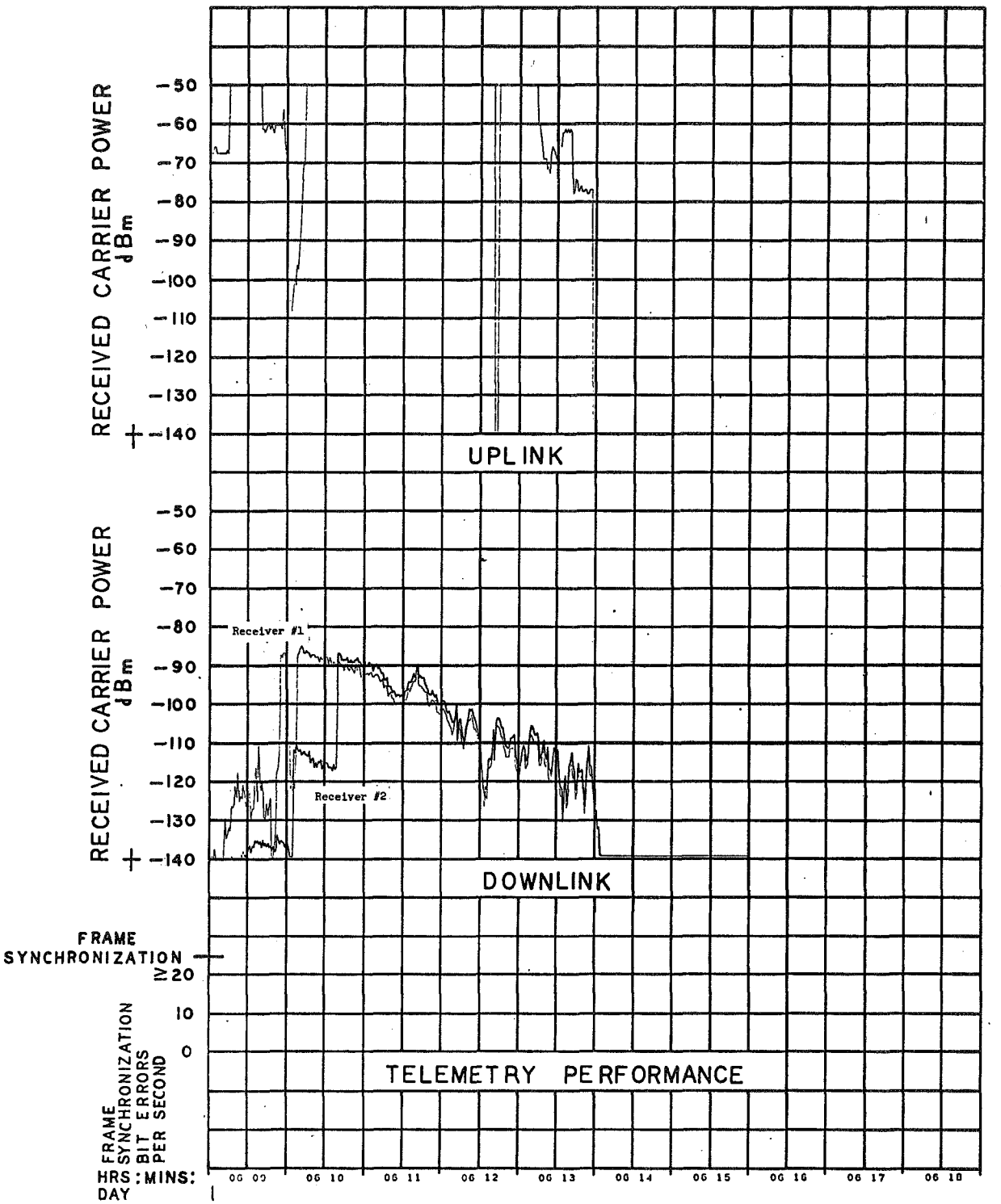

FIGURE 3-12. RECEIVED S-BAND CARRIER POWER, GOLDSTONE, REVOLUTION 19.

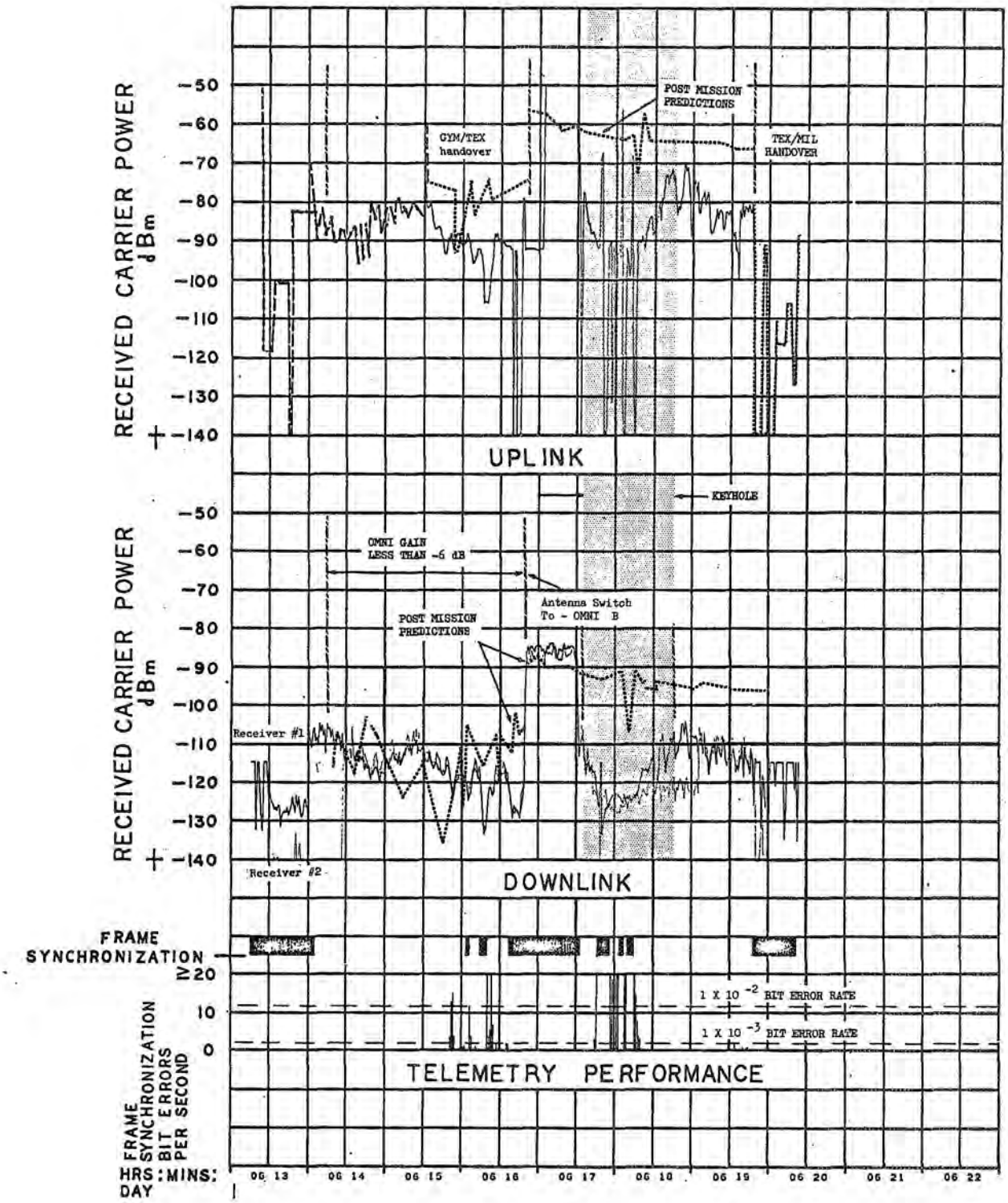

FIGURE 3-13. RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, TEXAS, REVOLUTION 19.

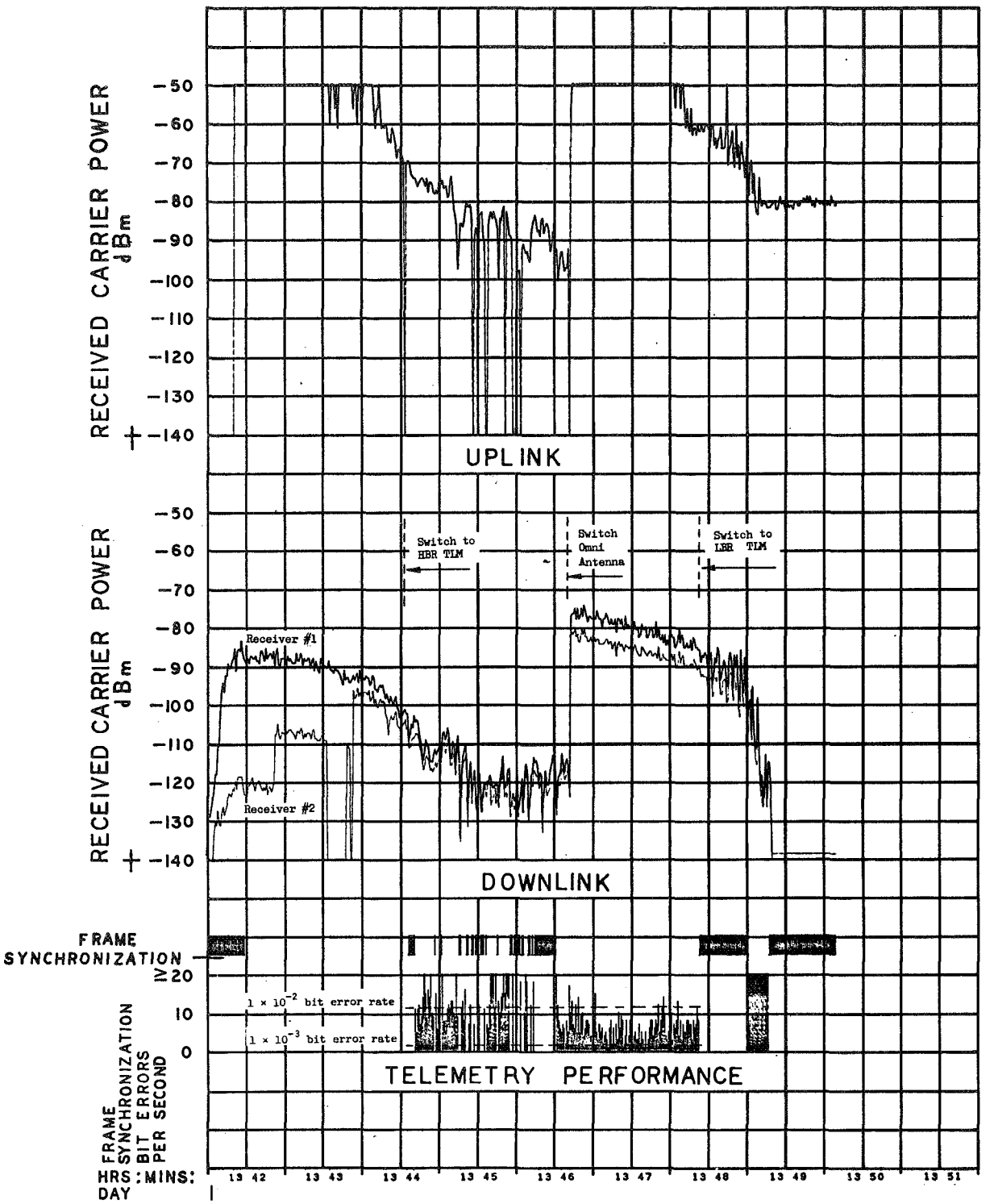

FIGURE 3-14. RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, GUAM, REVOLUTION 24.

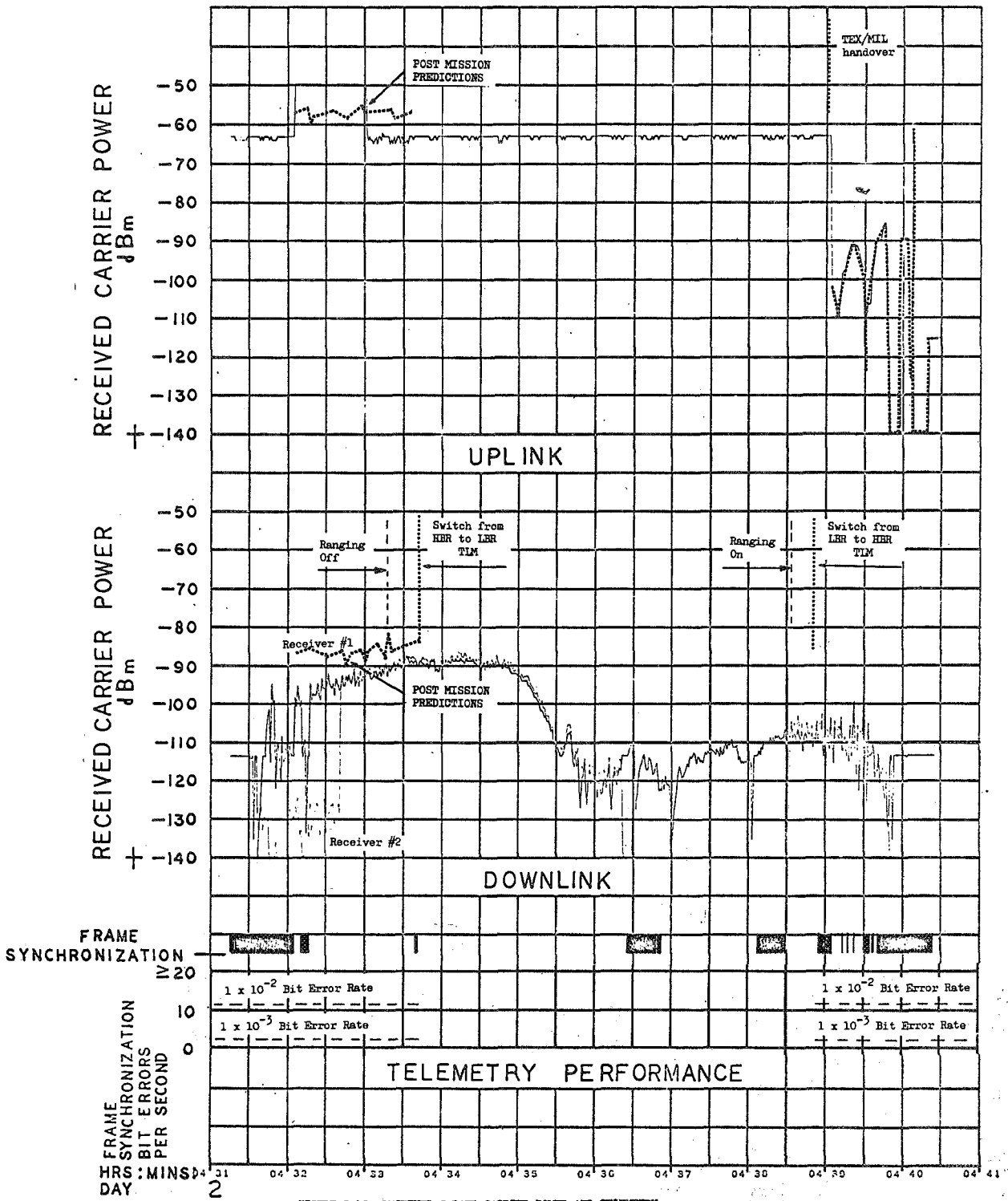

FIGURE 3-15. RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, TEXAS, REVOLUTION 33.

