MSC-00126
SUPPLEMENT 11

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 10 MISSION REPORT
SUPPLEMENT 11

COMMUNICATION SYSTEM PERFORMANCE

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MANNED SPACECRAFT CENTER
HOUSTON, TEXAS
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Supplement 11

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COMMUNICATION SYSTEM PERFORMANCE

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS
December 1969

SUPPLEMENTAL REPORT ON COMMUNICATIONS SYSTEM PERFORMANCE DURING THE APOLLO 10 MISSION

PREFACE

This supplement report to the Apollo 10 mission report on the communications system performance has been prepared for the Tele/Communications Systems Division (TCSD) of NASA's Manned Spacecraft Center under Contract NAS 9-5191. The information in this document is primarily a discussion of data not available when the Apollo 10 mission report was published. The document also contains results of special investigations not previously reported.

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(CONCLUDED)

1.0 INTRODUCTION

This document supplements the information contained in the Apollo 10 mission report. The information contained in this report was obtained and analyzed after the Apollo 10 preliminary report (Reference 1) was issued. This evaluation emphasizes the lunar module communications performance during lunar operations. The evaluation was conducted in accordance with the Communications System Flight Evaluation Program Plan for Apollo 10 (Reference 2). The discussion sequence is based upon mission occurrence as found in the Apollo 10 Flight Plan (Reference 3) with mission up-dates. All times in this report are referenced to range zero, the integral second before lift-off. Range zero for this mission was 138:16:49:00 Gmt. This report has been prepared as Supplement 11 to the Apollo 10 Mission Report (MSC-00126).

2.0 SUMMARY

Performance of the communications systems, including the command module, lunar module, and the Manned Space Flight Network, was generally as expected. The S-band communications system provided good quality voice throughout most of the mission, and the very high frequency (VHF) link provided good voice within its normal range capabilities. The performance of the command module and lunar module S-band update links was nominal. The performance of the realtime and playback telemetry channels was excellent. Excellent quality color television pictures were received during each of the sixteen transmissions from the command module. The received uplink and downlink S-band signal levels corresponded to predictions for spacecraft operations on the omnidirectional and directional antennas. Communications systems management including antenna switching was generally good.

Two-way phase lock with the command module S-band equipment was established by the Manned Space Flight Network prior to launch. The stations at Merritt Island, Grand Bahama Island, Bermuda Island, and USNS Vanguard successfully maintained phase lock through orbital insertion except for several momentary losses during station-to-station handovers. Station handovers were accomplished with a minimum loss of data. From 00:01:15 to 00:01:39, the station at Merritt Island was tracking on a ground antenna side lobe. There were no data losses or voice losses in conjunction with this side lobe tracking. VHF voice operations from this station were generally favorable except for one period from 00:01:03 to 00:02:06. From liftoff through one minute, the VHF receiver used for the command and service module downlink had a higher squelch threshold than the VHF receiver used after one minute at the Merritt Island station. This launch configuration was used to prevent interference from the 258.5 MHz S-IVB link as in previous missions. When the low squelch threshold receiver was used after one minute, the receiver performance was degraded by interference from the S-IVB link. The station at Grand Bahama Island had good VHF communications except for one period from 00:02:08 to 00:06:00. Subsequent to these problems, Bermuda Island acquisition and coverage was characterized by rapid variations of the uplink and downlink carrier power levels and at least one period of data dropout. The rapid variation of the uplink and downlink carrier power levels and the data dropout were caused by the failure of the crew to switch from omni antenna B to omni antenna D prior to 00:10:12, as recommended in the pre-mission planning. The remainder of the launch phase and earth orbits 1 and 2 were characterized by nominal communications performance.

The USNS Mercury, USNS Redstone, and Hawaii tracking stations provided coverage of the translunar injection phase. Prior to translunar injection, the S-band uplink was handed over as early as possible from Carnarvon to the Mercury because the Carnarvon command computer was not operational. The instrumentation unit uplink was handed over from the Mercury to the Redstone as early as possible. Early handover of the instrumentation unit uplink apparently caused an operator error on the USNS Mercury. The operator error resulted in the command module uplink remaining on past the scheduled time, interfering with the acquisition by the Redstone. The command module uplink was not acquired by the Redstone until the Mercury turned off uplink modulation at 02:35:50. During the Redstone two-way lock period a sudden loss of the command module downlink signal occurred. This discrepancy cannot be resolved from the available data. The uplink and downlink were reacquired for a brief period and then lost again. After the sudden loss of signal by the Redstone, the Hawaii station made a nominal acquisition followed by normal tracking.

During crew rest periods ground commands were used to switch between B and D omni antennas. Prior to each of the crew rest periods except the first, the command module S-band signal combination was changed by switching off the S-band voice subcarrier. As predicted, this signal combination change enabled reception of high bit rate telemetry approximately 25 percent of each passive thermal control revolution at slant ranges up to 200,000 nautical miles.

The command module high gain antenna was utilized extensively during the lunar orbit activities. Also, the high gain antenna automatic reacquisition mode was utilized during the crew rest periods in lunar orbit. The performance in this mode was excellent. Telemetry and voice data recorded while the spacecraft was in lunar occultation were played back through the high gain antenna during each revolution. Solid frame synchronization by the telemetry decommutation system was reported on each of the playbacks of command module data. Good quality voice was obtained during data storage equipment playbacks at the recorded speed. Good voice was also obtained during playbacks at 32 times the recorded speed at all 85-foot stations except Madrid. A station configuration change (relocation of the 64 kHz post-detection voice filter) at Madrid during the transearth coast phase corrected the problem.

The lunar module communications equipment was powered up for the first time during lunar orbit 4. Then a special series of communications checks were performed. During these checks, good quality voice and high bit rate telemetry were received while the spacecraft was operating in the phase and frequency modulation modes and transmitting through the steerable antenna. Good quality low bit rate telemetry, backup voice, and normal voice were received through the 85-foot antenna at Goldstone while the lunar module was operating on an omnidirectional antenna. Good quality high bit rate telemetry was received and recorded at the Goldstone 210-foot site during the omnidirectional antenna operations. The normal S-band voice was received at the 85-foot site during omnidirectional antenna utilization because the spacecraft to Goldstone line-of-sight was within the positive gain region of the antenna. Since the gain distribution of the lunar module omnidirectional antenna is such that positive gain is available only over a small region of the antenna pattern, reception of normal voice through an 85-foot site when the spacecraft is in lunar orbit can be expected only over a very small range of spacecraft-to-ground station look angles. During the check of the S-band backup upvoice mode in conjunction with the backup downvoice mode, the Capsule Communicator received his own transmissions delayed by the two-way transmit time between the Mission Control Center and the spacecraft. This retransmission will occur when backup upvoice is used and the lunar module transmitter is keyed.

A time history of the nominal received uplink and downlink carrier power levels, the utilization of the omnidirectional and steerable antennas, and the normal and backup downvoice for tracking station coverage of lunar module revolutions 4 and 12 through 16 are presented in Figure 1. As shown in this figure, approximately 6 dB variations of received uplink and downlink carrier power were noted during steerable antenna operation on revolution 12 between 98:41:14 and 98:53:58. Peak-to-peak variations of 2 dB were noted between 99:02:00 and 99:07:58, at which time the signal was lost when the antenna reached its gimbal limits as the spacecraft was being maneuvered to a platform alignment attitude. The 6 dB peak-to-peak variation in the received carrier power levels are not commensurate with proper autotrack. Between 98:41:14 and 98:55:00, the line-of-sight was within a region where multipath off the lunar module and lunar module blockage of the antenna field of view caused the variations as shown in Figure 10. At 99:34:57, the lunar module pilot switched from the steerable antenna to an omnidirectional antenna. This switching momentarily interrupted uplink phase lock. The transients within the lunar module transceiver which resulted from the sudden loss-of-lock caused the transceiver to reacquire lock on an uplink subcarrier in place of the carrier. The Madrid station personnel recognized the false lock and reacquired valid two-way lock at 99:37:58.

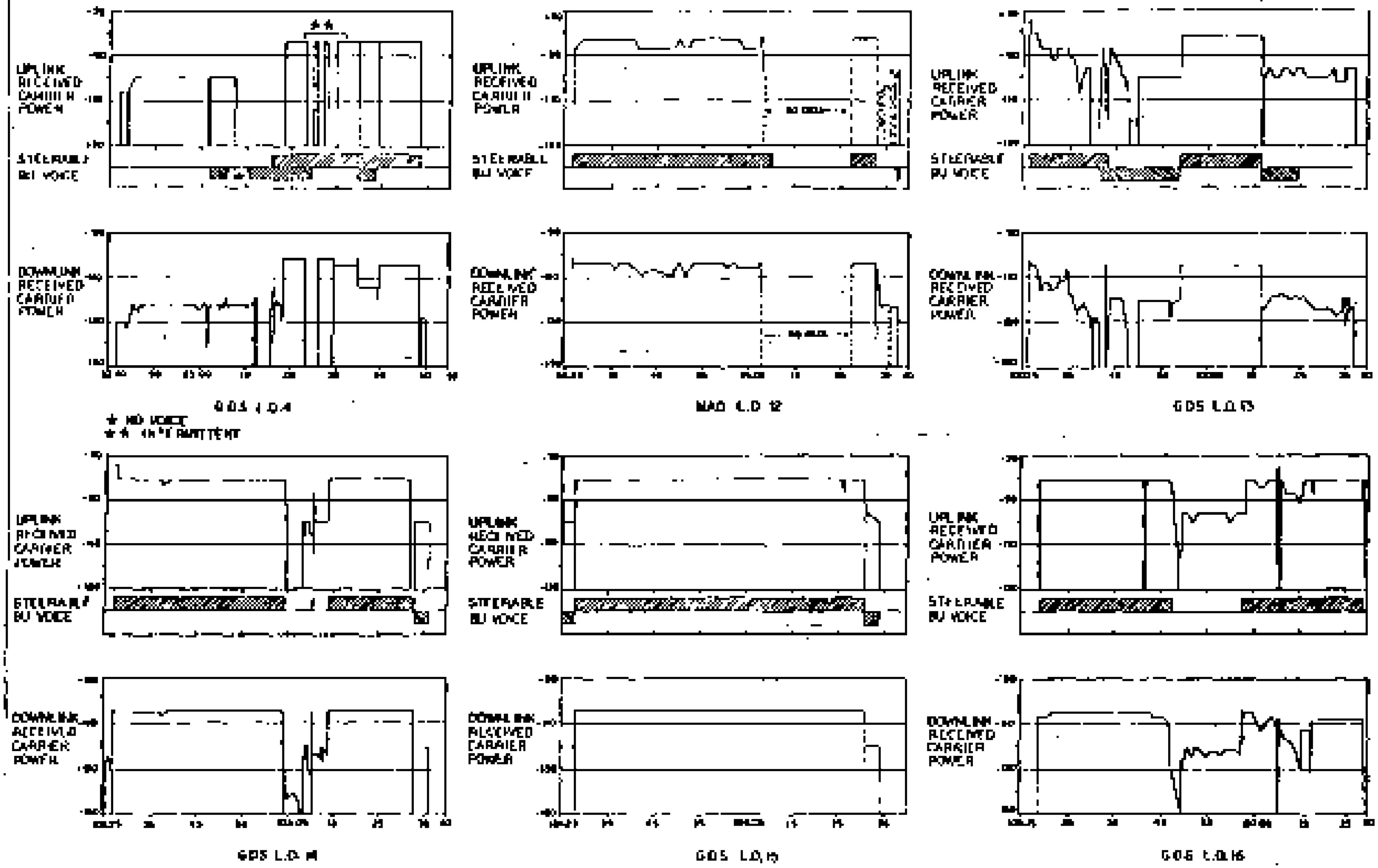


FIGURE 1 APOLLO 10 LUNAR MODULE COMMUNICATIONS PERFORMANCE

The only significant communications difficulty involving the command and service module occurred during lunar revolution 12. Downlink voice from the command module pilot was not received at the Mission Control Center until approximately 14½ minutes after acquisition of signal by Goldstone. This problem has been identified as improper configuration at the site and at Goddard Space Flight Center. Goldstone selected the wrong signal data demodulating system for remoting, causing the lunar module voice to be received from both Goldstone and Madrid. Receipt of lunar module voice from two sources caused echos to be generated, and Goddard Space Flight Center voice control removed the Goldstone transmit capability. Madrid was requested to remote both command module voice and lunar module voice in order to reestablish two way voice communications. To eliminate similar delays in establishing voice communications in the future, reporting procedures for backup stations were revised.