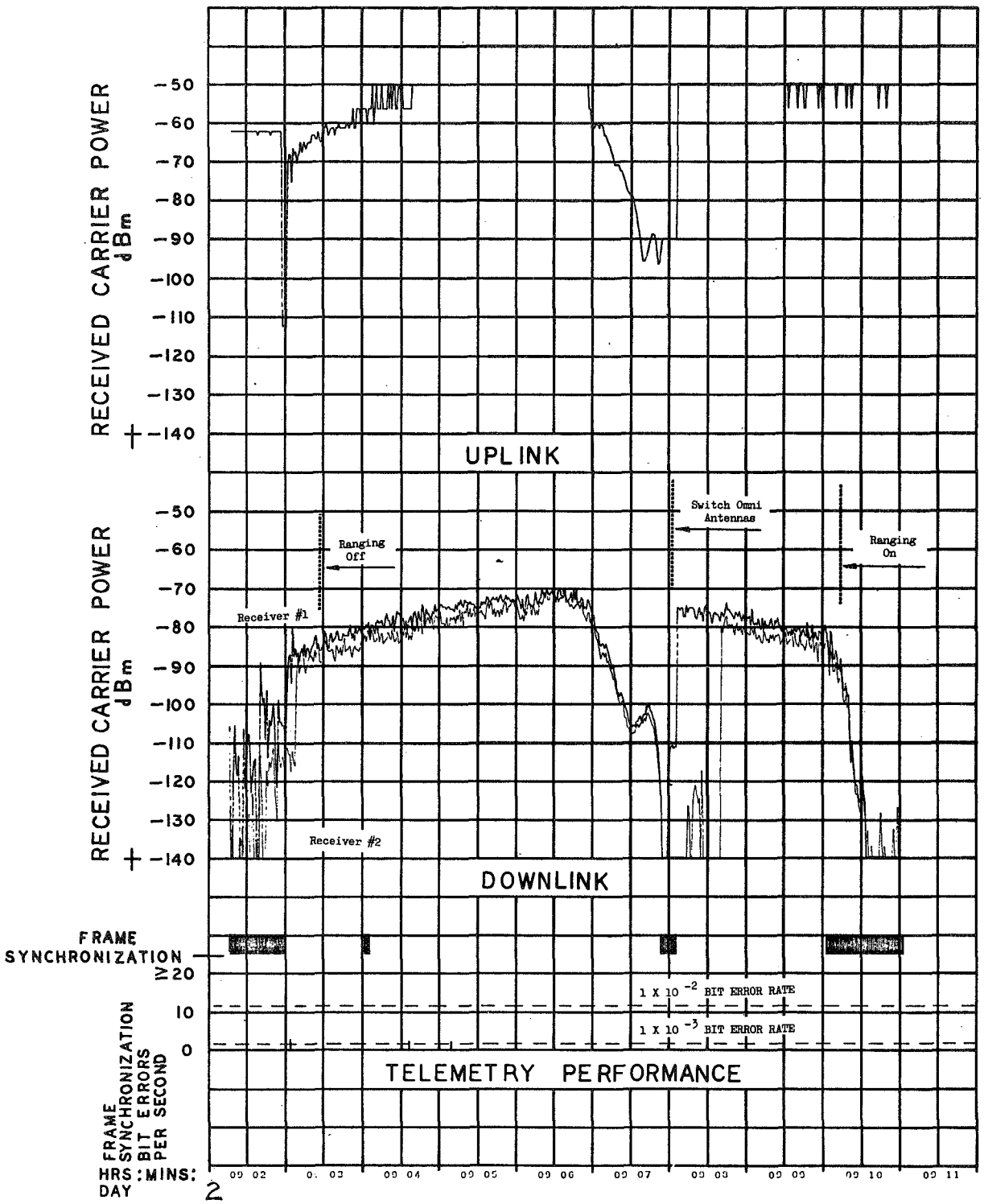

FIGURE 3-16. RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, HAWAII, REVOLUTION 36.

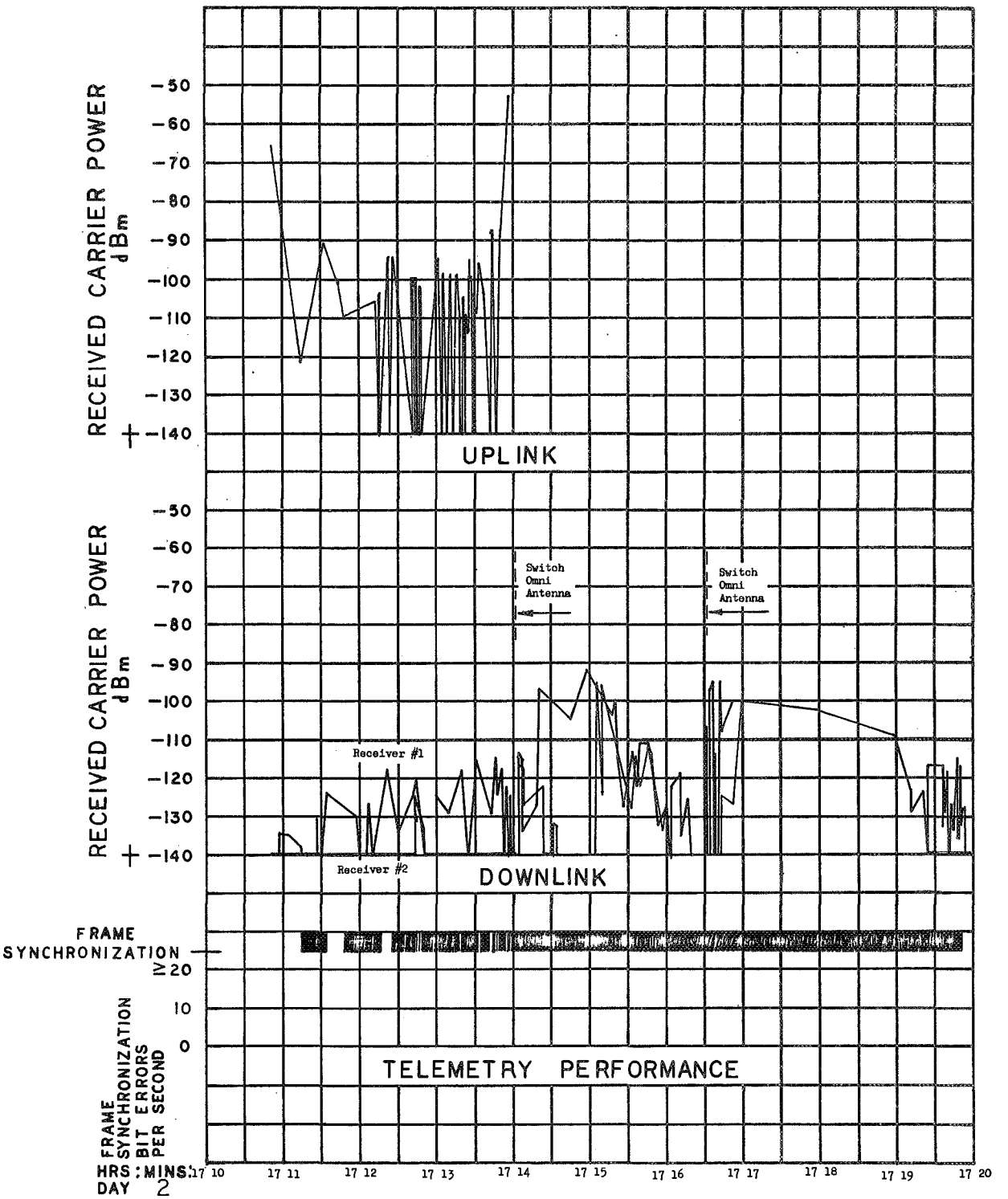

FIGURE 3-17. RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, U.S.N.S. REDSTONE, REVOLUTION 41.

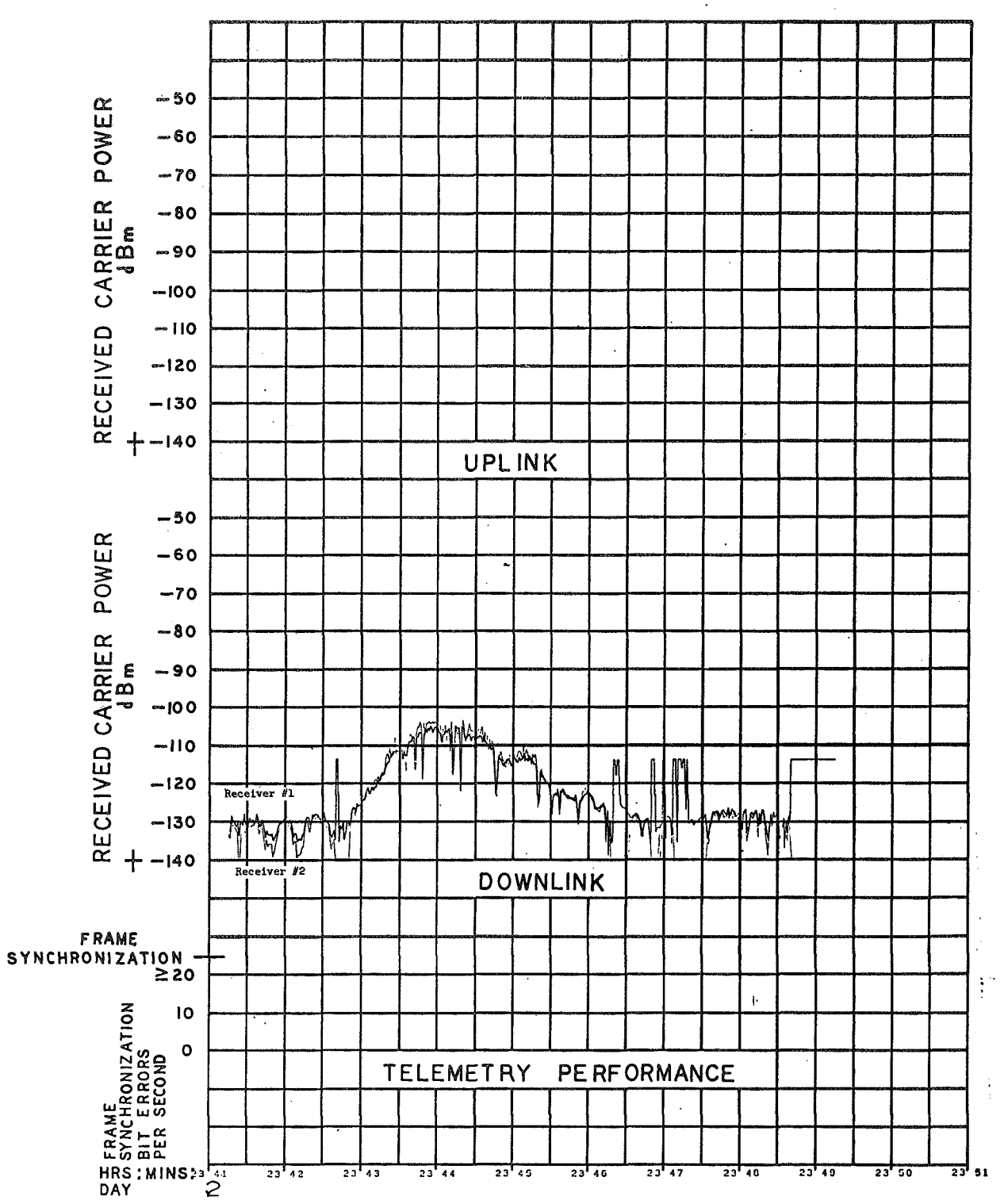

FIGURE 3-18. RECEIVED S-BAND CARRIER POWER, TEXAS, REVOLUTION 45.

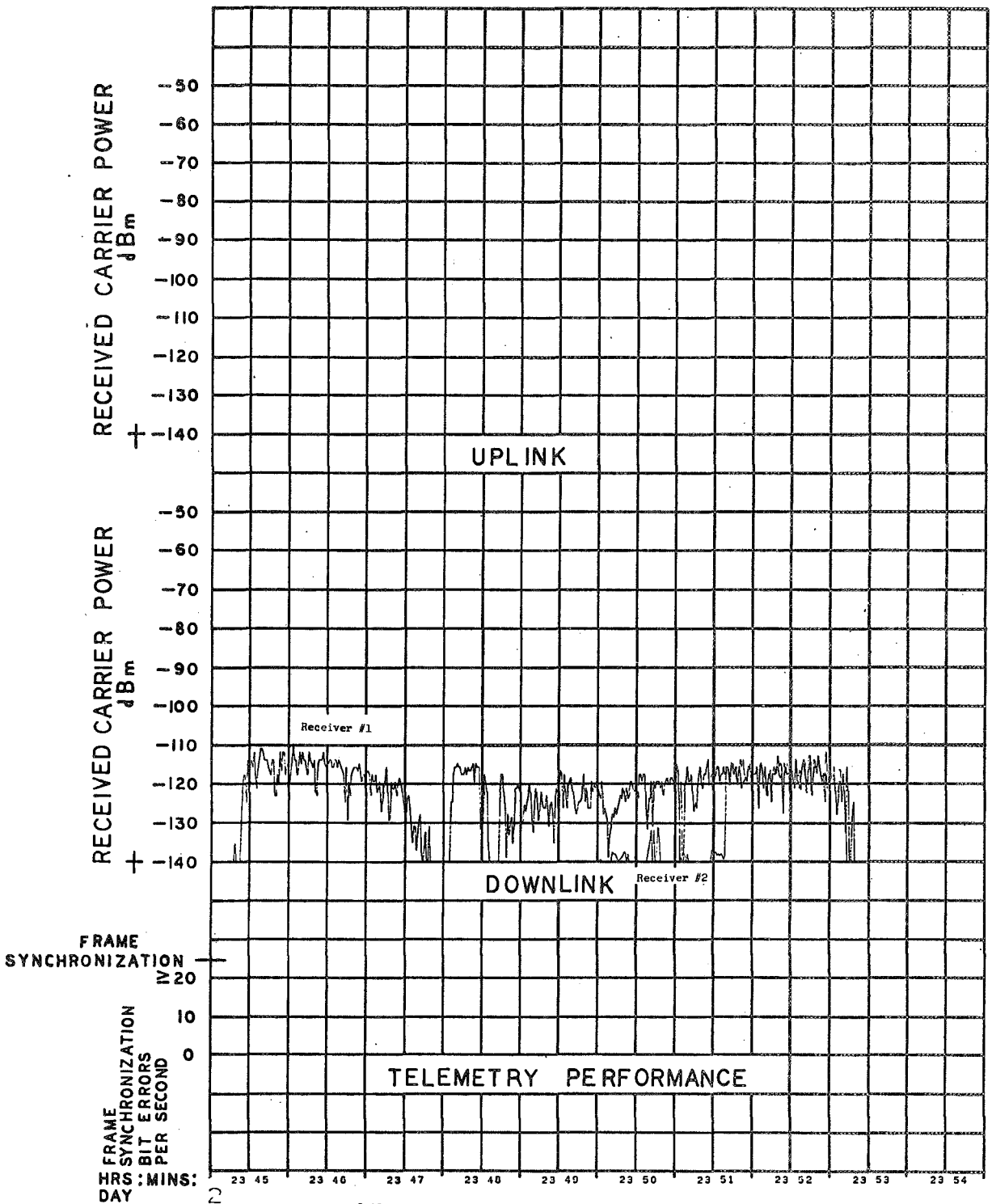

FIGURE 3-19. RECEIVED S-BAND CARRIER POWER, MERRITT ISLAND, REVOLUTION 45/46

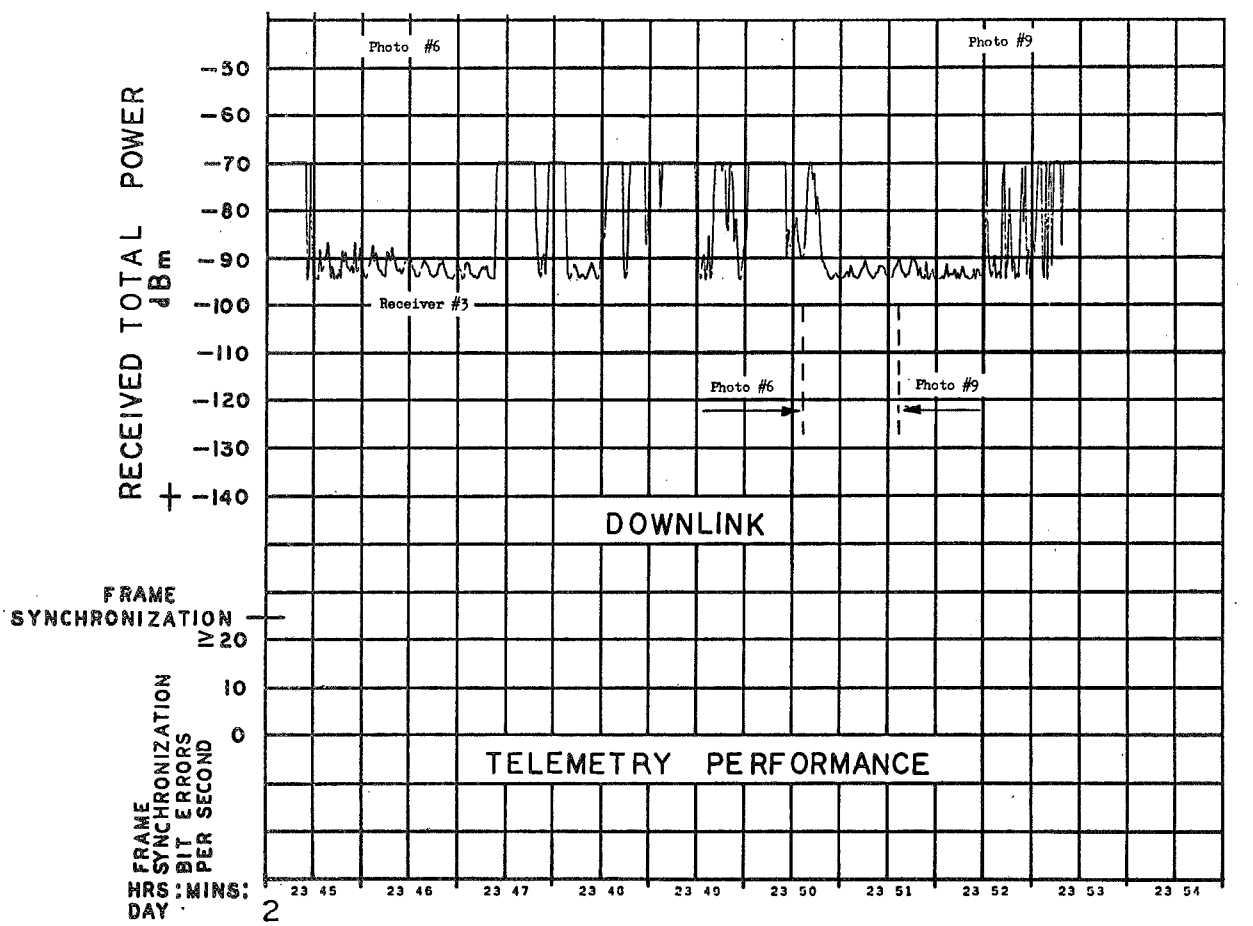

FIGURE 3-20 RECEIVED S-BAND TOTAL POWER (FM) AND SELECTED TELEVISION PHOTOGRAPHS, MERRITT ISLAND, REVOLUTION 45/46.

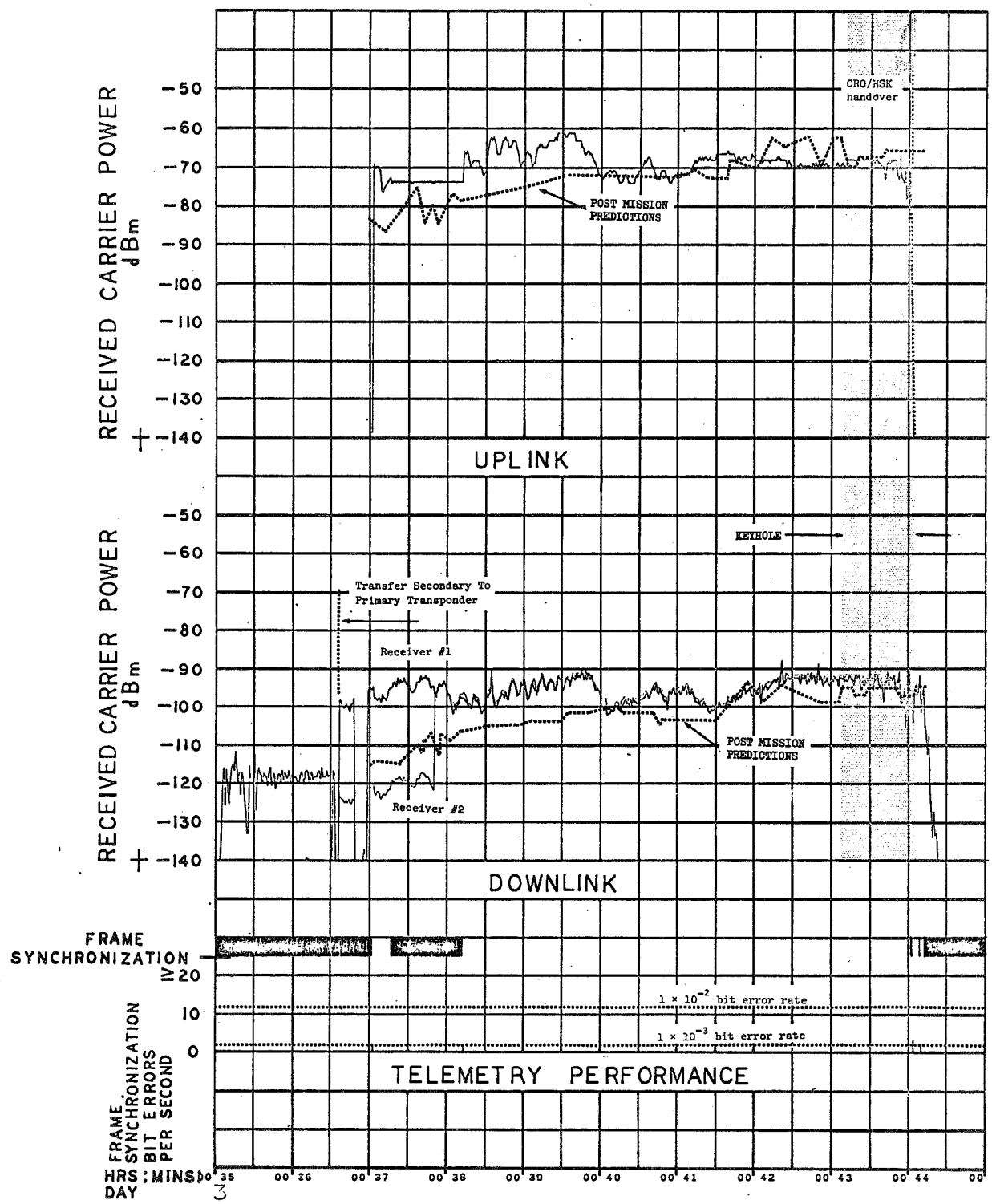

FIGURE 3-21. RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, CARNARVON, REVOLUTION 46.

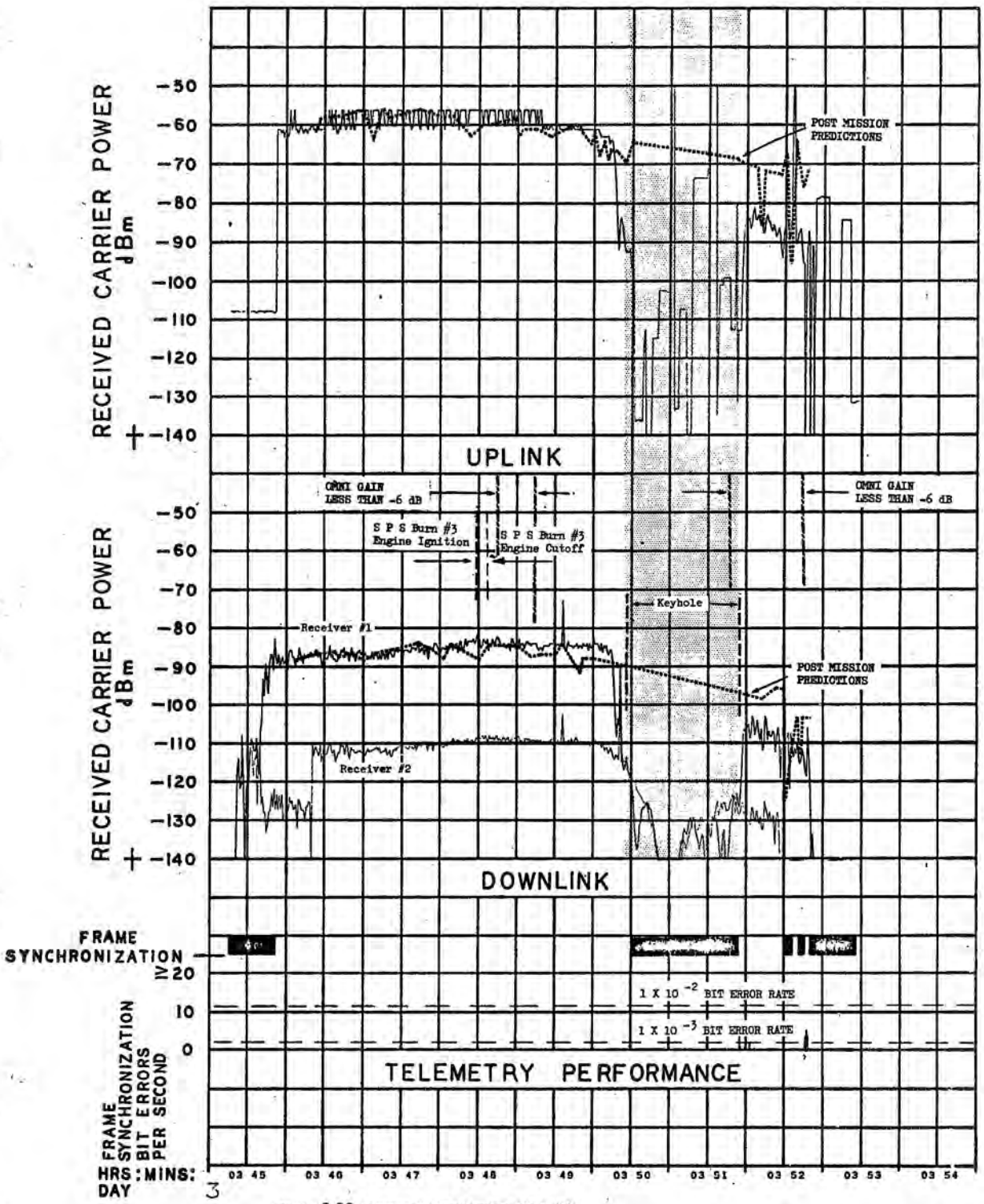

FIGURE 3-22 RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, CARNARVON, REVOLUTION 48.

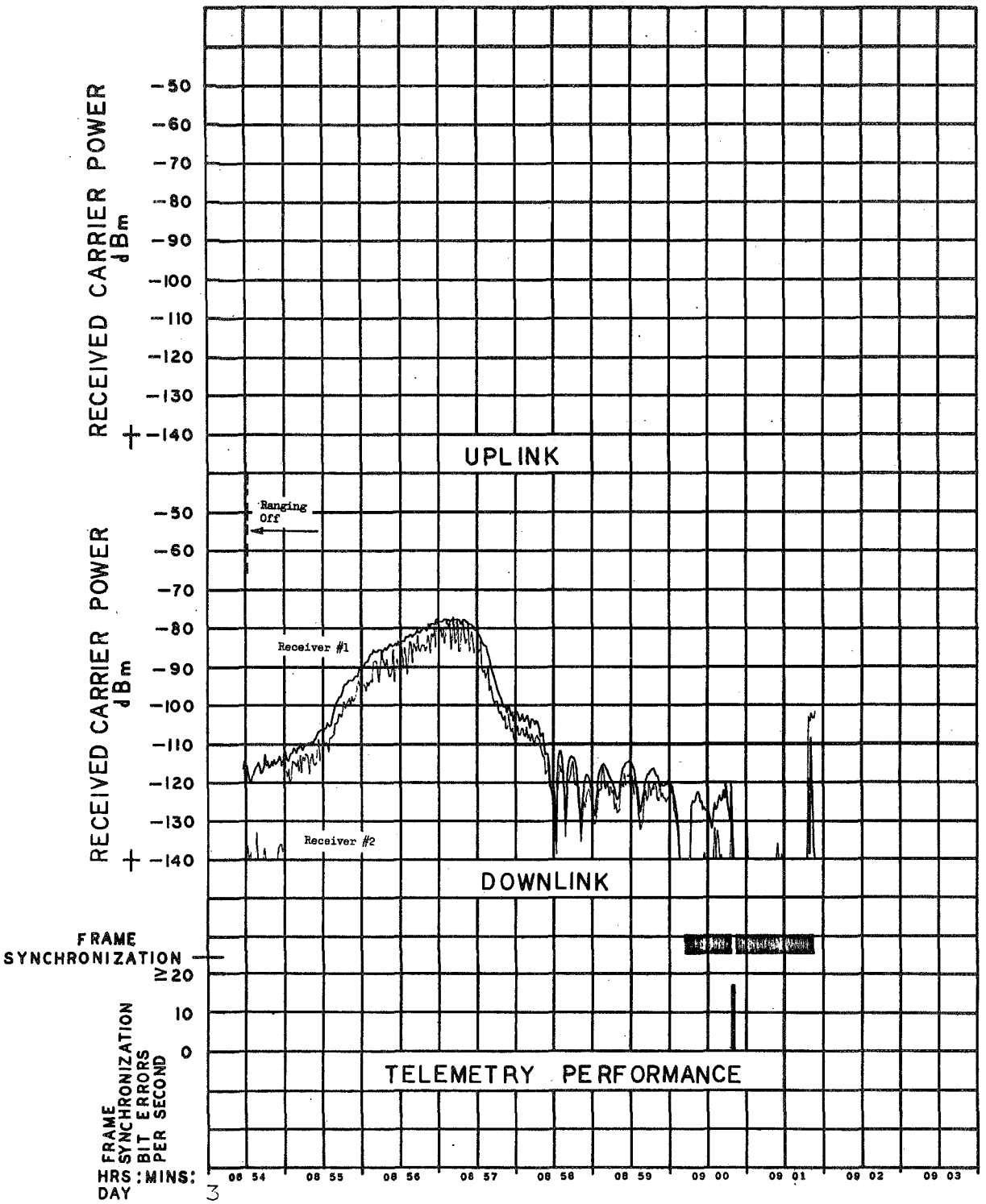

FIGURE 3-23 RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, HAWAII, REVOLUTION 51.

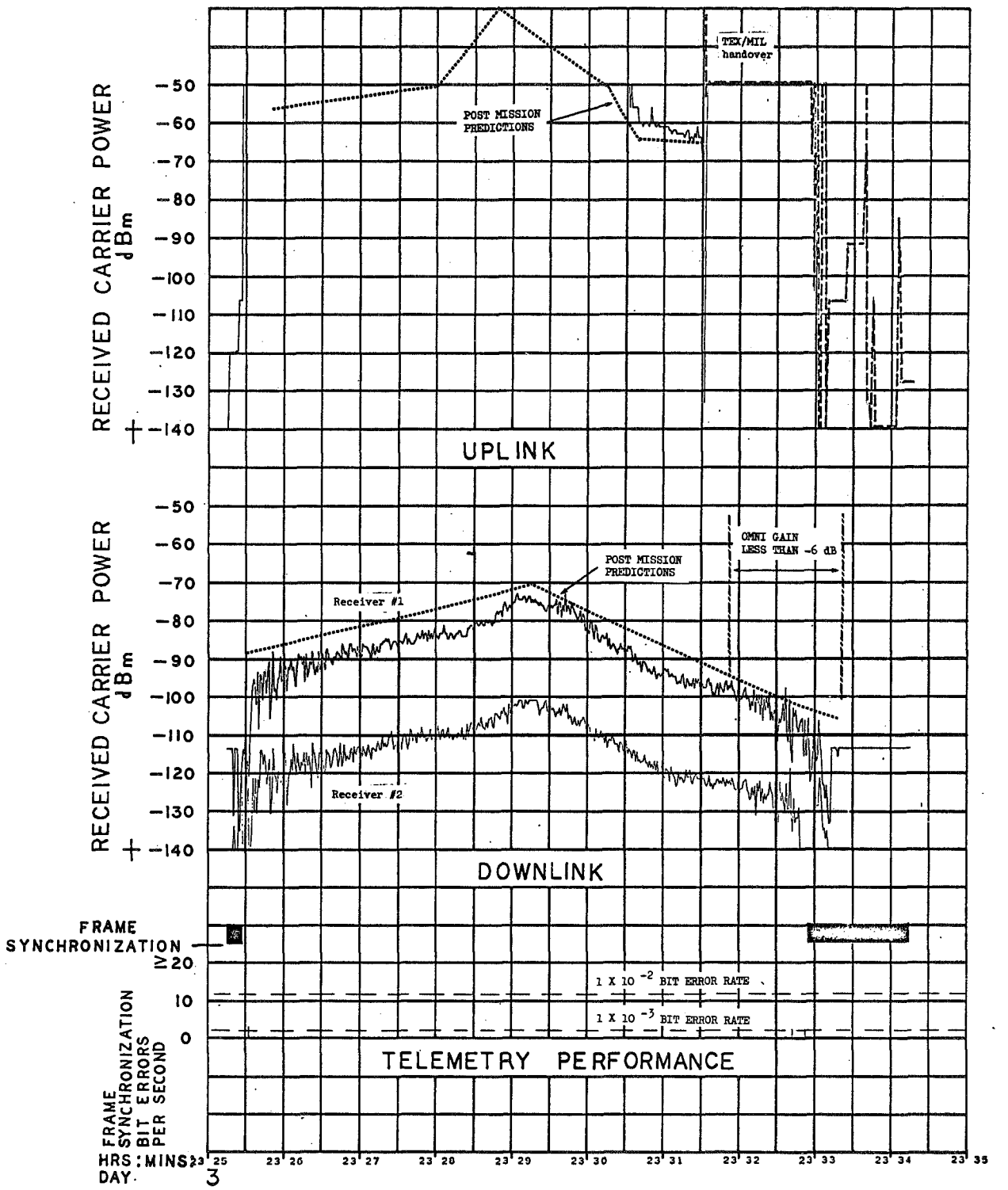

FIGURE 3-24. RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, TEXAS, REVOLUTION 60.