Between acquisition of signal from the lunar module during revolution 13 at 100:26:20 and initiation of the phasing maneuver, steerable antenna autotrack was not maintained, and the lunar module pilot had to select the best omnidirectional antenna. Selection of the omnidirectional antenna negated receipt of the high bit rate telemetry and degraded the downlink voice quality. As shown in Figure 2, the received downlink carrier power at acquisition-of-signal was consistent with correct pointing of the lunar module steerable antenna. However, shortly after acquisition, a slow decay in received carrier power began. This decay continued until the receivers at Goldstone and Madrid lost phase lock at 100:40:40. As shown in Figures 2 and 3, the flight data correspond with post-mission predictions with the antenna remaining in a fixed position relative to the lunar module instead of autotracking the uplink signal. The problem was probably caused by an improper switch configuration or a mechanical problem. The steerable antenna was reacquired prior to the phasing maneuver and the steerable antenna performance was nominal throughout the remainder of the lunar module activities.

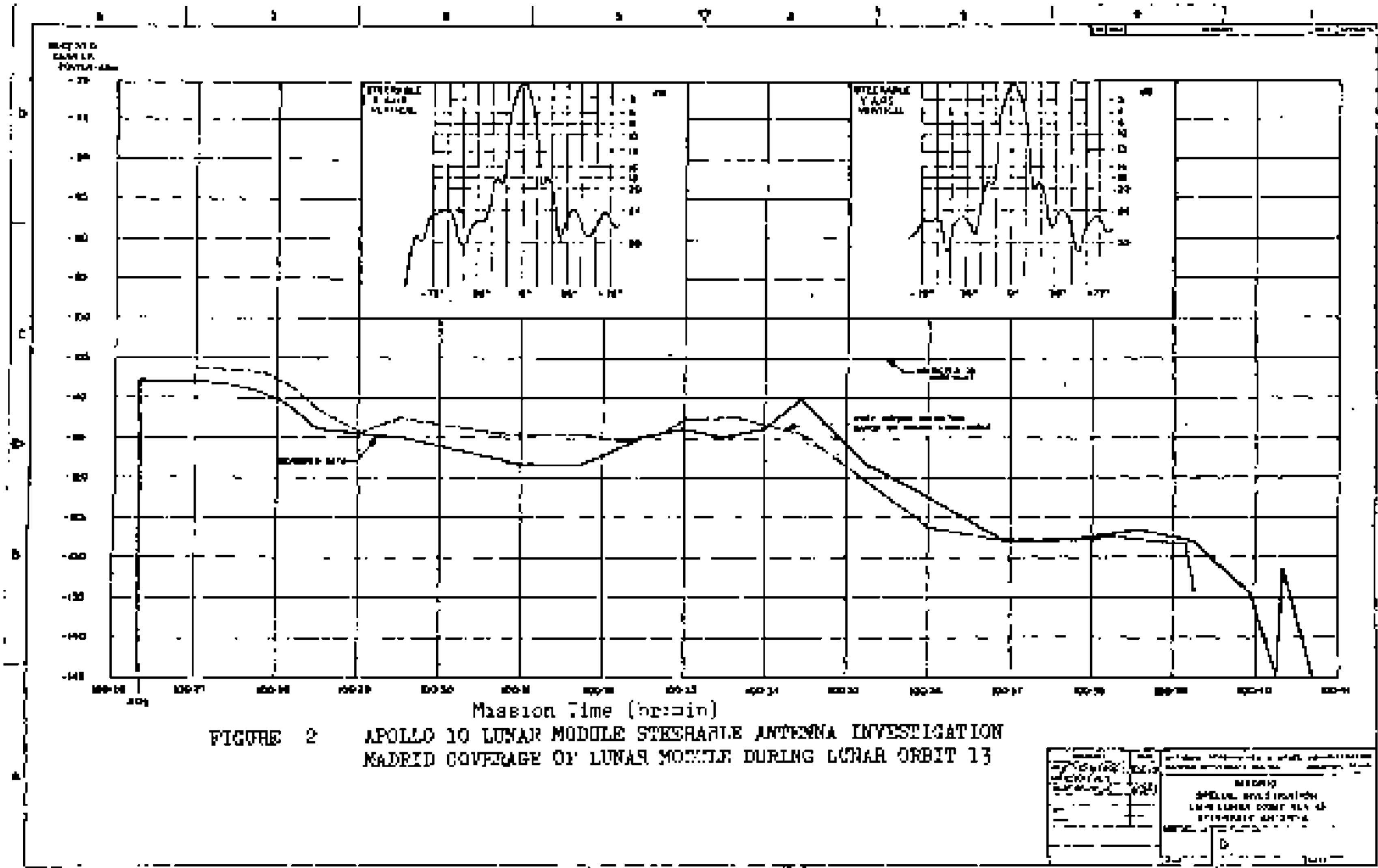


FIGURE 2 APOLLO 10 LUNAR MODULE STEERABLE ANTENNA INVESTIGATION
MADRID COVERAGE OF LUNAR MODULE DURING LUNAR ORBIT 13

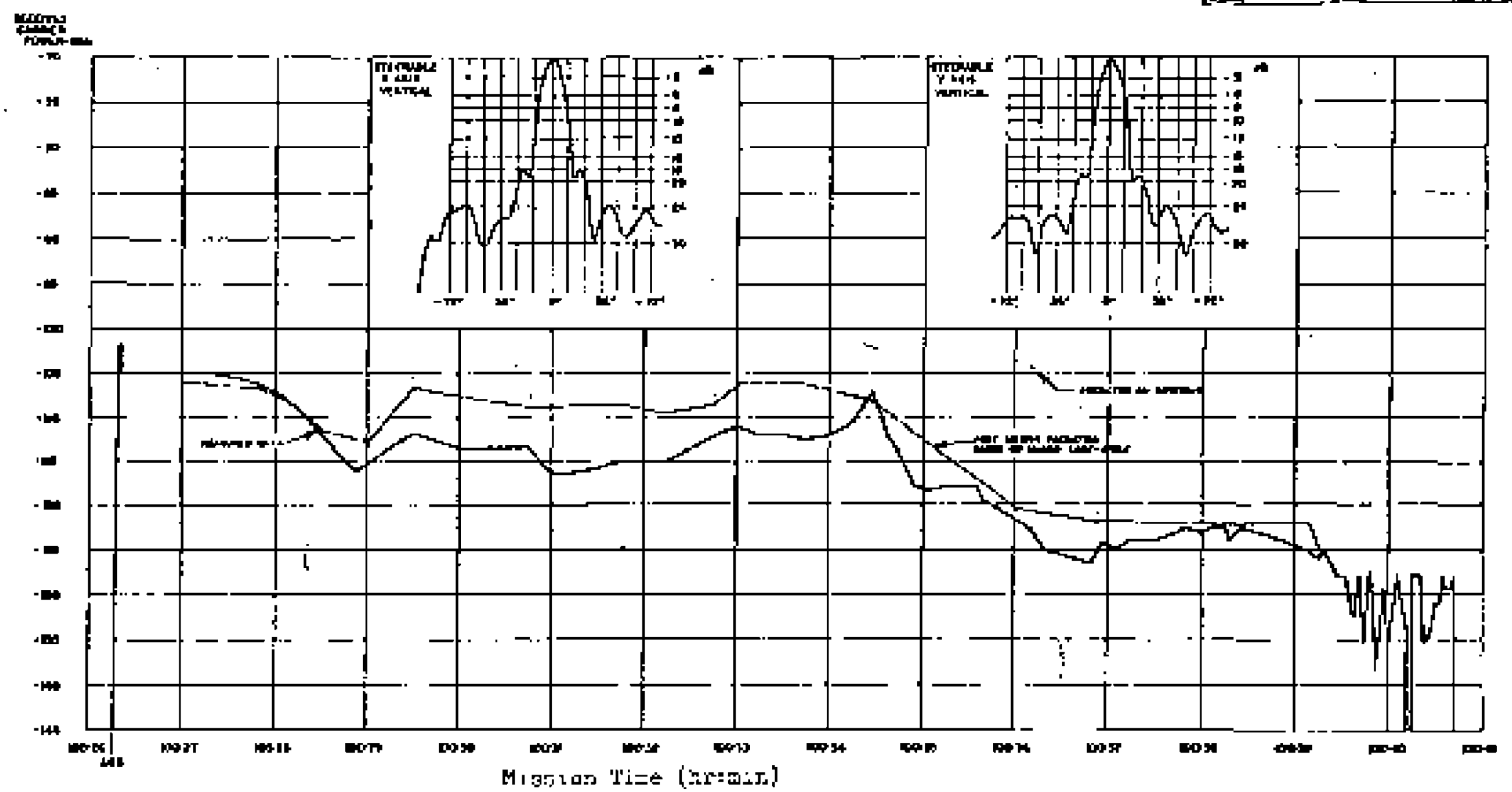


FIGURE 3 APOLLO 10 LUNAR MODULE STEERABLE ANTENNA INVESTIGATION
GOLDSTONE COVERAGE OF LUNAR MODULE DURING LUNAR ORBIT 13

The steerable antenna manual mode was selected and the antenna pointed to the earth for the ascent propulsion system burn to fuel depletion. Except for a momentary loss of two-way lock at command and service module and lunar module separation, this technique enabled continuous tracking of the ascent stage to approximately 122 hours.

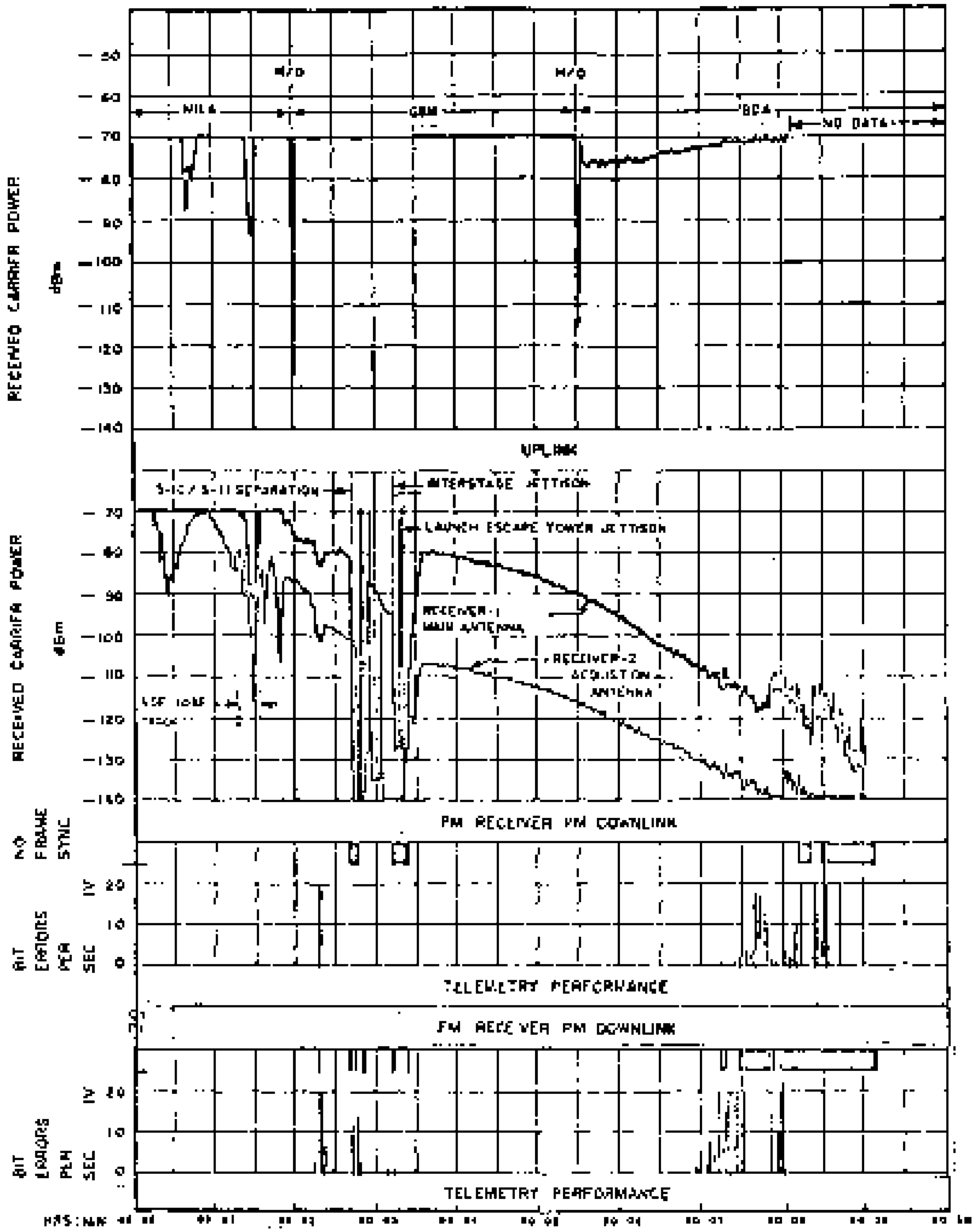
3.0 DETAILED ANALYSIS

3.1 Launch

Two-way phase lock with the command module S-band equipment was established by the Manned Space Flight Network prior to launch. The stations at Merritt Island, Grand Bahama Island, Bermuda Island, and USNS Vanguard successfully maintained phase lock through orbital insertion except for several momentary losses. Station handovers were accomplished with a minimum loss of data. Staggering of the instrumentation unit and command module handover times instead of handing over both vehicles at the same time helped improve the continuity of the handovers. In addition to brief data losses during handovers, data losses occurred during tracking coverage from the unified S-band stations at Merritt Island and Grand Bahama Island.

Figure 4 is a plot of the uplink and downlink received carrier powers during the coverage at the Merritt Island station. As shown in Figure 4, the ground antenna slewed from the antenna main lobe track onto the antenna first side lobe track at approximately 00:01:15, and remained on the side lobe until 00:01:38. The unified S-band received carrier power level associated with this side lobe tracking dropped 20 dB to -90 dBm. A loss of phase modulation downlink occurred at the S-IC/S-II stage separation. Reacquisition was performed and additional losses occurred during the interstage and launch escape tower jettison. Subsequent to that, the station reacquired downlink lock and continued to track with excellent telemetry on the phase modulation downlink until approximately 00:06:10.

For launch, a frequency modulation receiver was configured to receive the normal command module phase modulation downlink and to demodulate the pulse code modulated data. This test was performed to determine if pulse code modulation data losses due to loss of S-band phase lock during the launch phase could be minimized. Also shown in Figure 4 are telemetry performance comparisons of pulse code modulation data



DAY 0

CSM MIL LAUNCH

COMMAND MODULE

SEQ. NO. 172 SYSTEM USB LINK UP T MODE 6.

APOLLO 10 ANTENNA 30' DOWN MODE 2.

[illegible]

from the phase modulation receiver and pulse code modulation data from the frequency modulation receiver. Approximately 50 percent more data were obtained during the period between 00:02:00 and 00:03:30 from the frequency modulation receiver than from the phase modulation receiver during the dropout period. As shown in Figure 4, there was a higher bit error rate from the frequency modulation receiver data than from the phase modulation receiver data during this period.

In laboratory testing, the frequency modulation receiver reached threshold at a level (4 dB to 6 dB depending on the signal combination) higher than the phase modulation receiver. This difference in threshold level can be observed in Figure 4 during the time period between 00:07:00 and 00:09:00.

Premission predicted received carrier power levels from Communications Systems Performance and Coverage Analysis for Apollo 10 (reference 4) and actual received carrier power levels during the Merritt Island coverage compare much more favorably on the Apollo 10 mission than any of the previous Saturn V launches. This is due to the look angles being more favorable during this launch than in previous launches (Spacecraft Operational Trajectory for Mission G, reference 5). The effects of flame attenuation and booster shadowing on communications performance appeared to be less during this mission than previous missions.

As on previous missions, tracking data during the first one minute of launch were degraded because the elevation angles did not exceed the usable 5 degree elevation for the first 30 seconds, or 20 degrees during the first one minute.

With the exceptions of uplink or downlink losses already mentioned, the S-band voice was of good quality and good intelligibility throughout the launch coverage. VHF voice operations at Merritt Island were generally favorable with the exception of one period from 00:01:05 to 00:02:06 when VHF voice communications received at the station were noisy.

Because the 259.5 MHz S-IVB downlink caused interference with the 259.7 MHz CSM downlink at close range (strong signal levels) on previous missions, two different 259.7 MHz receivers were used at the Merritt Island station during the launch phase. During the first minute of the launch phase, a high squelch threshold receiver was used to receive the 259.7 MHz CSM downlink, eliminating the interference problem. At 00:01:00 (because of weakening signal levels due to the increasing range), a lower squelch threshold receiver was used. The performance of the low squelch threshold receiver was degraded by the S-IVB downlink until approximately 00:02:06.

The station at Grand Bahama Island maintained VHF communications during the launch phase except between 00:02:09 and 00:06:00. Subsequent to this problem, Bermuda acquisition and coverage was characterized by rapid variations of the uplink and downlink carrier power levels and at least one period of data dropout. The rapid variation and the data dropout were caused by the failure of the crew to switch from omni B to omni D prior to 00:10:12. The switching was scheduled for 00:06:15.

The remainder of the launch phase and earth orbits 1 and 2 were characterized by nominal command module communications performance.

5.2 Translunar Injection

The USNS Mercury, USNS Redstone, and Hawaii stations provided coverage of the translunar injection phase. Prior to translunar injection, uplink was handed over early from Carnarvon to the Mercury because the Carnarvon command computer was not operational. The instrumentation unit uplink was handed over from the Mercury to the Redstone early to stagger command module and instrumentation unit uplink handover. The command module uplink was to be handed over at 02:34:30. Early handover of the instrumentation unit uplink caused an operator error by the Mercury station personnel. The Mercury command module uplink remained on past the scheduled handover time, interfering with the acquisition by the Redstone of the command module uplink. The command module uplink was not acquired by the Redstone until the Mercury turned off uplink modulation at 02:55:50.

During the Redstone two-way lock period, a sudden loss of the command module downlink signal occurred at 02:37:36. After the initial sudden loss of the signal, intermittent two-way lock occurred for the duration of the Redstone pass. This discrepancy is unresolved. However, since a phase modulated downlink signal was present in the intermediate frequency stage of the phase modulation receiver, a change in configuration or station operator error are suspected as the cause of this abrupt data dropout. Also, the possibility of a receiver failure has not been ruled out.

The Hawaii station successfully acquired the command module at approximately 02:44:00, on omni D. Communications performance during the Hawaii coverage was good.

3.3 Translunar Coast

Command module S-band communications were generally good during translunar coast. The color television transmissions from the spacecraft during translunar coast were of excellent quality.

A high gain antenna auto re-acquisition test was conducted from 28:38:50 to 29:23:00. The Madrid station actively tracked during this test. The purpose of the test was to provide flight data concerning the high gain antenna operation during translunar and transearth coast sleep periods.

For this test, the spacecraft attitude was positioned so that the high gain antenna would track into the scan limits. After a loss of signal, if the antenna drives into the scan limit, the antenna will go to preset angles and will automatically reacquire and track the uplink signal when the spacecraft acquires signal levels above threshold values. During this test, the uplink transmitted power from Madrid was reduced from 10 kilowatts to 500 watts (-15 dB). The antenna operated as expected throughout the auto re-acquisition check. When properly used, omni switching provides more continuous coverage; therefore, omni use was deemed more feasible for the sleep cycles. Omni operation was performed for the translunar and transearth coast sleep phase communications.

Communications during passive thermal control periods were generally good; however, in several instances communication data were lost because of late commands being transmitted. As an example, from 56:01:03 to 56:09:40, all data from Goldstone were lost when ground control failed to switch omni antennas before reaching uplink command threshold (about -110 dBm depending upon communications combination). As a result, Goldstone lost uplink and downlink S-band lock.

During the auto re-acquisition test when spacecraft to earth line of sight was blocked, data were recorded on the data storage equipment and then played back. Station analysis of the dump telemetry data identified sync bit errors. At approximately 149:00:00, the spacecraft dumped 5:1 data storage equipment data to stations at Madrid and Goldstone. Station analysis of the dump telemetry data again identified sync bit errors. Further analysis of the bit errors indicated that the error was being introduced within the spacecraft data storage equipment.

During passive thermal control, the spacecraft rolled at about 2.5 revolutions per hour with nominal switching between opposite omni antennas occurring every 12 to 13 minutes. At about 60:00:00, the downlink received carrier power varied from about -123 dBm (maximum) to -132 dBm (minimum) while the uplink varied from approximately -93 dBm (maximum) to about -105 dBm (minimum) at the omni antenna switching points. These values correlated to predicted values within 2 dB for signal combinations 6.09 and 6.15.

5.4 Lunar Operations

5.4.1 Lunar Orbit 4

Lunar module communications checks were performed during lunar orbit 4. The lunar module checks performed included an omni S-band voice and telemetry check, a steerable antenna voice and telemetry check, and a backup voice check. These were all successful. During these checks, good quality voice and high bit rate telemetry were received while the spacecraft was operating in the phase and frequency modulation modes and transmitting through the steerable antenna. Good quality low bit rate telemetry, backup voice, and normal voice were received through the 85-foot antenna at Goldstone while the lunar module was operating on an omnidirectional antenna. Good quality high bit rate telemetry was received and recorded at the Goldstone 210-foot site during the omnidirectional antenna operations.

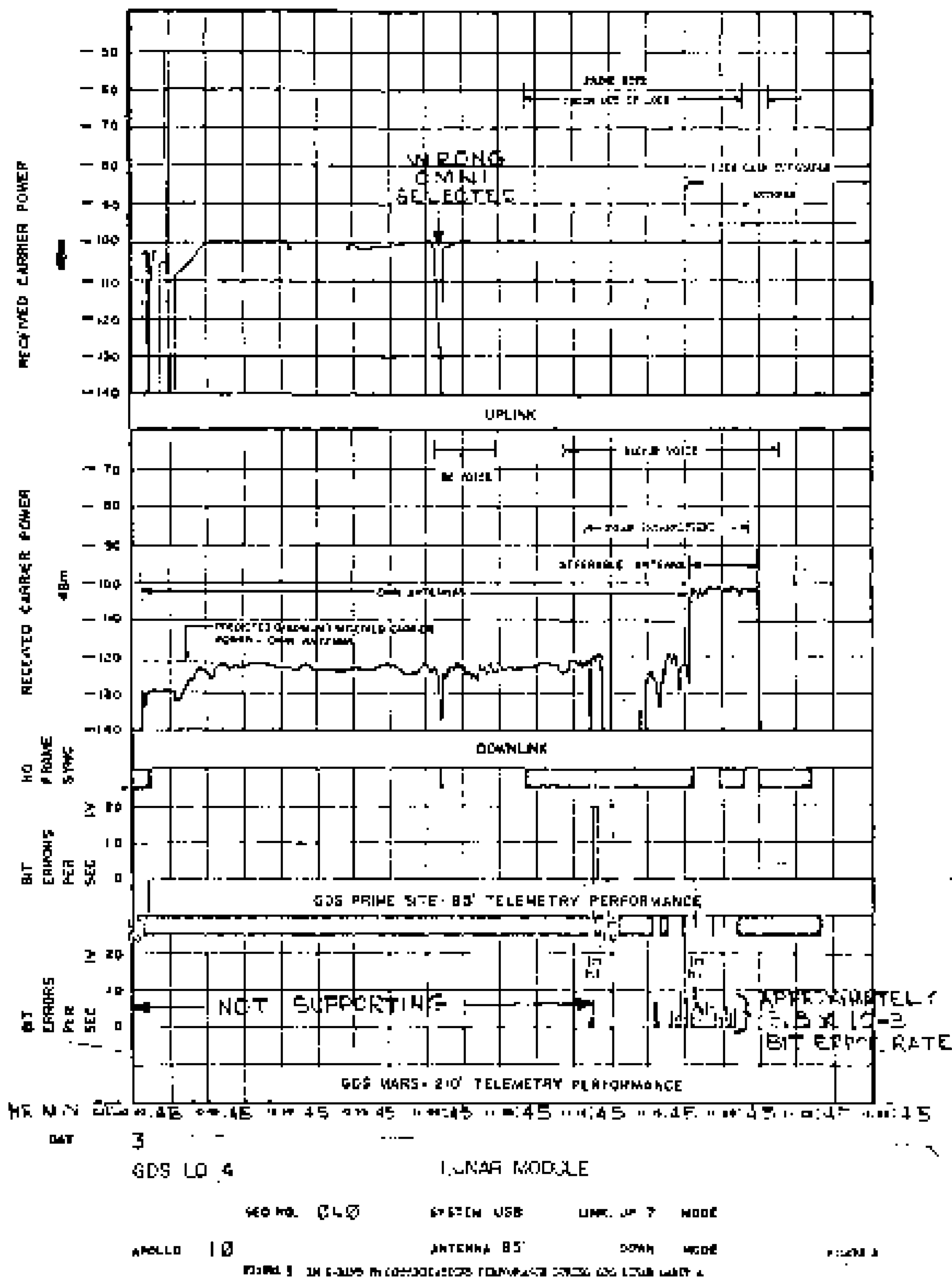
The normal S-band voice was received at the 85-foot site during omnidirectional antenna utilization because the spacecraft to Goldstone line-of-sight was within the positive gain region of the antenna. Since the gain distribution of the lunar module omnidirectional antennas is such that positive gain is available only over a small region of the antenna pattern, reception of normal voice through an 85-foot site when the spacecraft is in lunar orbit can be expected only over a very small range of spacecraft to ground station look angles.