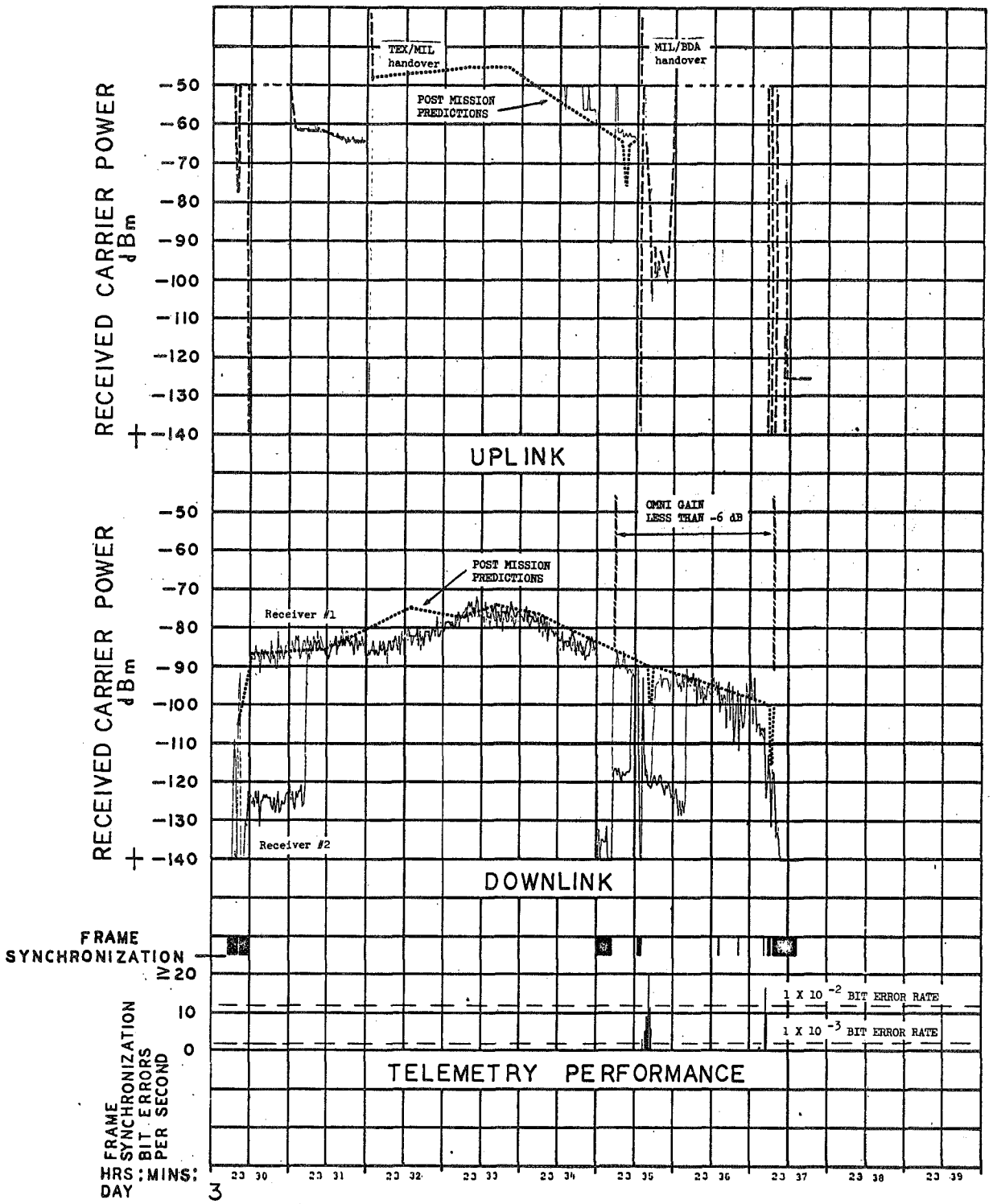

FIGURE 3-25. RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, MERRITT ISLAND, REVOLUTION 60/61.

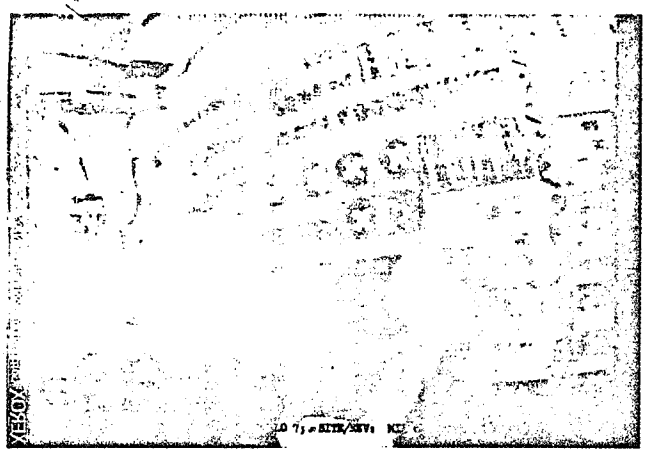

Photo #7

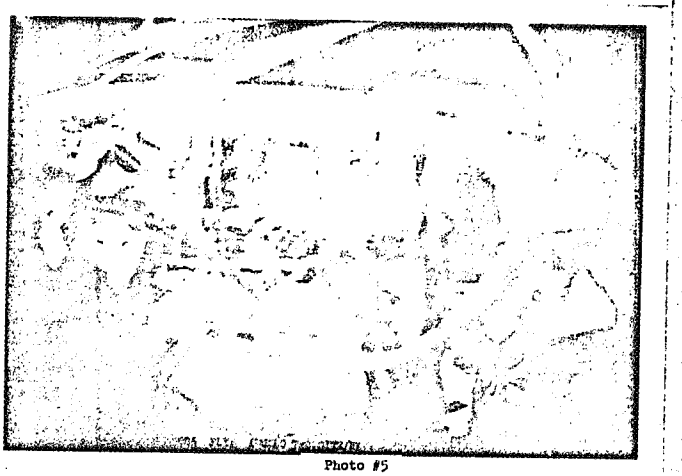

Photo #5

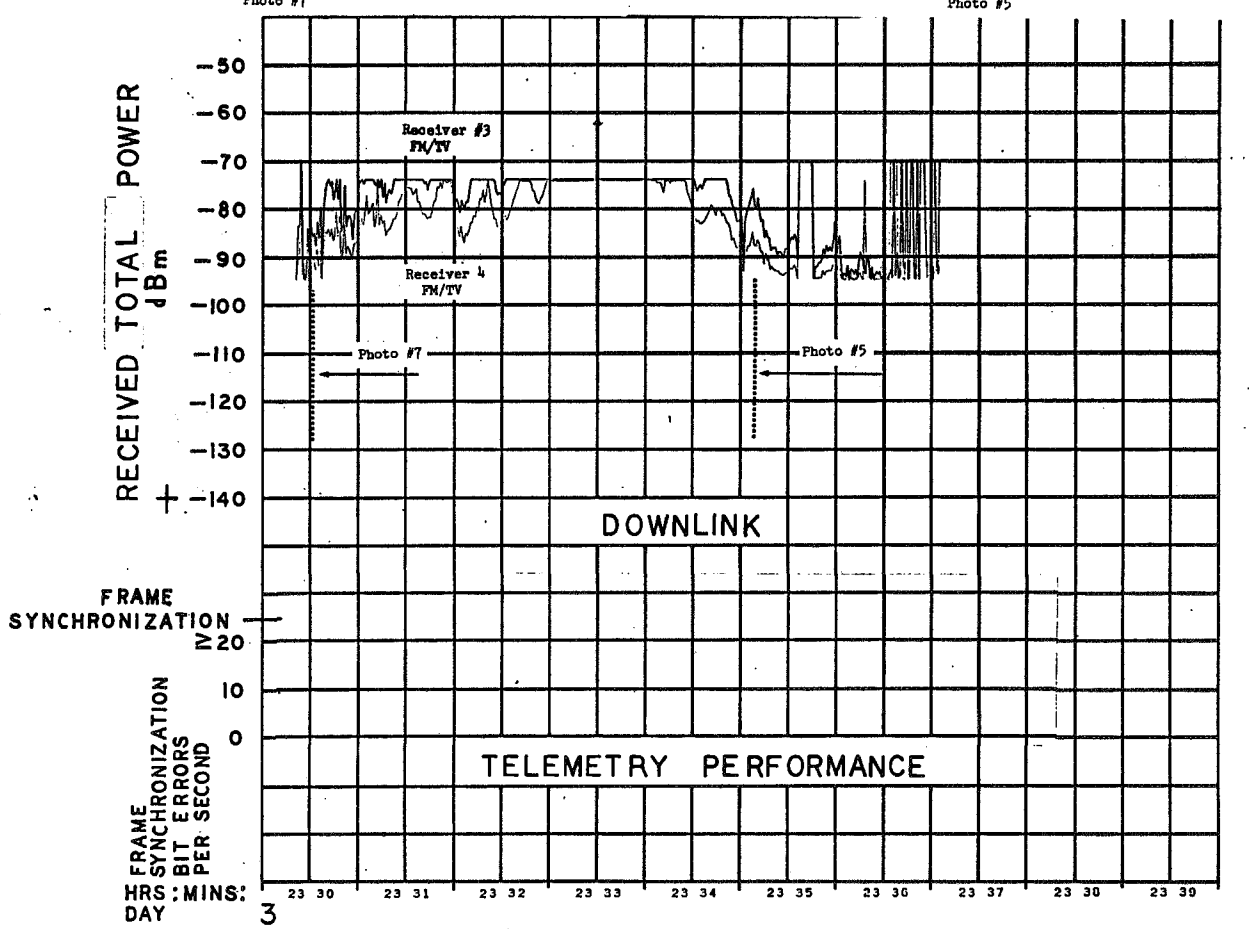

FIGURE 3-26 RECEIVED S-BAND TOTAL POWER (FM) AND SELECTED TELEVISION PHOTOGRAPHS, MERRITT ISLAND, REVOLUTION 60/61.

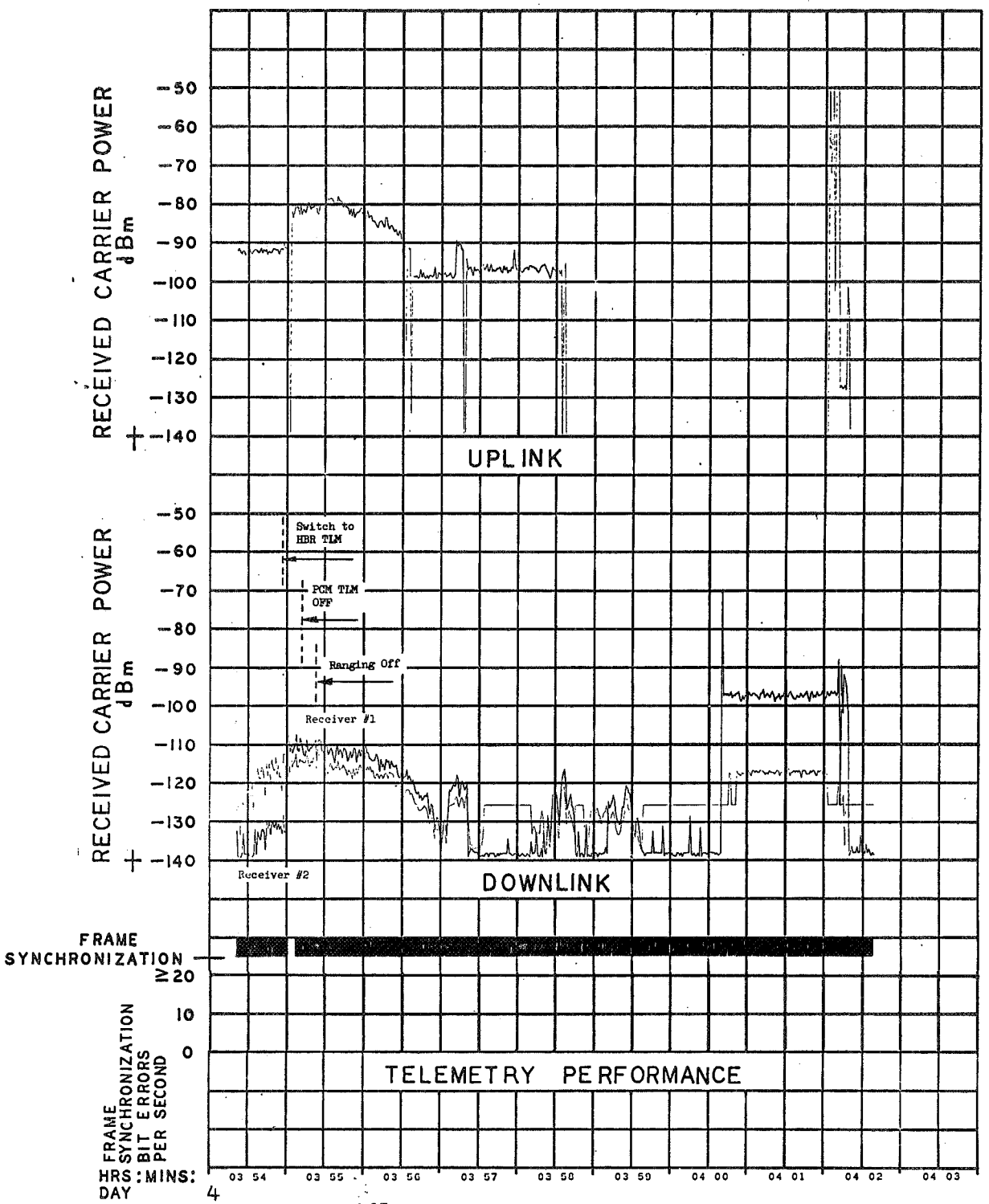

FIGURE 3-27 RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, HAWAII, REVOLUTION 63.

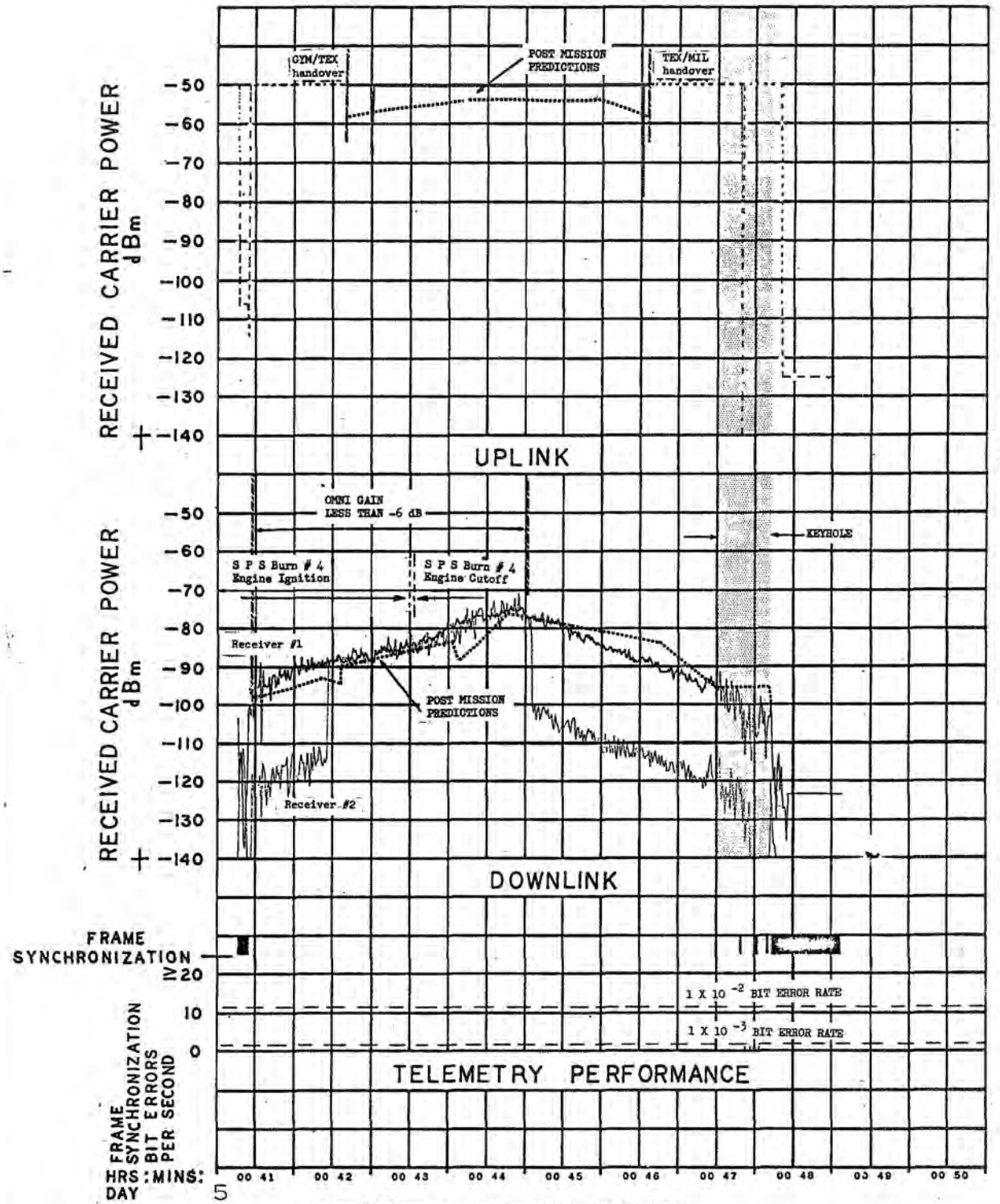

FIGURE 3-28. RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, TEXAS, REVOLUTION 76.