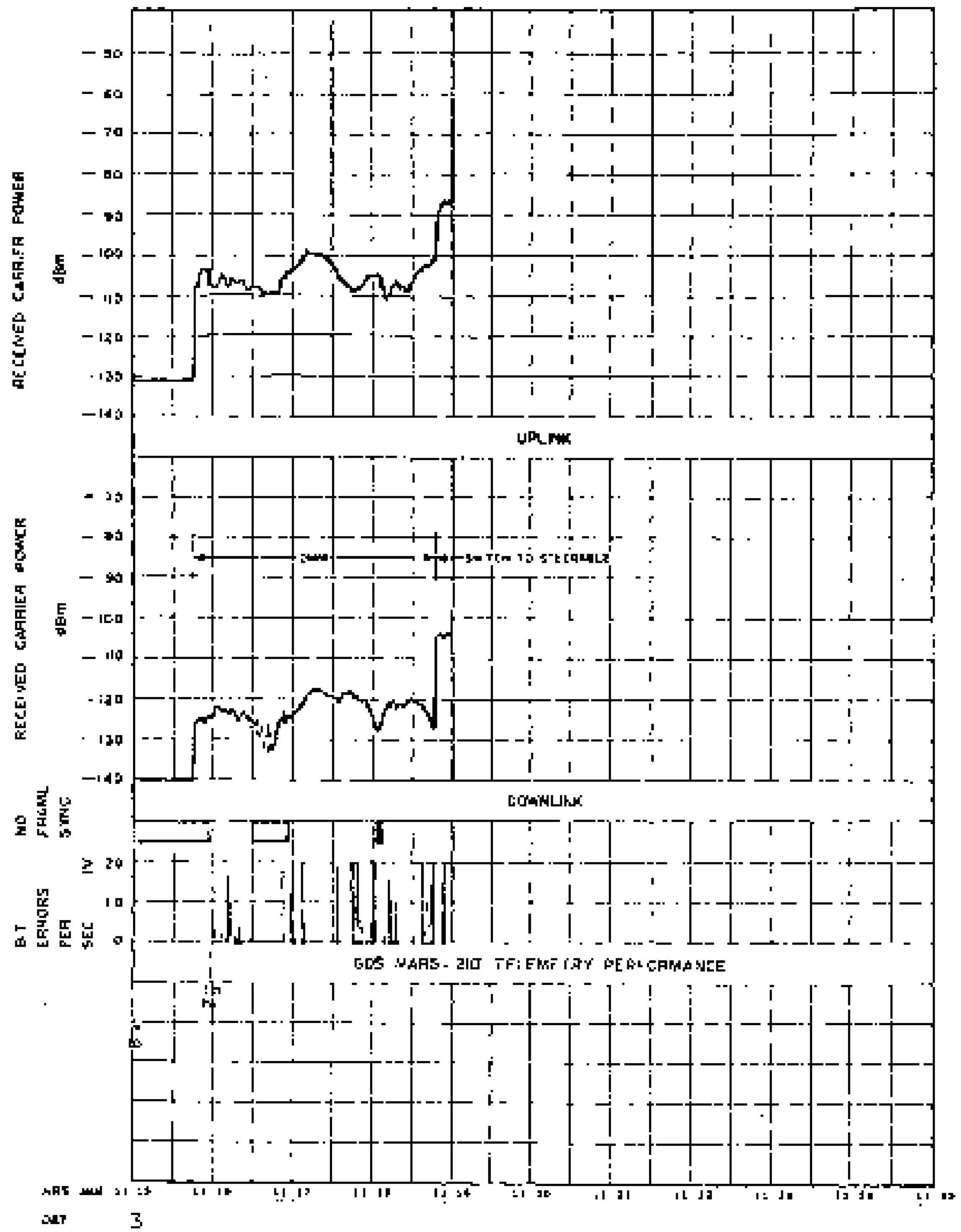
During the check of the S-band backup upvoice mode in conjunction with the backup downvoice mode, the Capsule Communicator received his own transmissions delayed by the two-way transmission time between the Mission Control Center and the spacecraft. This retransmission will occur when backup upvoice is used and the lunar module transmitter is keyed.

The lunar module voice relay check, the command module voice relay check, and the Manned Space Flight Network voice relay check were not attempted due to lack of time.

Figure 5 is a plot of the Goldstone tracking during lunar orbit 4 and covers the time period over which some of the detailed communications checks were performed. Although the plot of uplink and downlink signal strengths was with respect to the 85-foot prime antenna site, the telemetry as shown indicated both prime site (85-foot antenna) and Mars site (210-foot antenna) telemetry performance. A majority of the pass was conducted on omni antennas because the high gain antenna look angles were not favorable. The uplink and downlink received carrier powers compared with predicted powers for omni antenna gains between -3 and +3dB. Steerable antenna communications checks were performed during this orbit. Acquisition and tracking of the steerable antenna was satisfactory. During this period, the 1.024 MHz subcarrier power level was below threshold for maintaining solid pulse code modulation decommutator lock. As shown on Figure 5, the downlink received carrier power was approximately -102 dBm at the 85-foot antenna while operating on the steerable antenna. Using an 8 dB improvement figure, the received carrier power at the 210-foot antenna would have been approximately -94 dBm. The bit error rate associated with this period of operation for the 210-foot antenna data was approximately 3.6×10^{-3}. This high bit error was caused by the baseband voice modulation (backup downvoice) affecting the high bit rate telemetry data.

Figure 6 is a partial plot of Goldstone station coverage for lunar orbit 4, using 85-foot antenna received carrier powers. This plot depicts the lunar module omni antenna performance just prior to switching to the steerable antenna. The plot also indicates the telemetry threshold performance for the lunar module high bit rate mode while utilizing the omni antenna and the 210-foot antenna site.


RECEIVED CARRIER POWER
WRONG OMNI SELECTED
UPLINK
RECEIVED CARRIER POWER
dBm
DOWNLINK
NO FRAME SYNC
BIT ERRORS PER SEC
GDS PRIME SITE - 85' TELEMETRY PERFORMANCE
BIT ERRORS PER SEC
NOT SUPPORTING
BIT ERROR RATE
GDS MARS - 210' TELEMETRY PERFORMANCE
DAY
3
GDS LO 4
LUNAR MODULE
SEQ NO.
SYSTEM USB
APOLLO
10
ANTENNA 85'



DAY 3

GDS LO 4

LUNAR MODULE

SEQ. NO. 180

SYSTEM USB

LINK. UP 2 MODE

APOLLO 10

ANTENNA 85' HF MARS - 210' TLM

DOWN MODE

3.4.2 Lunar Orbit 10

Figure 7 is a plot of the uplink and downlink received carrier powers during Madrid lunar orbit 10 coverage. Initial acquisition was performed on the omni antennas. The steerable antenna then was selected. The omni antenna was again selected prior to lunar occlusion. The received carrier powers agreed with premission predicted powers. The sudden change in downlink received carrier power as shown in Figure 7 was caused by tape recorder incompatibility.

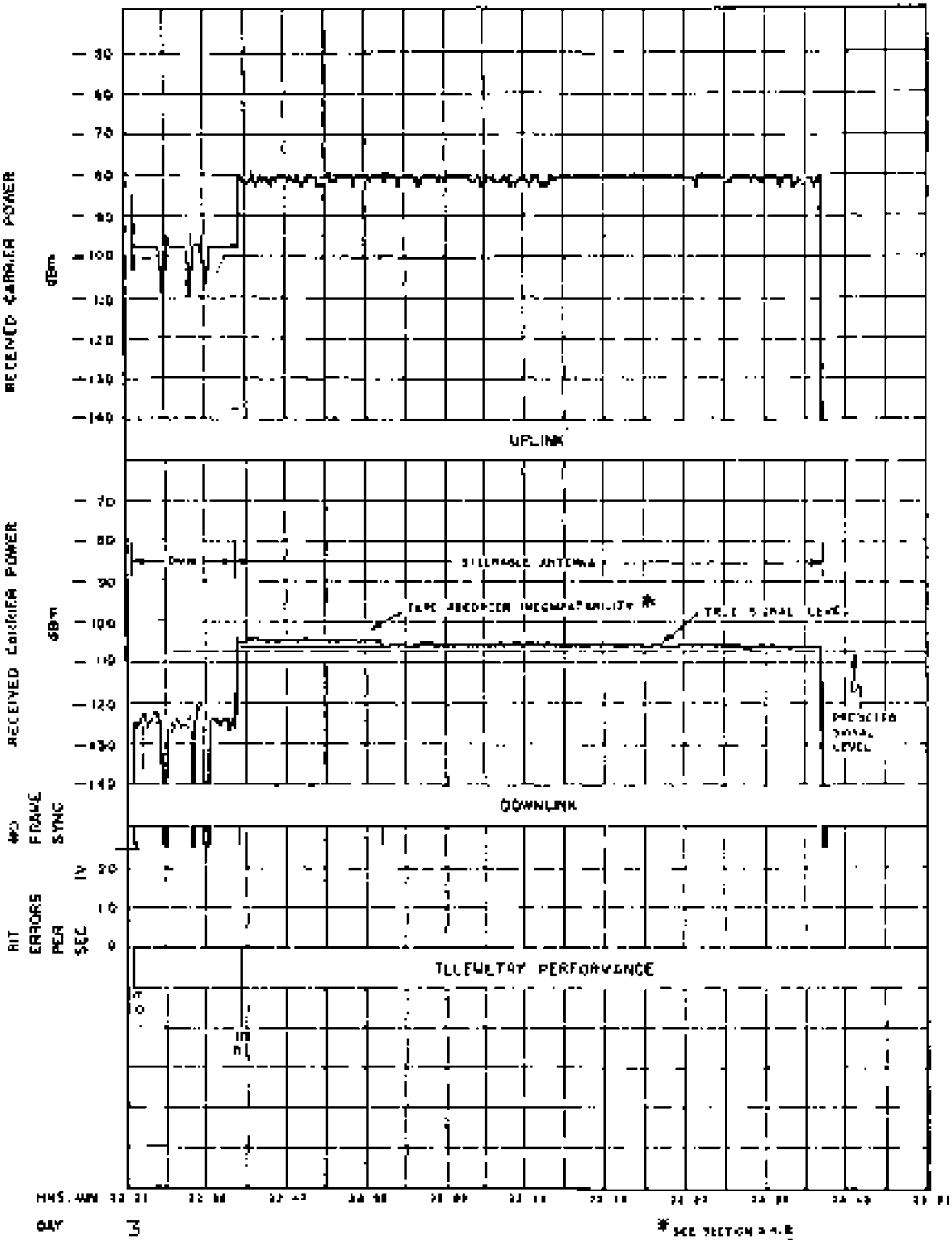
3.4.3 Lunar Orbit 11

Figure 8 is a plot of the performance during the Madrid coverage of lunar orbit 11. The received carrier powers generally agreed with the predicted carrier powers. The true downlink received carrier power is shown on this plot as -104 to -105 dBm. The sudden change in downlink received carrier power as shown in Figure 8 was caused by tape recorder incompatibility.

3.4.4 Lunar Orbit 12

Figure 9 is a plot of the uplink and downlink carrier powers during the Madrid lunar orbit 12 coverage. As shown in the plot, during the first portion of the pass, a fluctuation of approximately 6 dB in power in both the uplink and downlink occurred.

The trajectory and attitude of the lunar module were such that the steerable antenna tracked through the region where the antenna beam was partially blocked by the spacecraft. The tracking angles at the time were such that multipath signals in both the uplink and downlink resulted in a degradation of the uplink and downlink received carrier power (Apollo Communications, CSM High Gain Antenna/LM Steerable Antenna Look Angle Conversions, reference 6).



DAY 3

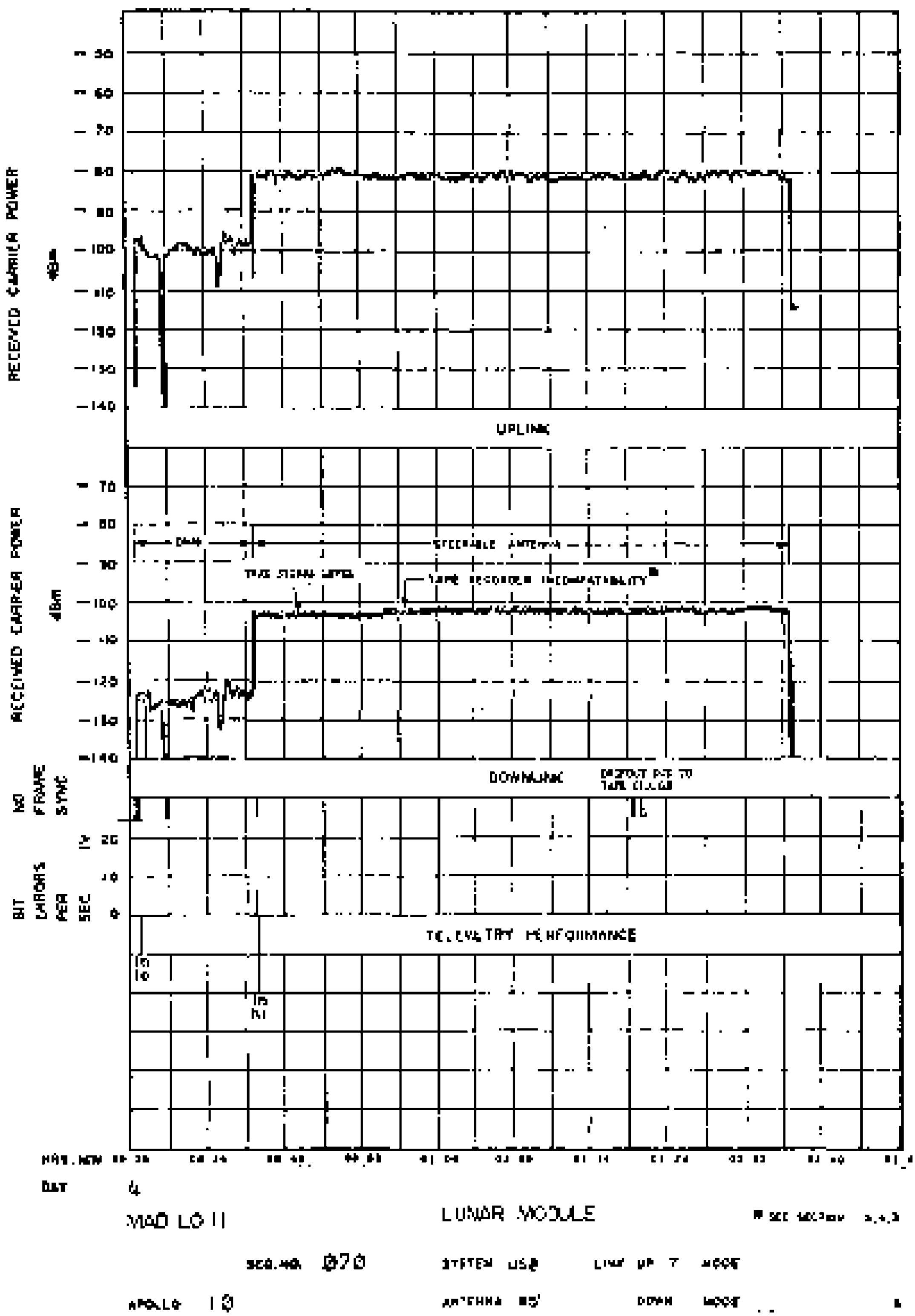
* SEE SECTION

MAD LO 10 "LUNAR MODULE"

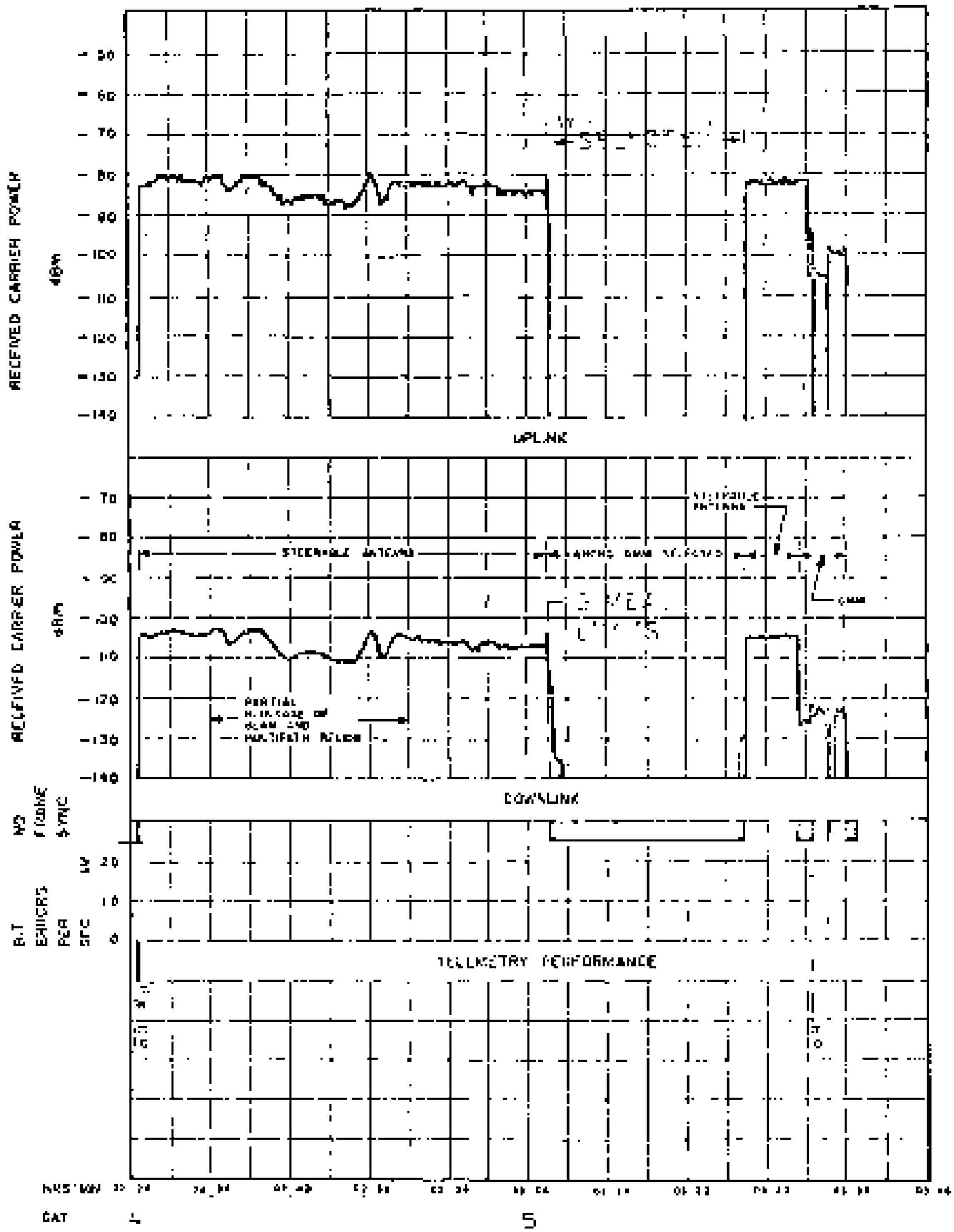
REG. NO. 200 SYSTEM USB MODE

APOLLO 10 ANTENNA 85' DOWN MODE

FIGURE 7 [illegible]


RECEIVED CARRIER POWER
dBm
-100
UPLINK
RECEIVED CARRIER POWER
dBm
-100
STEERABLE ANTENNA
TAPE RECORDER INCOMPATIBILITY
DOWNLINK
NO FRAME SYNC
BIT ERRORS PER SEC
TELEMETRY PERFORMANCE
DAY
4
MAD LO II
LUNAR MODULE
SEQ. NO. 070
SYSTEM USB
APOLLO 10
ANTENNA 85'
DOWN MODE

[illegible]



MAD LO 12

LUNAR MODULE

SEQ NO. 033 SYSTEM USB LINK UP 7 MODE

APOLLO 10 ANTENNA 85' DOWN MODE

Degradation of the automatic tracking performance also occurred. As shown in Figure 10, the antenna look angles during lunar orbit 12 entered the region where multipath and partial blockage of the antenna main beam occurred.

As shown in Figure 9, an abrupt loss of signal occurred at approximately 99:08:00. This loss was due to the steerable antenna reaching its mechanical gimble limits. Failure to select the proper omni antenna resulted in a complete loss of data until the lunar module maneuvered to an attitude which would permit reacquisition of the steerable antenna. The steerable antenna correctly autotracked while it was in use until reselection of the omni antennas just prior to lunar occlusion. The abrupt drop in signal level due to the antenna switching at approximately 99:33:00 resulted in a spacecraft transceiver false lock condition (See Figure 9). Just prior to loss of signal at 99:36:00, the Madrid station personnel recognized the false lock and successfully reacquired solid two-way S-band lock.

Prior to these problems the quality and intelligibility of the S-band voice was good. Voice quality did improve when received from the lunar module steerable antenna. Just prior to loss of signal, the voice received at the ground station was only fair and readable. However, the use of the omni antenna and backup voice mode account for this change.

The only significant discrepancy involving the command and service module during lunar orbit operations was the failure of the Goldstone site to properly remote command module downvoice to the Mission Control Center. An erroneous patching configuration at the site caused lunar module voice to be remoted from Goldstone. Since the Madrid station was correctly remoting lunar module voice, the Goldstone voice remoting capability was inhibited at the Goddard Space Flight Center. Therefore, at 98:34:00, when Goldstone initiated correct command module voice remoting, the voice was not received in the Mission Control Center due to the inhibit. At 98:42:00, the Madrid site remoted command module voice to the Mission Control Center because no command module voice could be obtained from the Goldstone site.