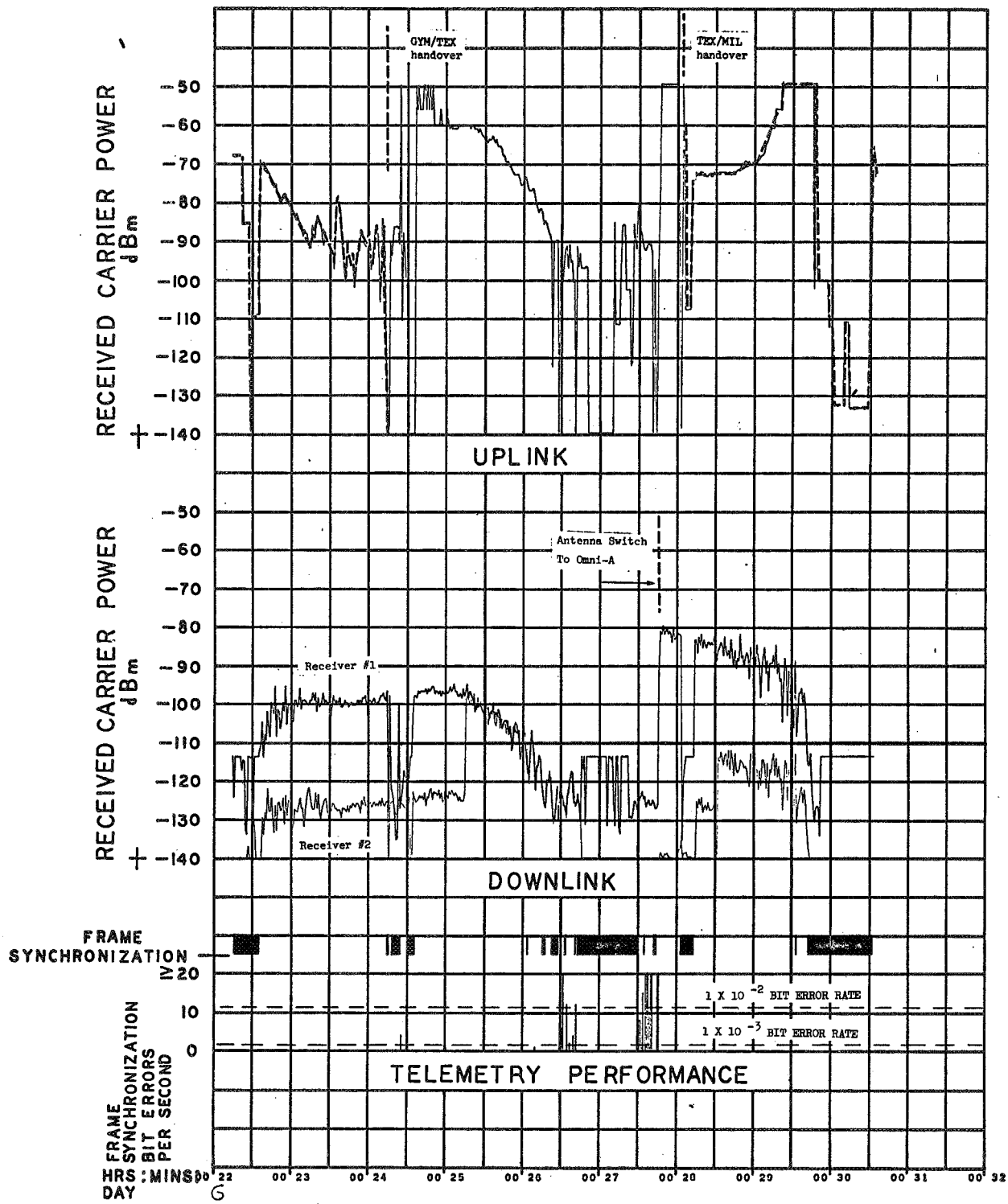

FIGURE 3-29 RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, TEXAS, REVOLUTION 91.

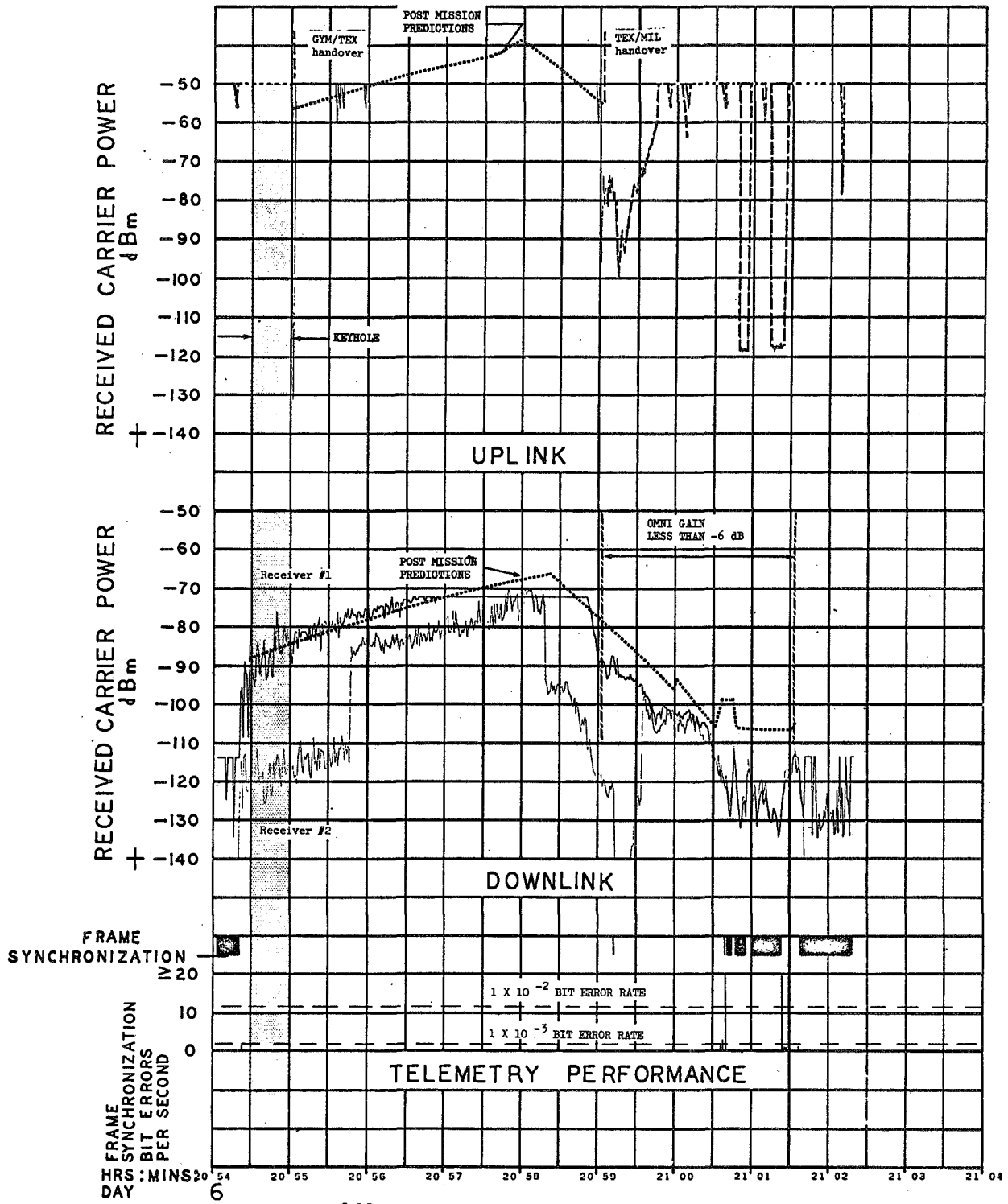

FIGURE 3-30. RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, TEXAS, REVOLUTION 104.

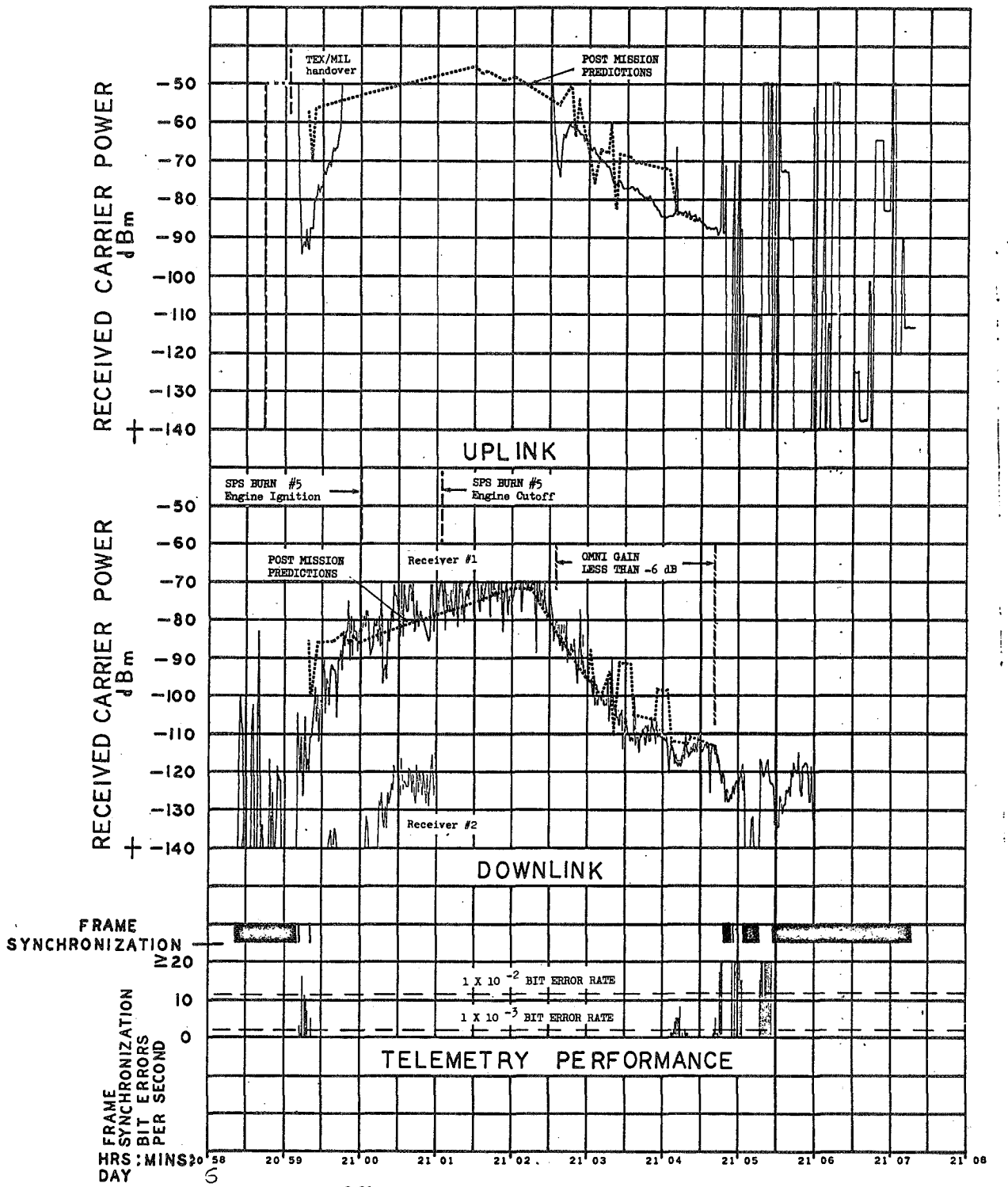

FIGURE 3-31. RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, MERRITT ISLAND, REVOLUTION 104/105.

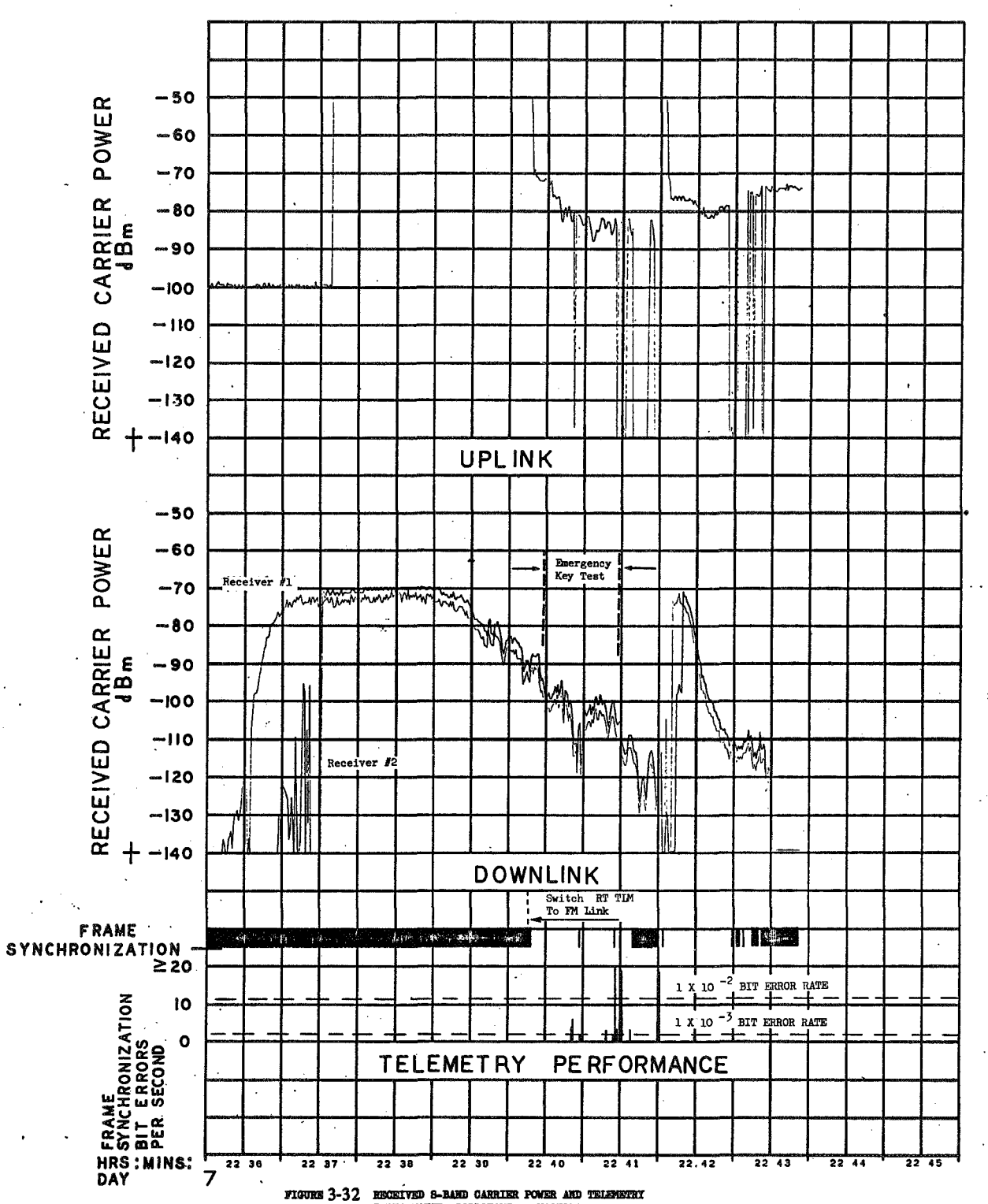

FIGURE 3-32 RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, GOLDSTONE, REVOLUTION 120.