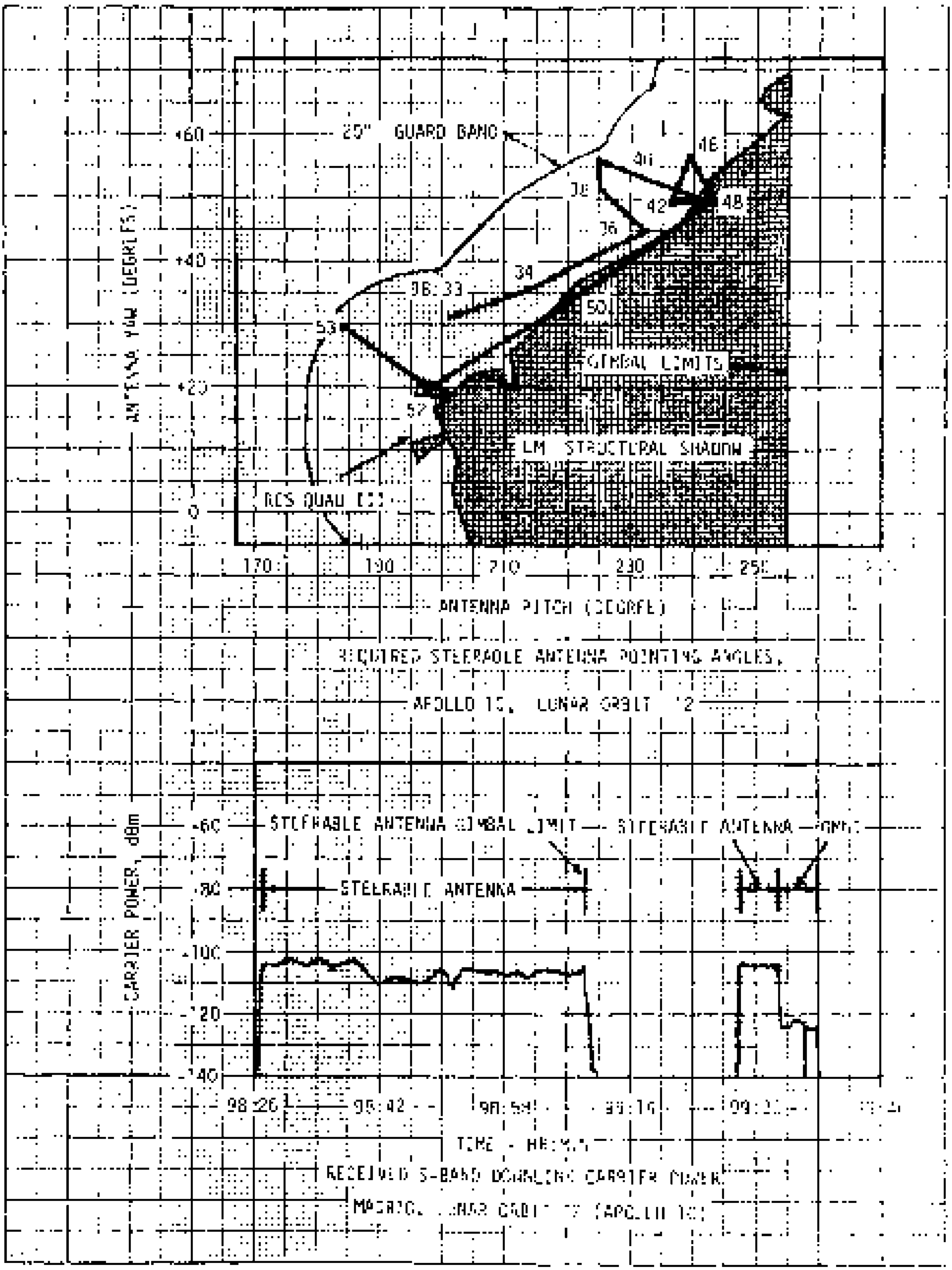
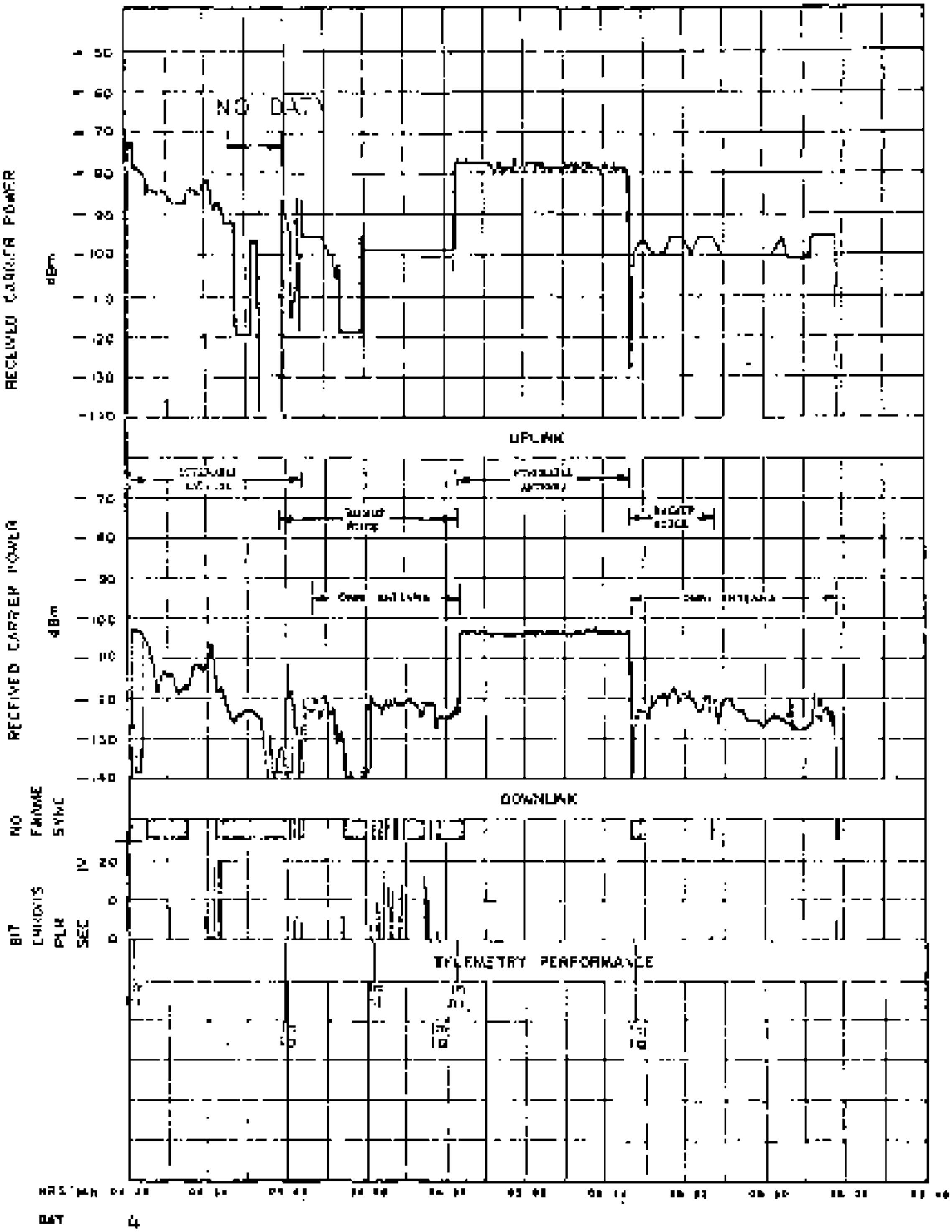


FIGURE 10 LM STEERABLE ANTENNA POINTING ANGLES AND DOWNLINK CARRIER POWER DURING POWERED DESCENT

3.4.5 Lunar Orbit 13

Figure 11 is a plot of the uplink and downlink carrier powers during Goldstone lunar orbit 13 coverage. Between acquisition of signal from the lunar module at 100:26:20 and initiation of the phasing maneuver, steerable antenna autotrack was not maintained, and the lunar module pilot had to select the best omnidirectional antenna. The failure to autotrack the uplink was determined by comparing the received carrier power with the predicted carrier power if the antenna had remained in a fixed position relative to the lunar module structure. The results showed that the antenna remained in a fixed position. Figure 2 is a detailed plot of the downlink received carrier power relative to antenna pitch and yaw angles for the Madrid station. Figure 3 is a detailed plot of the downlink received carrier power relative to antenna pitch and yaw angles for the Goldstone station. These plots show the antenna patterns for the X and Y axis of the steerable antenna that were used in concluding that the steerable antenna remained in a fixed position relative to the spacecraft between acquisition of signal at 100:26:00 and 100:40:00. The steerable antenna failure to autotrack was possibly caused by: (1) the steerable antenna "Slew-Off-Auto" switch could have been left in the "Slew" (bottom) position, (2) the switch could have been placed in the "Off" (middle) position, (3) the antenna equipment might have failed. However, the most likely cause is improper switch position (Volume II, LM Data Book, reference 7). The steerable antenna was reacquired prior to the phasing maneuver and the steerable antenna performance was nominal throughout the remainder of the lunar module activities.

From 100:26:51 to 100:41:47, normal downvoice mode with the steerable antenna allowed good voice intelligibility and fair to good voice quality. At 100:41:47, while the omni antenna was selected, the backup downvoice mode was selected. This mode provided voice that was weak, but intelligible. The poor quality of the backup voice during this



GDS 1.0 13

LUNAR MODULE

SEQ NO. Ø53 SYSTEM USB LINK UP T MODE

APOLLO 10 ANTENNA 85' DOWN MODE

[illegible]

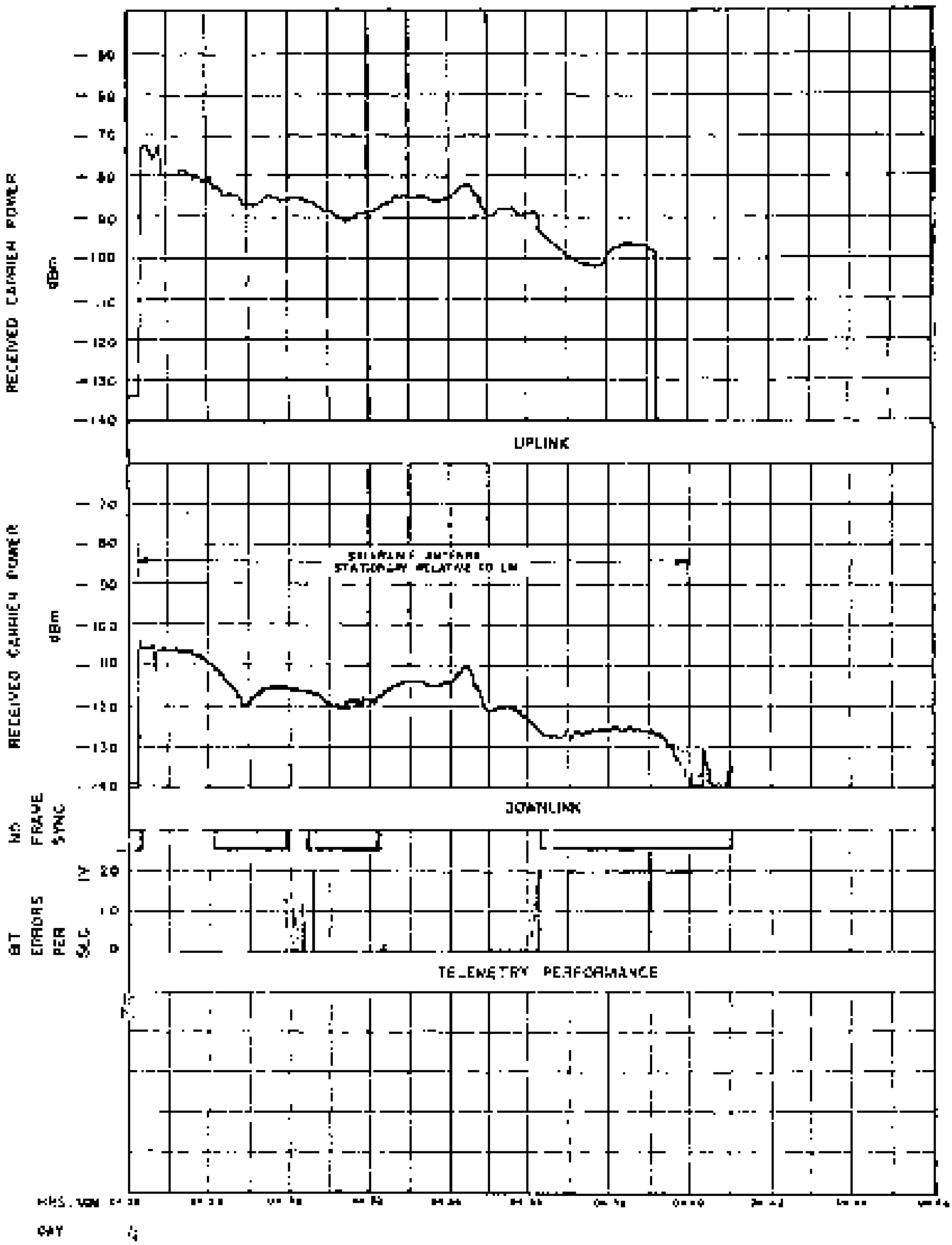
period has been attributed to a configuration error at the Goldstone station. Post mission data indicated that the site had actually remoted both normal and backup voice simultaneously to the Mission Control Center. Post mission testing at Goldstone confirmed that a configuration of this simultaneous remoting would produce the results as obtained during this period. When the steerable antenna was again used from 100:58:00 to 101:16:16, this mode again provided good quality voice.

Figure 12 is an expanded part of the early portion of the Goldstone lunar orbit 13 coverage during the time period when the steerable antenna failed to autotrack the Goldstone uplink. This figure shows 85-foot antenna received carrier power and 210-foot antenna telemetry performance.

5.4.6 Lunar Orbit 14

Figure 13 is a plot of the uplink and downlink received carrier power levels during Goldstone coverage of lunar orbit 14. Initial acquisition of the spacecraft was made on omni antennas. The crew then switched to the steerable antenna with proper tracking until the antenna approached gimbal limits. The steerable antenna was switched off, and the Capsule Communicator requested that the aft omni antenna be selected. A loss of signal occurred, and after approximately four minutes without acquisition, it appeared that another omni switch occurred.

Reacquistion of the steerable antenna occurred when the attitude improved for steerable antenna reactivation. Later, the omni antenna was selected just prior to loss of signal. The received carrier powers during this pass compared within 2 dB with premission predicted levels. In addition, voice quality and intelligibility were very good throughout the pass until omni antennas were again reselected at 103:33:00. However, even though voice communications performance on the omni antenna was not as good as on the steerable antenna, the voice was usable.



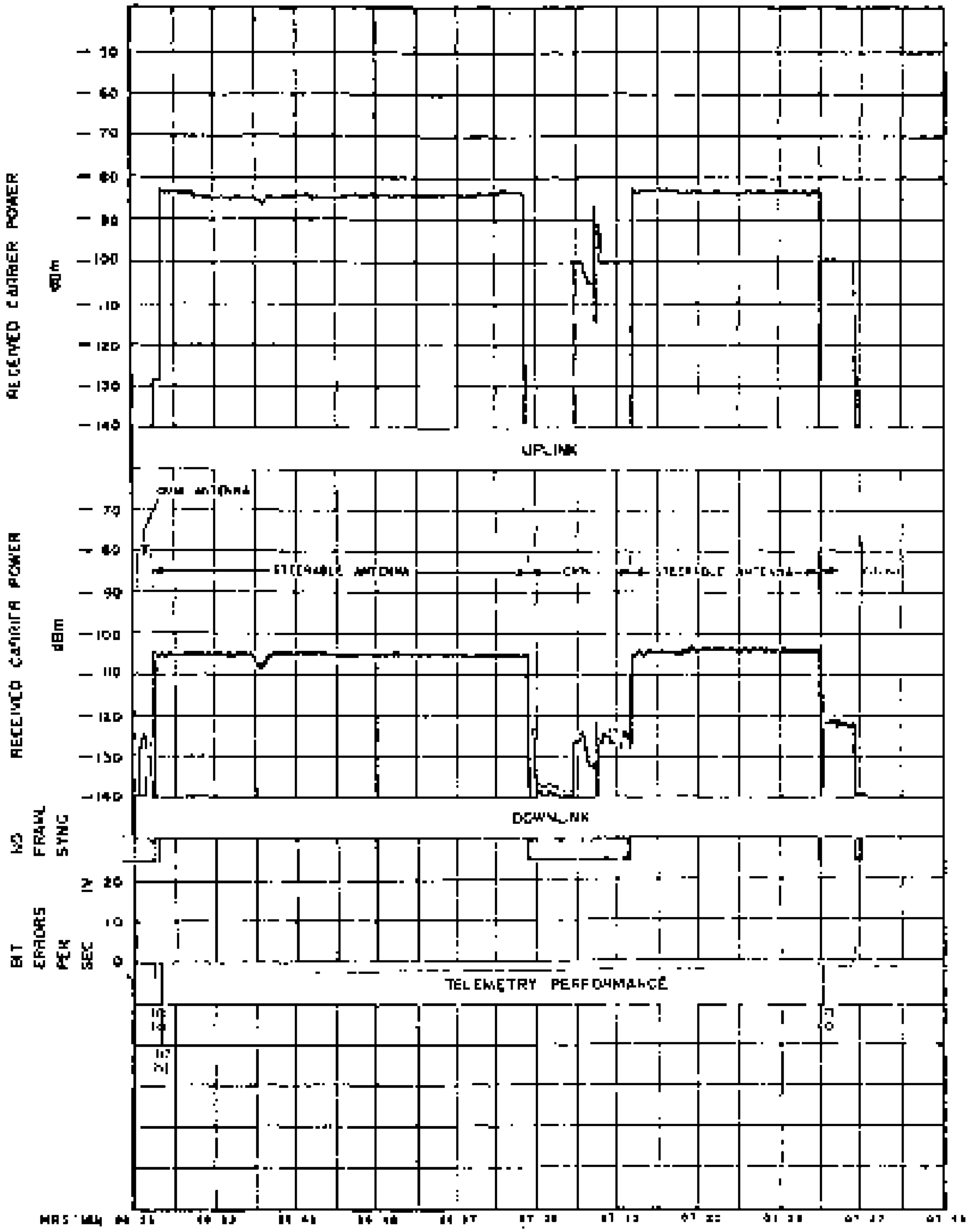
GDS LO 13

LUNAR MODULE

SEQ. NO. 140 SYSTEM USB LINK UP 7 MODE

APOLLO 10 ANTENNA 85' DOWN MODE

[illegible]



DAY 4

GDS LO 4 LUNAR MODULE

SEQ.NO. 110 SYSTEM USB LINK UP MODE

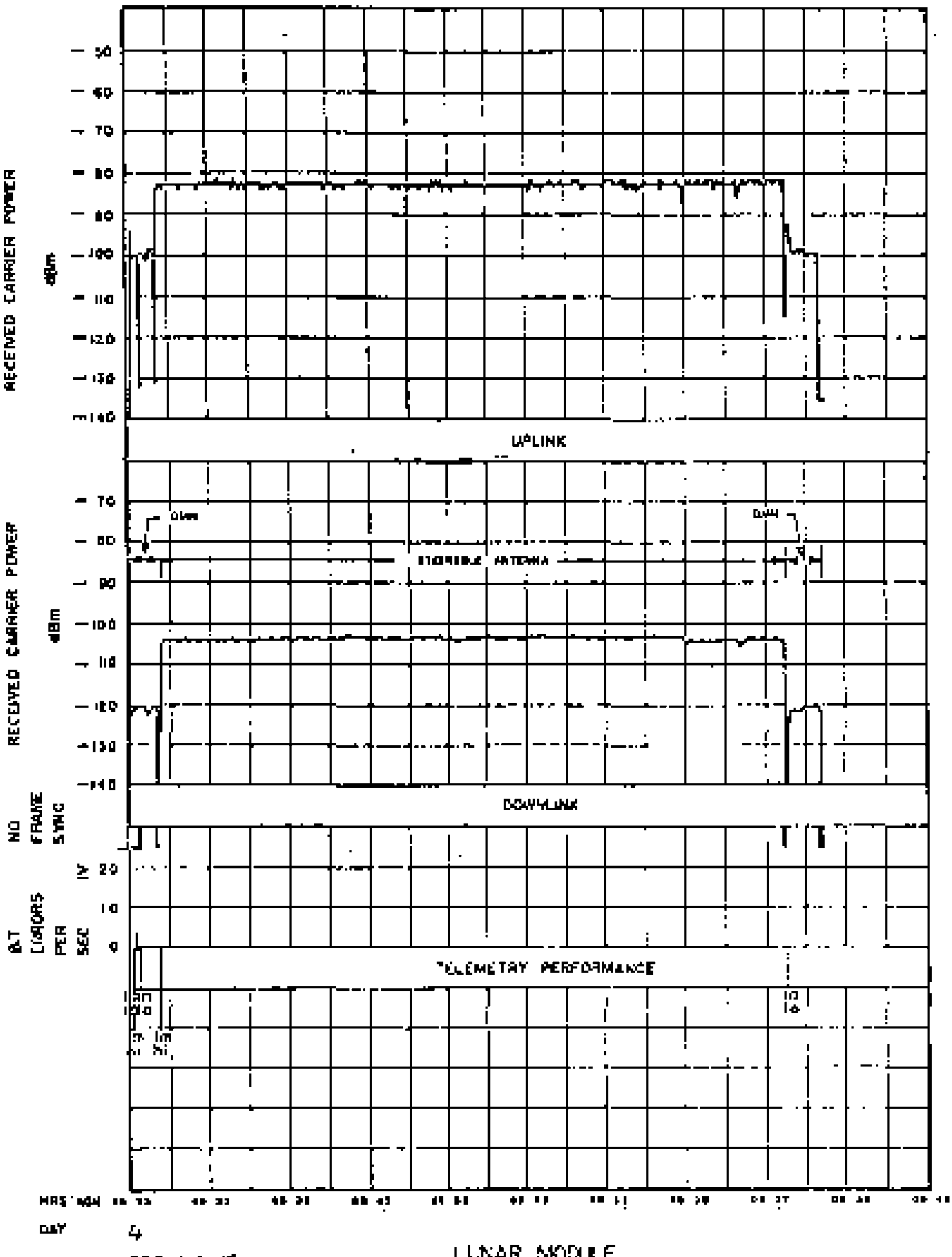
APOLLO 10 ANTENNA 85' RF DOWN MODE 3

5.4.7 Lunar Orbit 15

Figure 14 is a plot of lunar orbit 15 coverage by the Goldstone station. The received uplink and downlink carrier powers for the lunar module are shown in this figure. Initial acquisition was accomplished through the omni antenna. Shortly thereafter, acquisition of the lunar module steerable antenna was accomplished successfully. Automatic tracking was maintained until just prior to lunar occlusion. At that time, the omni antenna mode was again reselected. The telemetry performance was very good throughout the pass as can be seen in Figure 14. Also, voice quality and intelligibility throughout the pass were generally good.

5.4.8 Lunar Orbit 16

Figure 15 is a plot of the uplink and downlink received carrier powers during Goldstone lunar orbit 16 coverage. Deactivation of the lunar module in preparation for the ascent propulsion system burn to depletion was performed during this pass. Initially the lunar module was acquired on the steerable antenna. As the steerable antenna approached the gimbal limits, the forward omni antenna was selected. At the time of the steerable antenna approaching gimbal limits at 106:46:45, the lock angles were 165 degree (theta) and -126 degrees (phi). According to these angles, the aft omni antenna should have been selected instead of the forward omni antenna. Upon selection of the aft omni antenna, the signal levels returned to their respective nominal ranges. The steerable antenna manual mode was selected and the antenna pointed to the earth for the ascent propulsion system burn to fuel depletion. The received signal levels agreed with predicted levels during this pass, and the telemetry data were of good quality. Except for a momentary loss of two-way lock at command and service module and lunar module separation, the lunar module ascent stage was tracked until approximately 122 hours.

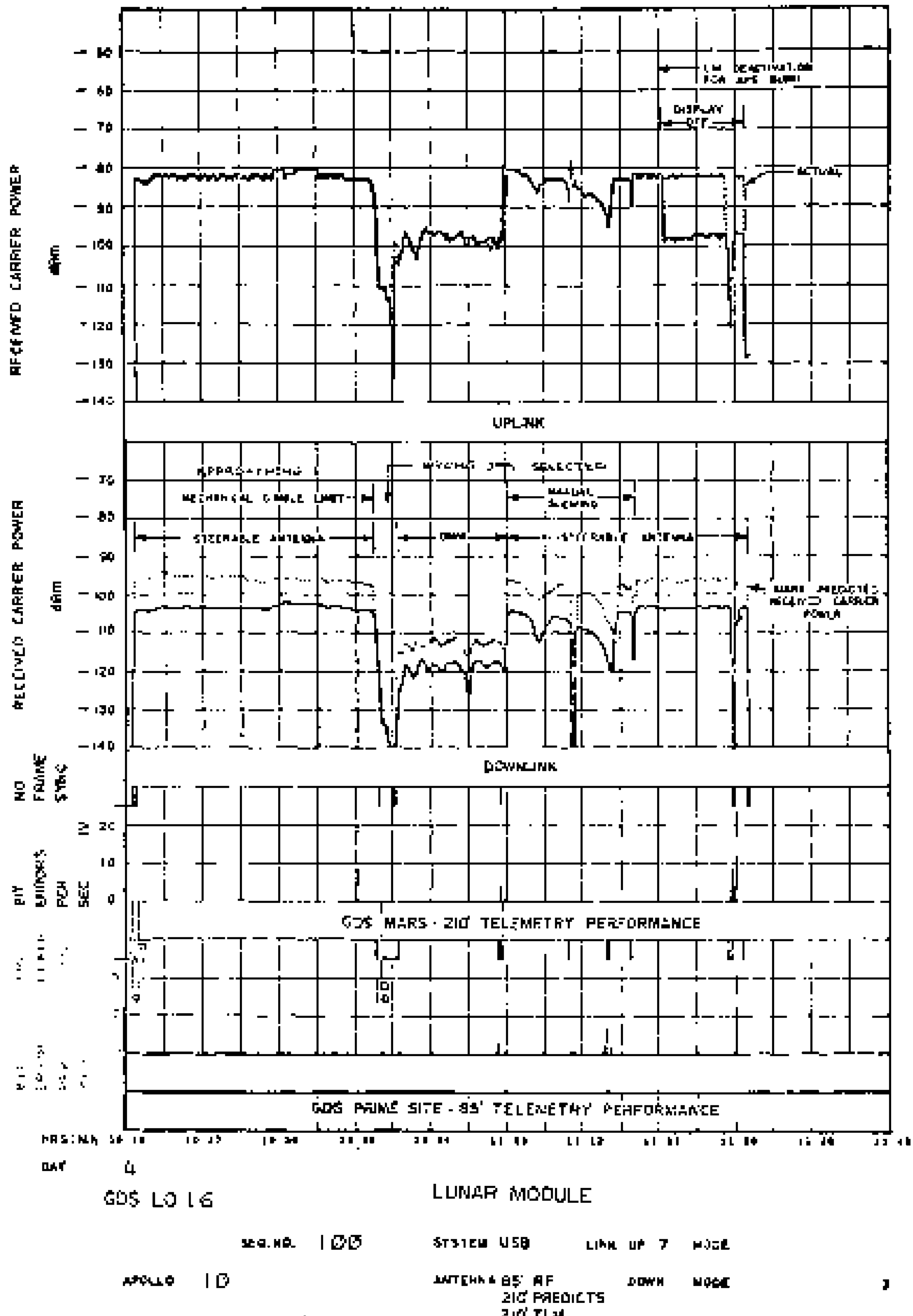


GDS LO 15.