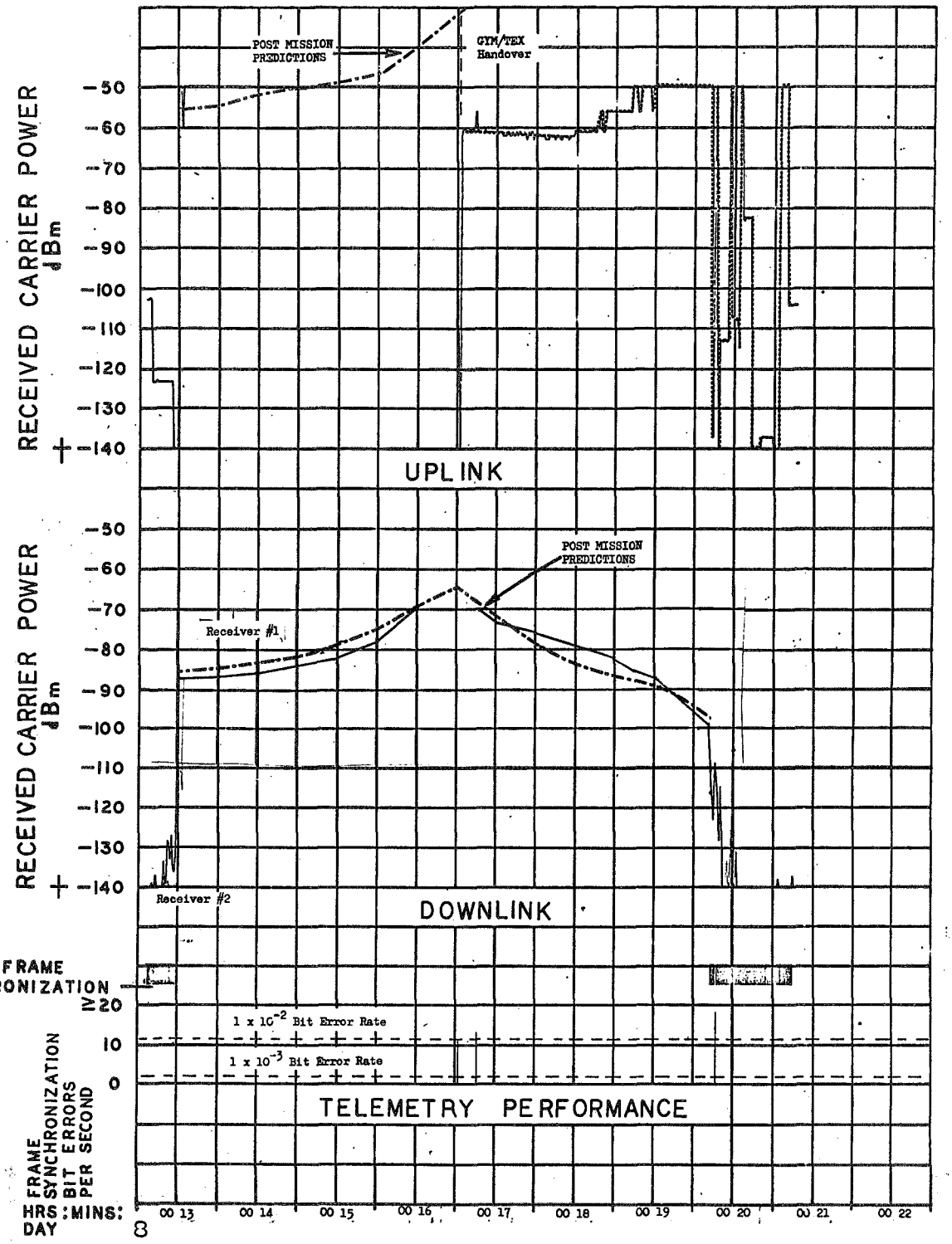

FIGURE 3-33. RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, GUAYMAS, REVOLUTION 121.

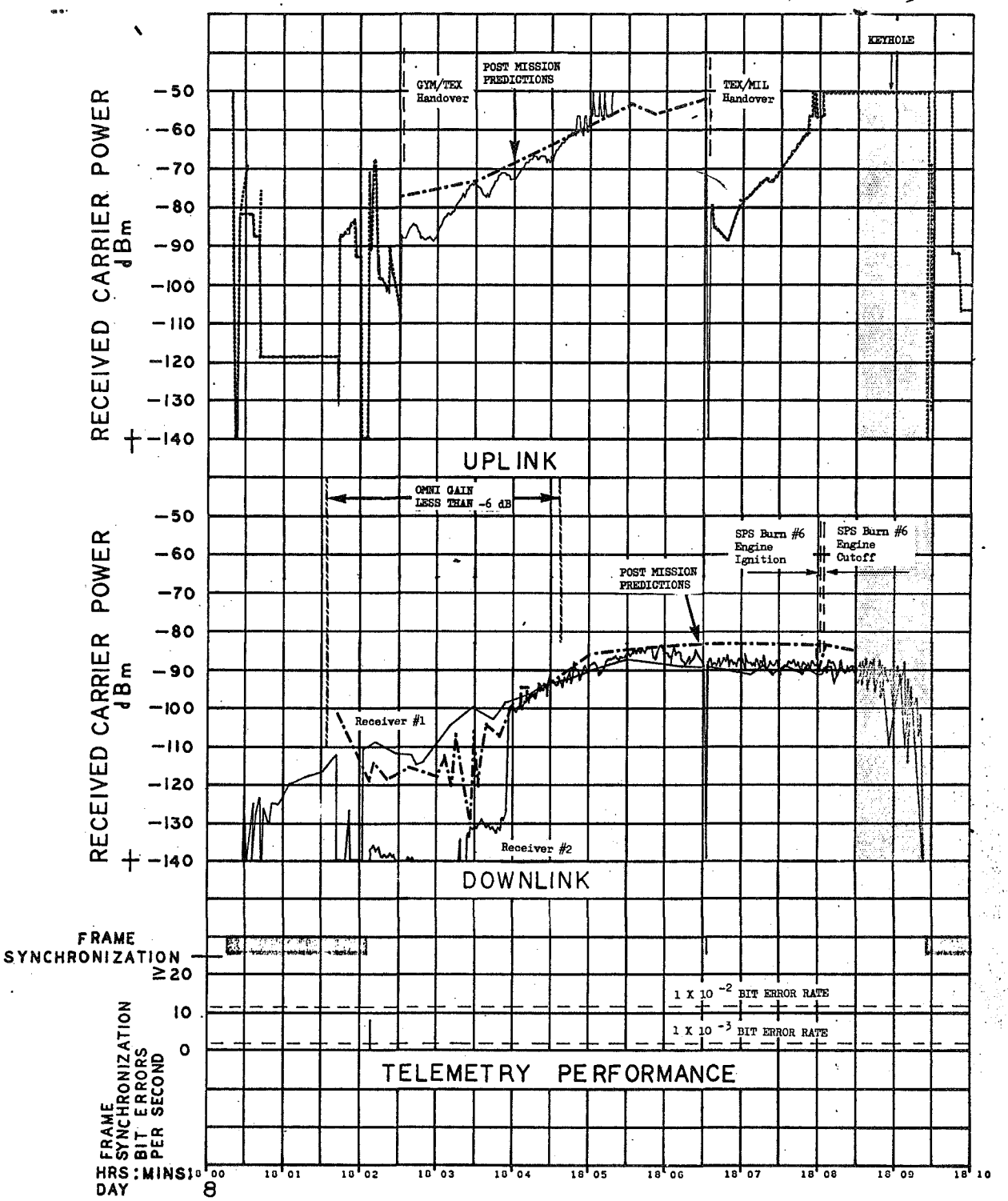

FIGURE 3-34 RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, TEXAS, REVOLUTION 132.

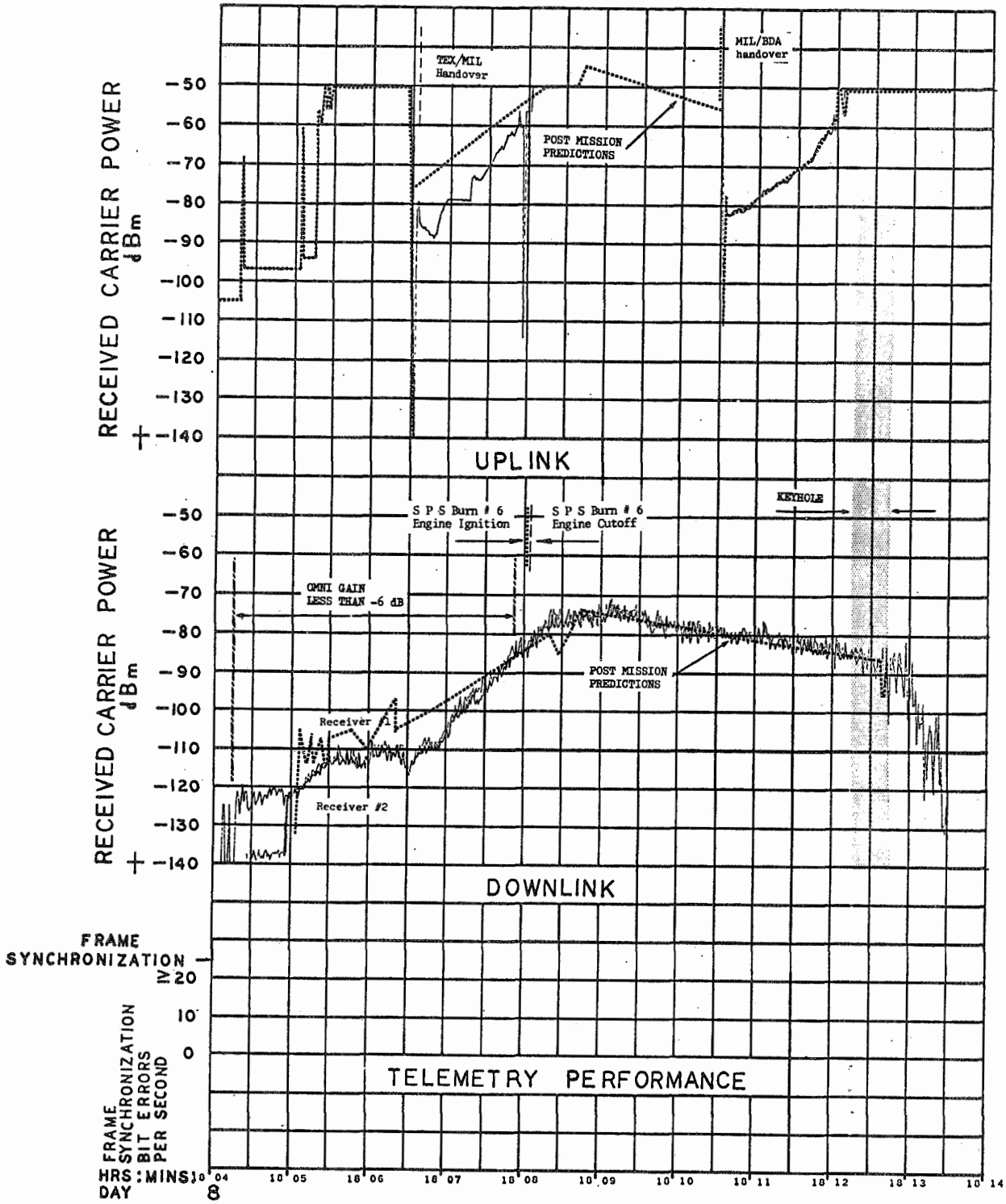

FIGURE 3-35 RECEIVED S-BAND CARRIER POWER, MERRITT ISLAND, REVOLUTION 132/133

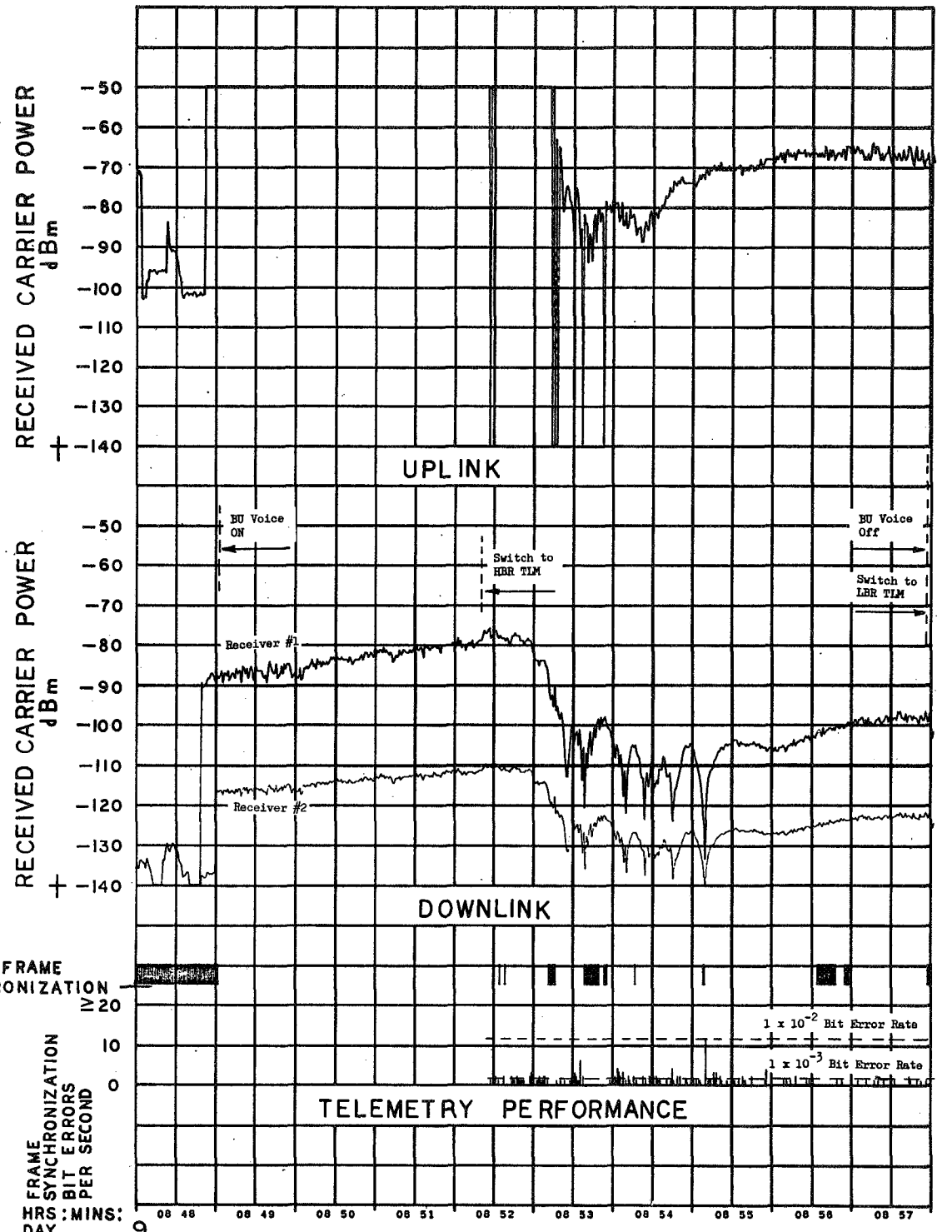

FIGURE 3-36 RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, ASCENSION, REVOLUTION 142.

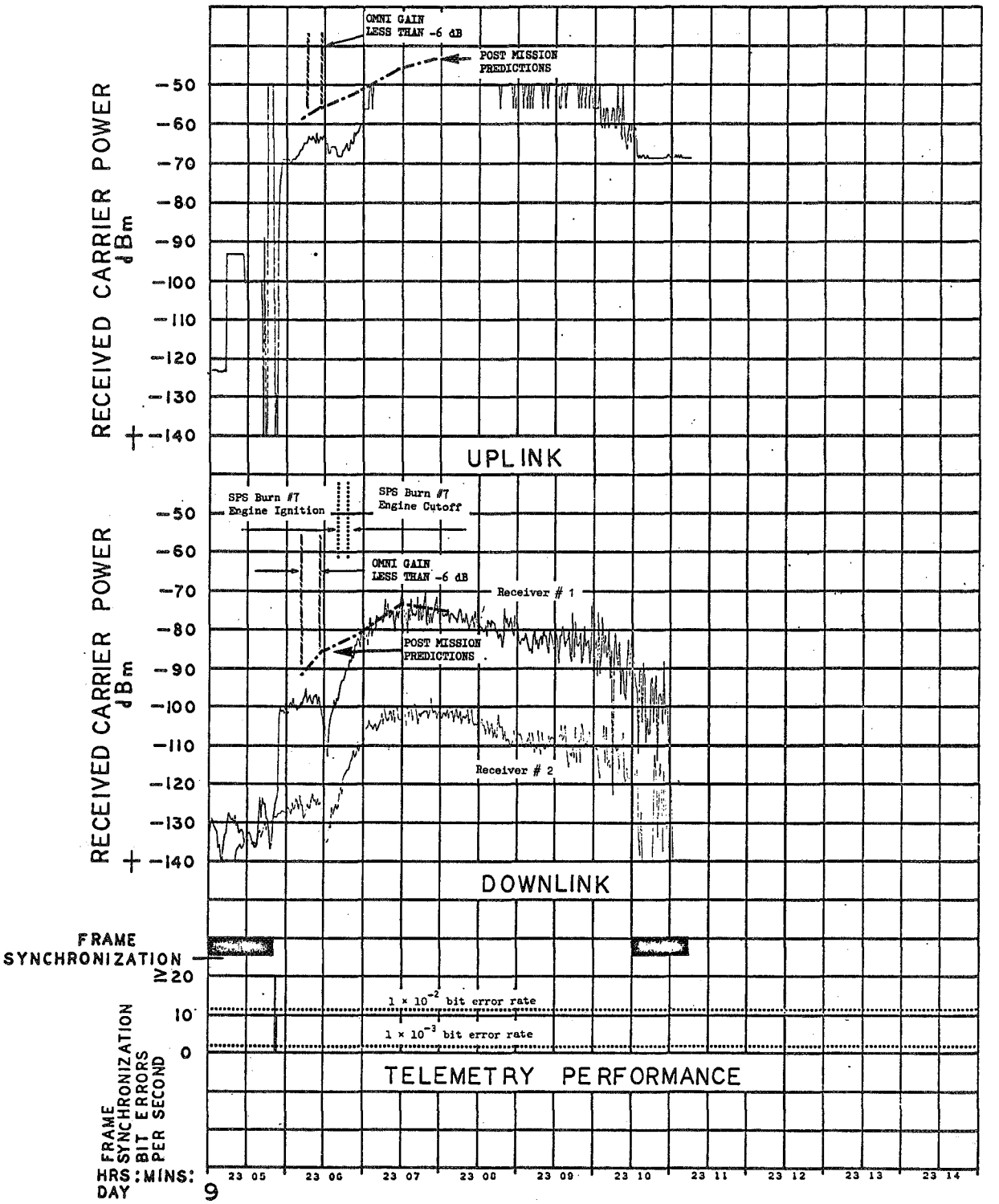

FIGURE 3-37. RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, ANTIGUA, REVOLUTION 151.

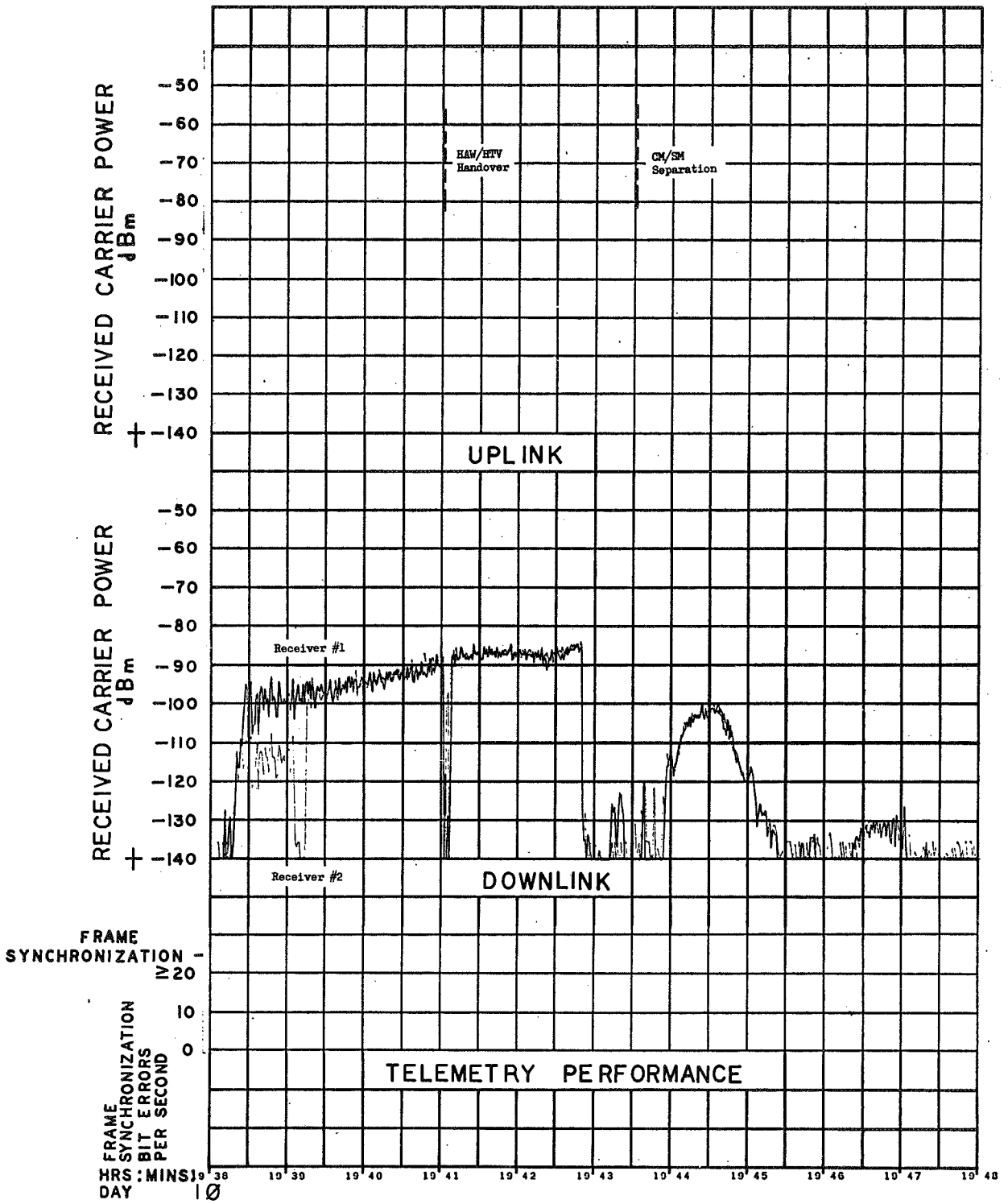

FIGURE 3-38 RECEIVED S-BAND CARRIER POWER, U.S.N.S. HUNTSVILLE, REVOLUTION 163.

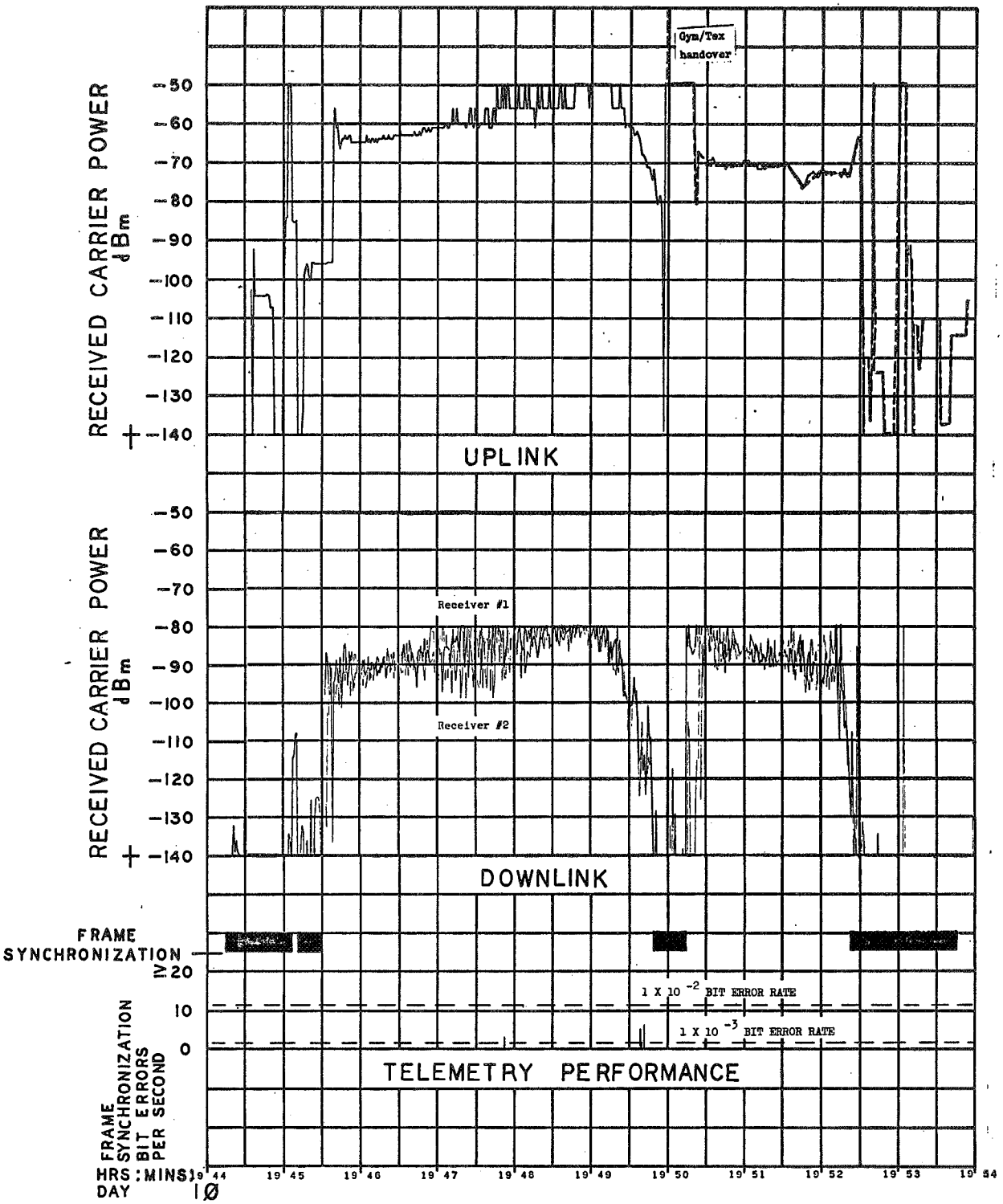

FIGURE 3-39 RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, GUAYMAS, REVOLUTION 163.

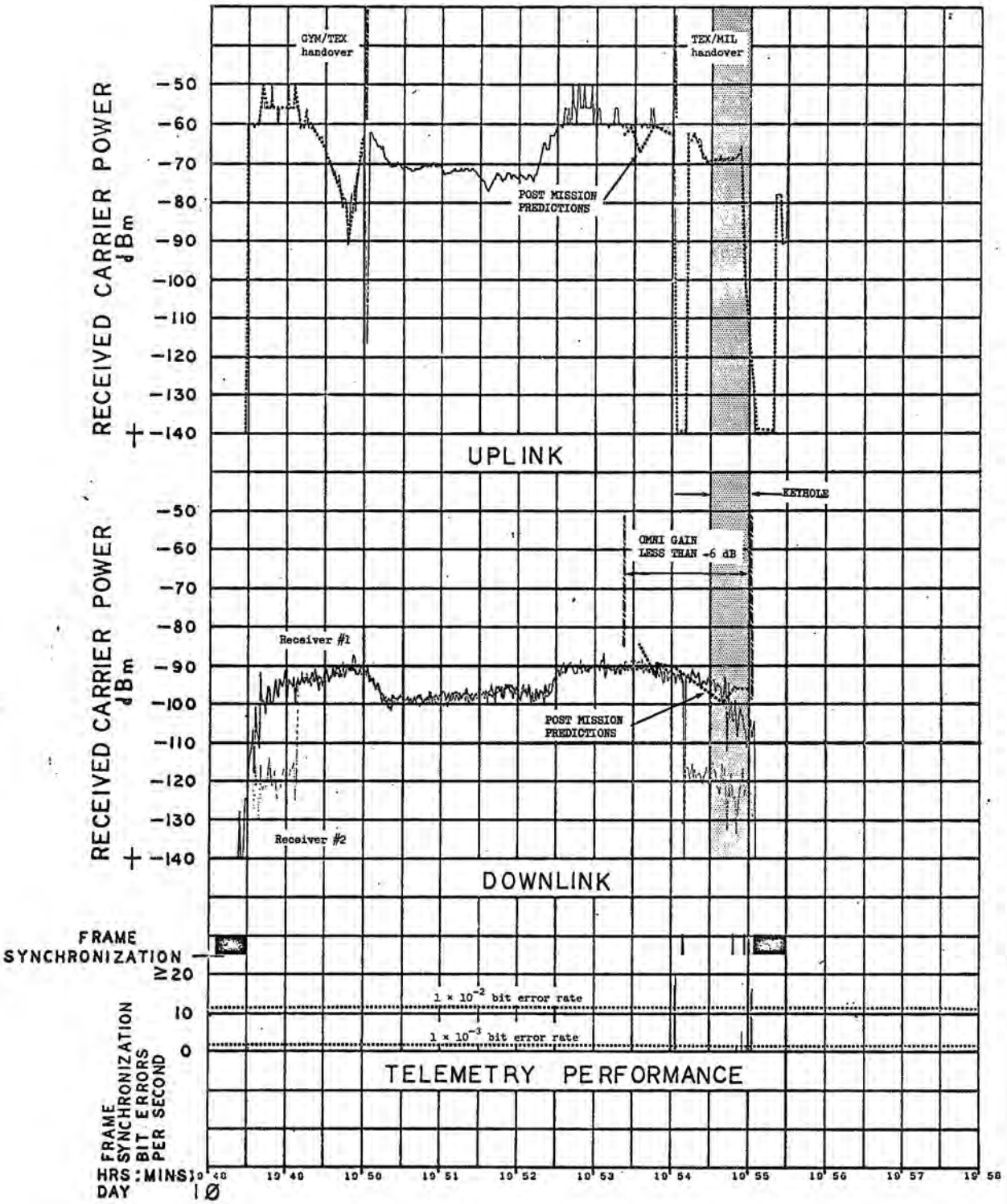

FIGURE 3-40 RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, TEXAS, REVOLUTION 163.

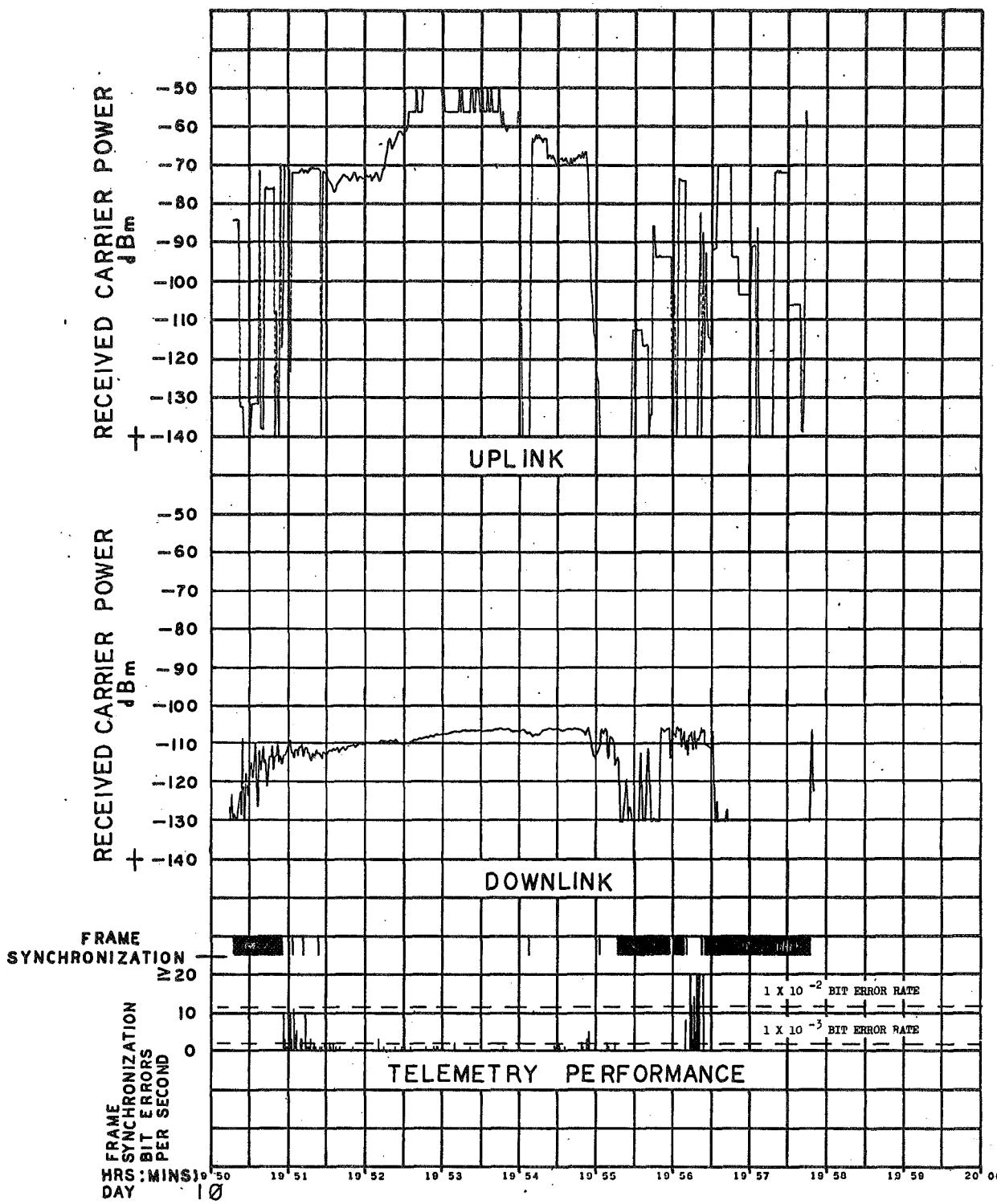

FIGURE 3-41 RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, A/RIA 5, REVOLUTION 163/164.

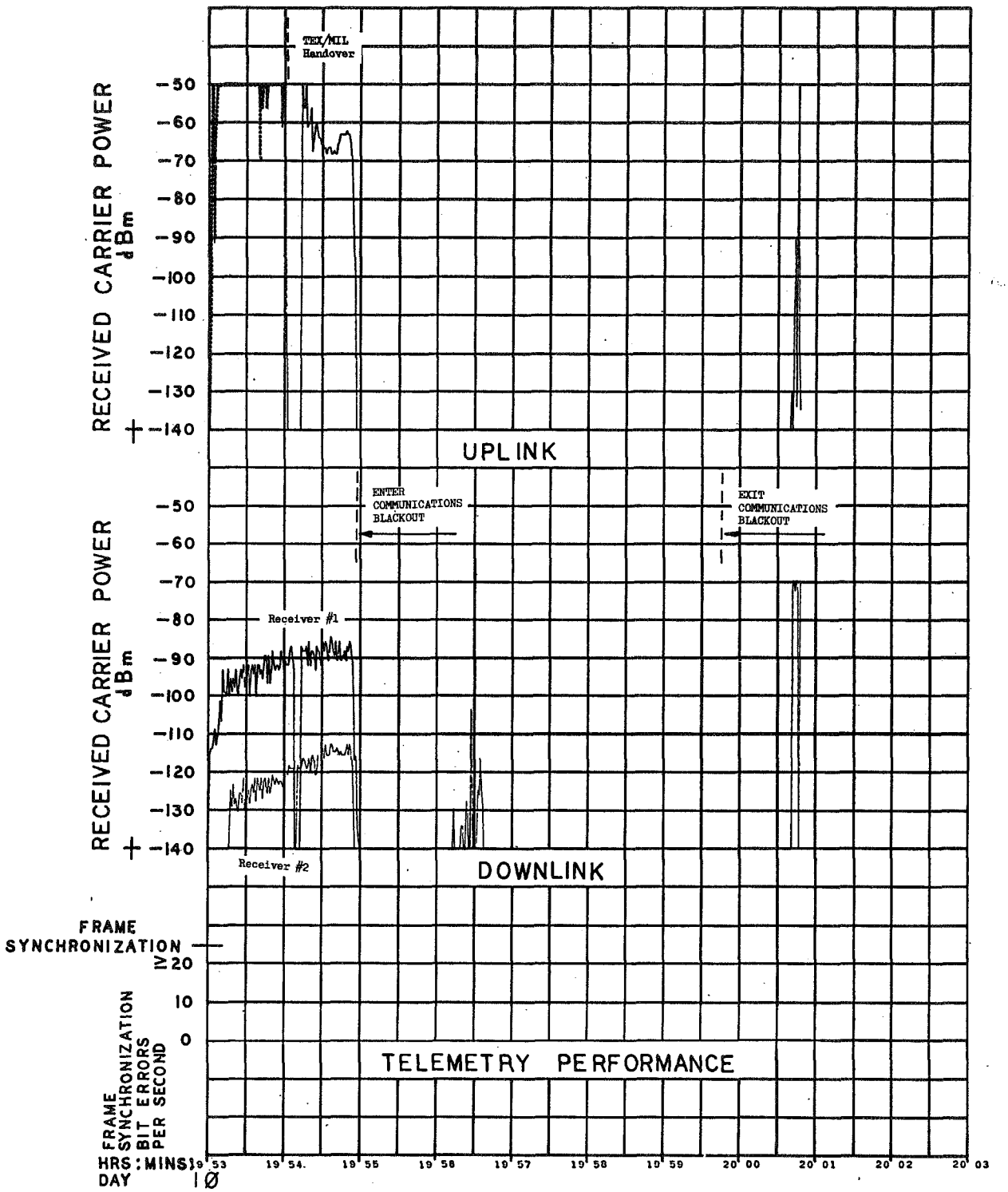

FIGURE 3-42 RECEIVED S-BAND CARRIER POWER, MERRITT ISLAND REVOLUTION 163/164

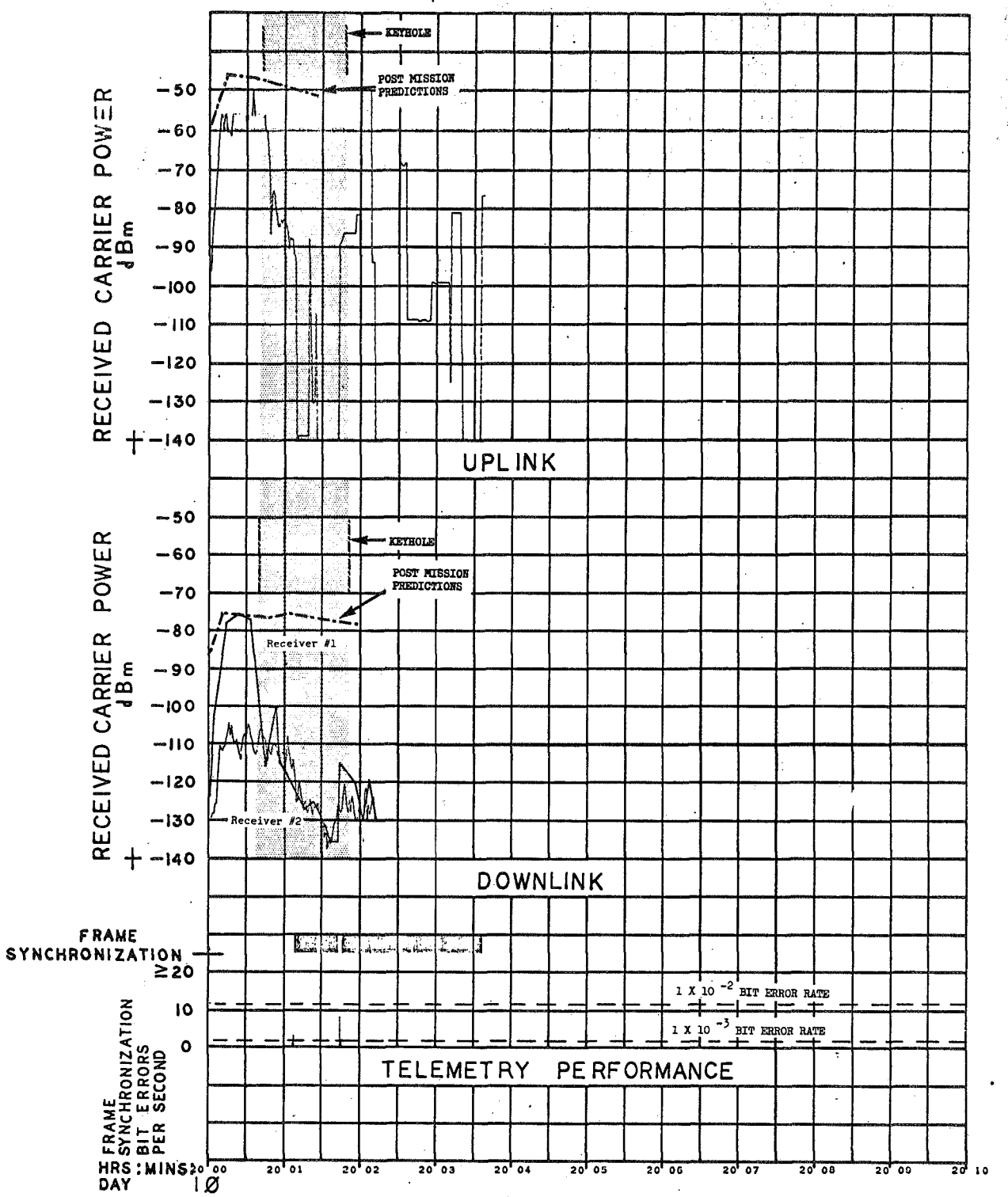

FIGURE 3-43 RECEIVED S-BAND CARRIER POWER AND TELEMETRY PERFORMANCE, BERMUDA, REVOLUTION 164.

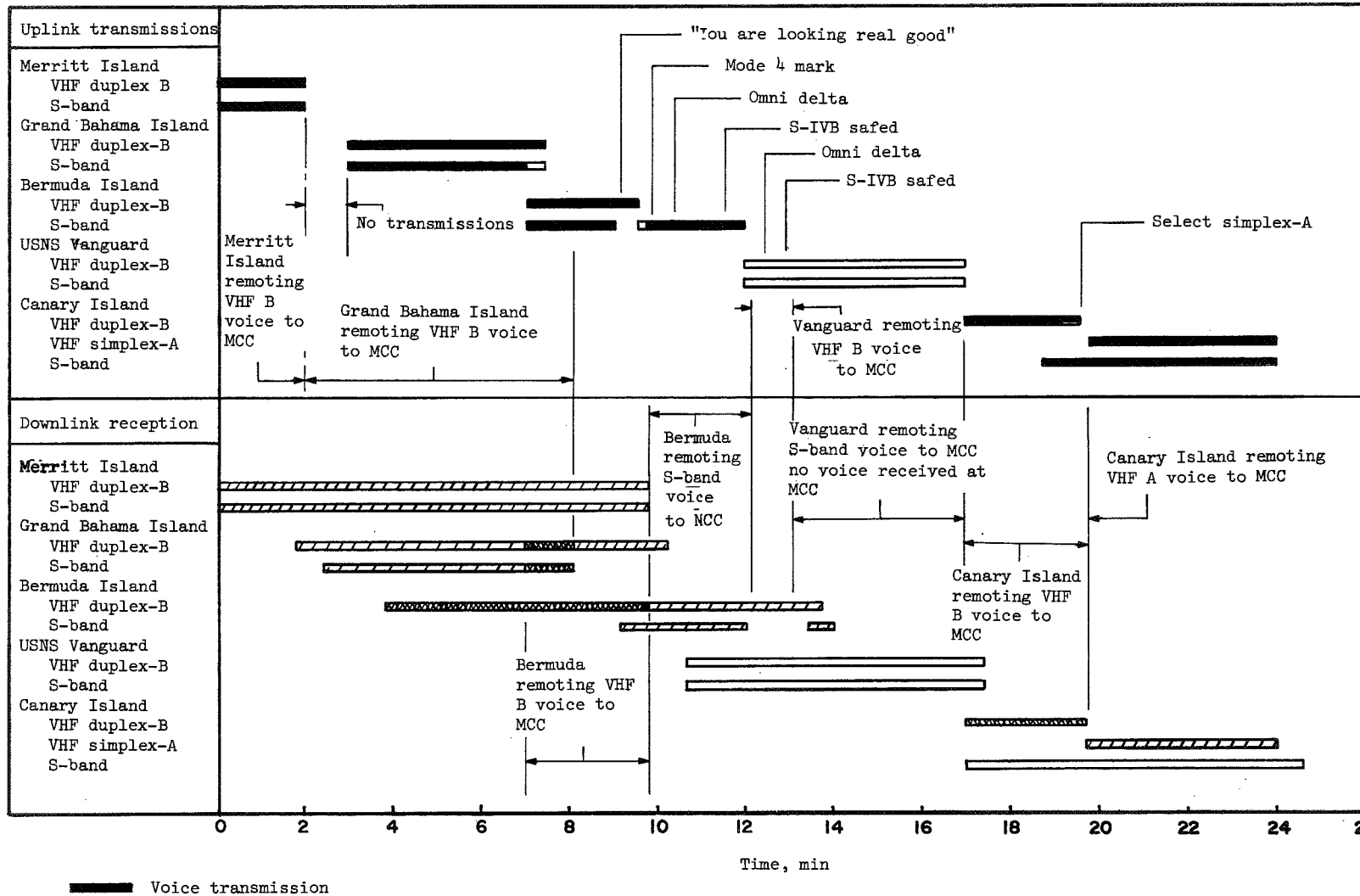

FIGURE 3-44 LAUNCH-PHASE VOICE COMMUNICATIONS

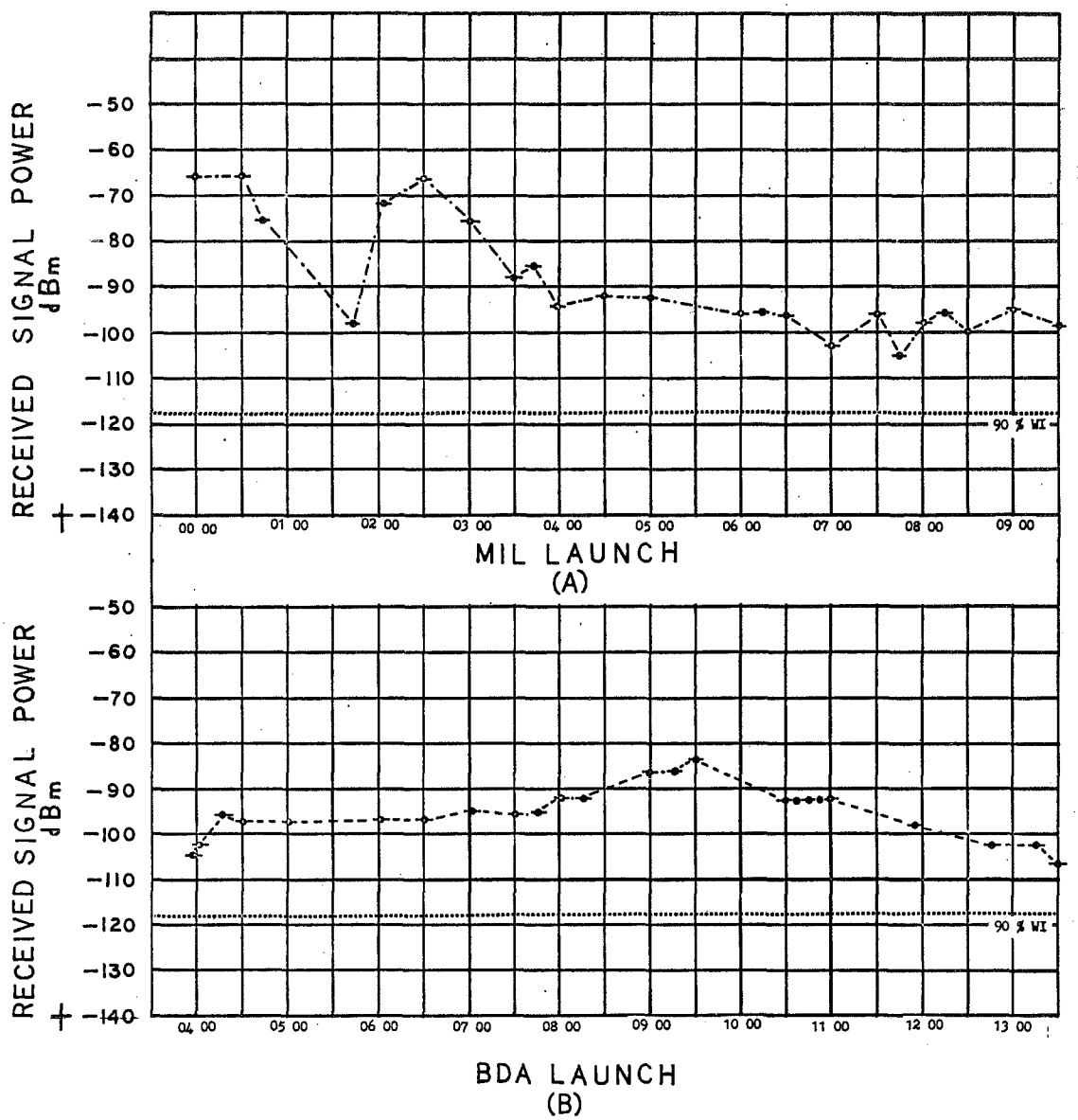

FIGURE 3-45 RECEIVED SIGNAL POWER VHF/AM 259.7 MHz, MERRITT ISLAND AND BERMUDA, LAUNCH.

APPENDIX A

REFERENCES

1. Lockheed Electronics Company, Apollo 7 Post-Mission Communications System Performance Evaluation, HASD No. 839228, 25 November, 1968.

2. NASA, Addendum Apollo Communication Systems Performance and Coverage Analysis For Mission Apollo 7 Revision 1, Volume 1, MSC Internal Note No. EB-R-68-12, 30 September 1968.

APPENDIX B

ACRONYMS AND ABBREVIATIONS

ACN	Ascension
AGC	Automatic Gain Control
AM	Amplitude Modulation
ANG	Antigua
AOS	Acquisition of Signal
A/RIA	Apollo/Range Instrumentation Aircraft
AS	Apollo Saturn
BDA	Bermuda
CM	Command Module
CMC	Command Module Computer
CRO	Carnarvon
CYI	Canary Islands
dB	Decibel
dBm	Decibel referenced to one milliwatt
DSE	Data Storage Equipment
EOM	End Of Mission
Er	Error
FM	Frequency Modulation
GBM	Grand Bahama Island
GDS	Goldstone
GWM	Guam
GYM	Guaymas
HAW	Hawaii
HBR	High Bit Rate
Hrs	Hours
HTV	Huntsville
Hz	Hertz
ISD	Information Systems Division
kHz	Kilohertz
LBR	Low Bit Rate
LOS	Loss Of Signal

APPENDIX B
ACRONYMS AND ABBREVIATIONS
(CONCLUDED)

MAP	Message Acceptance Pattern
MHz	Megahertz
MIL	Merritt Island USB site
Mins.	Minutes
MSC	Manned Spacecraft Center
MSFN	Manned Space Flight Network
NASA	National Aeronautics and Space Administration
PCM	Pulse Code Modulation
PIPA	Pulsed Integrating Pendulous Accelerometer
PM	Phase Modulation
RED	Redstone
Rev	Revolution
RF	Radio Frequency
RT	Real-Time
SM	Service Module
SPS	Service Propulsion System
TEX	Texas
TLM	Telemetry
TV	Television
USB	Unified S-Band
U.S.N.S.	United States Navy Ship
VAN	Vanguard
VHF	Very High Frequency