LUNAR MODULE

SEQ. NO. 090 SYSTEM USB

APOLLO 10 ANTENNA 85' RF 210' PREDICTS


RECEIVED CARRIER POWER dBm
LM DEACTIVATION FOR APS BURN
DISPLAY OFF
ACTUAL
UPLINK
APPROACHING MECHANICAL GIMBLE LIMIT
OMNI
STEERABLE ANTENNA
MANUAL SLEWING
MARS PREDICTED RECEIVED CARRIER POWER
DOWNLINK
NO FRAME SYNC
BIT ERRORS PER SEC
GDS MARS - 210' TELEMETRY PERFORMANCE
GDS PRIME SITE - 85' TELEMETRY PERFORMANCE
DAY 4
GDS LO L6
LUNAR MODULE
SEQ. NO. 100
SYSTEM USB
LINK UP
MODE
APOLLO 10
ANTENNA 85' RF
DOWN
MODE
210' PREDICTS
210' TLM

3.5 Transearth Coast

The communications system performance during the transearth coast was satisfactory. Six color television transmissions were received from the spacecraft during this period. All were of excellent quality.

During this coast period, the station personnel at the Madrid tracking station resolved a configuration problem affecting recovery of recorded voice from command module data storage equipment data dumps. During Apollo 8 and 10, Madrid recovery of 32:1 dump voice playback from the data storage equipment was degraded by improper installation of the 64-kHz filter. Upon relocation of the filter, better quality dump information was retrieved.

Three command module high gain antenna reflectivity checks were conducted from 167:50:00 to 168:12:00 to provide flight data concerning the capability of the antenna to track out of the reflectivity zone and achieve autotrack with the Manned Space Flight Network station uplink transmitted signal. During the first two checks, the antenna was manually positioned into the reflectivity zone. When the uplink signal was acquired, the antenna did not track from this zone. On the third check, the antenna did track from the reflectivity zone into proper track. The conclusion of these checks is that when the high gain antenna is in the reflectivity zone, it is difficult to predetermine whether the antenna will track out of the reflectivity zone (Effects of Vehicle Reflection on CSM S-band High Gain Antenna Performance, reference 8).

3.6 Earth Entry

For the earth entry phase, omni antenna C was selected. Performance before and after blackout was as expected. The USNS Redstone observed loss of signal at 191:49:12. In addition, the Apollo Range Instrumented Aircraft 5 acquired the spacecraft after blackout at 191:53:40. Communications after this coverage were with the recovery forces in the splashdown area.

APPENDIX A

MSFN RECEIVER CALIBRATION

The Manned Space Flight Network (MSFN) receiver automatic gain control (AGC) calibration is one of the prime measurements used to evaluate system performance during an Apollo mission. Station strip chart recordings and magnetic tape recordings are used in postflight evaluation, and the AGC from the Goldstone, Madrid and Honeysuckle stations is monitored in real time during the mission. The real time monitoring is used to determine and manage spacecraft communications modes. The accuracy and repeatability of station calibrations become critical when used to evaluate spacecraft modes and performance.

During the Apollo 10 mission, it was noted that the station AGC calibrations were not repeatable from day to day. Data from some stations indicated a change of 5 dB from the previous day's calibration, and in some instances, the shape of the AGC curve changed.

Figure 16 is a graph showing the total variation of AGC at the Honeysuckle station during Apollo 10. This graph indicates 4 to 5 dB variation in AGC during the mission.

It is unlikely that the receiver AGC characteristics actually changed as indicated by the calibration data (Block III-C, Ground Equipment, S-band RF Receiver/Exciter Subsystem Detail Specification, reference 9). Experience with MSFN receivers in the Electronic Systems Compatibility Laboratory indicates these receivers are very repeatable. Test history from October 1968 through May 1969 shows AGC is repeatable to ± .25 dB in the range from -90 to -130 dBm.

Figure 17 is a simplified block diagram of the instrumentation for calibrating and monitoring AGC versus received signal level. All instrumentation is monitored at a common point. The accuracy of the calibration depends on the accuracy of the RF path calibration from

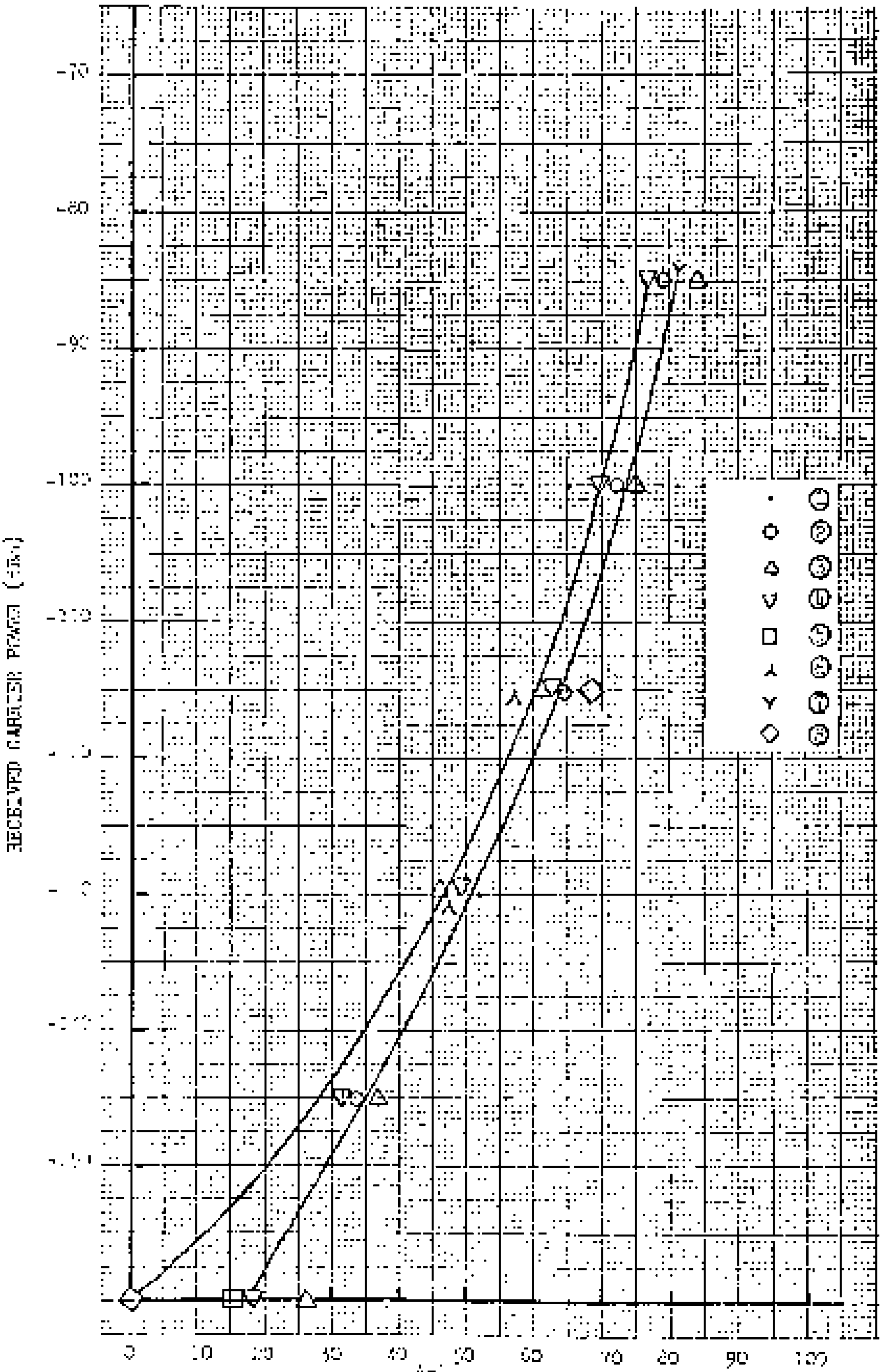


FIGURE [illegible] CALIBRATION SUMMARY

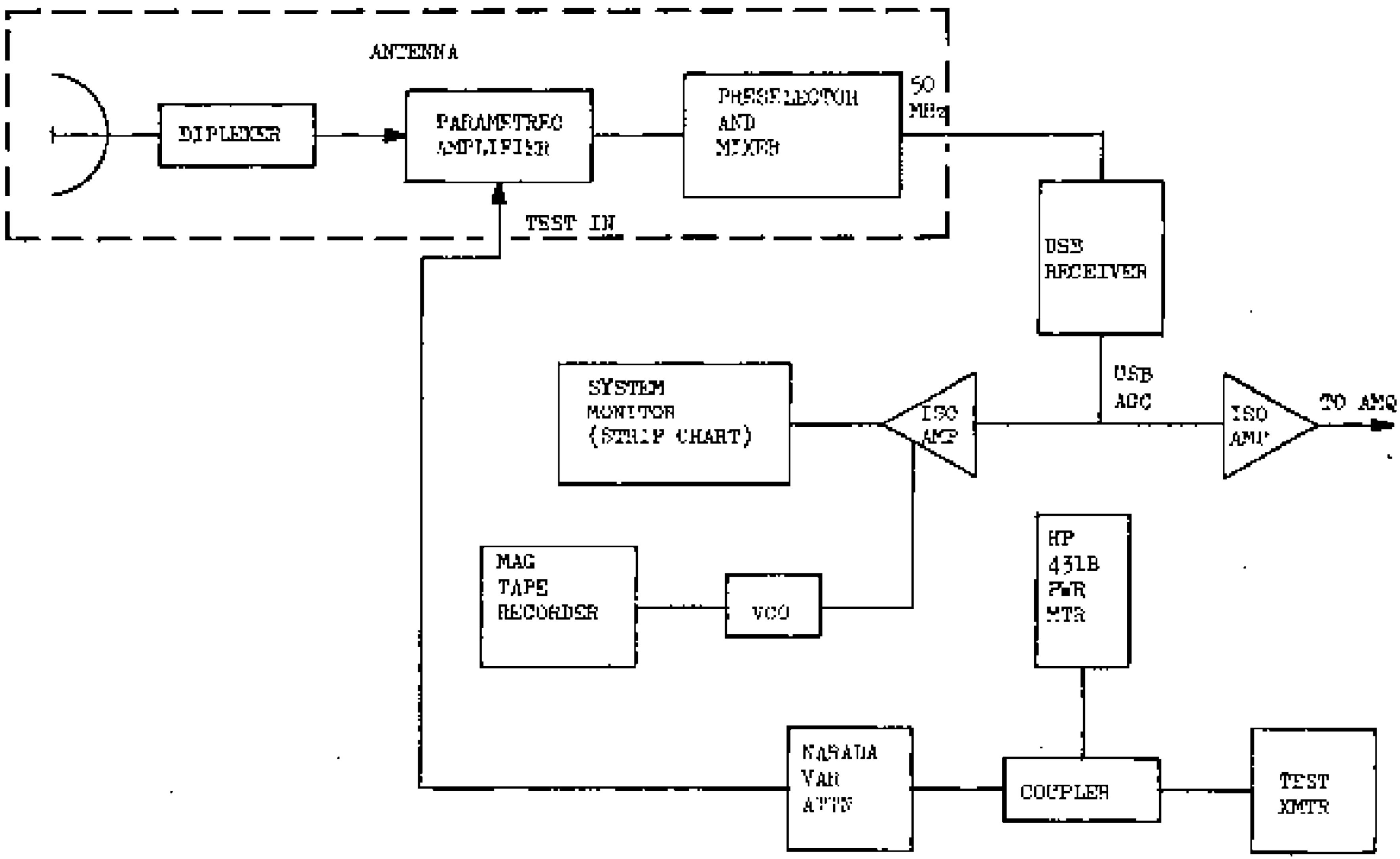


FIGURE 17 MSFN AGC CALIBRATION CONFIGURATION

the test transmitter to the parameteric amplifier test input. Once this path is calibrated, the received signal power versus Narda attenuator setting should be repeatable.

Strip chart and magnetic tape IRIG channels are calibrated for upper bandedge at -70 dBm and approximately threshold at lower bandedge. If these monitors were calibrated for 0 to -10 volts, all post mission evaluation would be considerably easier, since all station calibration would be standardized.

All stations could be set up to have very similar AGC characteristics. This would not only aid the Flight Evaluation Team, but would also be a good indication of station performance.

JPL Document No. DNP-1276-DTL3 (reference 9) contains the overall receiver exciter subsystem electrical characteristics. Figure 3d is a graph indicating the AGC characteristics for the MSFN modes. The center plot (broken line) represents the nominal design center for AGC voltage versus signal level. All MSFN receivers should have AGC characteristics very close to the nominal design center.

The following procedures will assure more repeatable AGC calibration:

1. Allow the test transmitter 30 minutes warmup to assure stable output.

2. Approach attenuator settings from the low end of the dial.

3. Calibrate strip chart and magnetic tape recorder AGC for 0 to -10 V.

4. Remove cable from the parametric amplifier test input and connect to the receiver preselector input.

5. Set the RF uplink signal level to -110 dBm at the preselector input.

6. Remove all attenuation from the switched attenuator (A411) and the variable attenuator (A406).

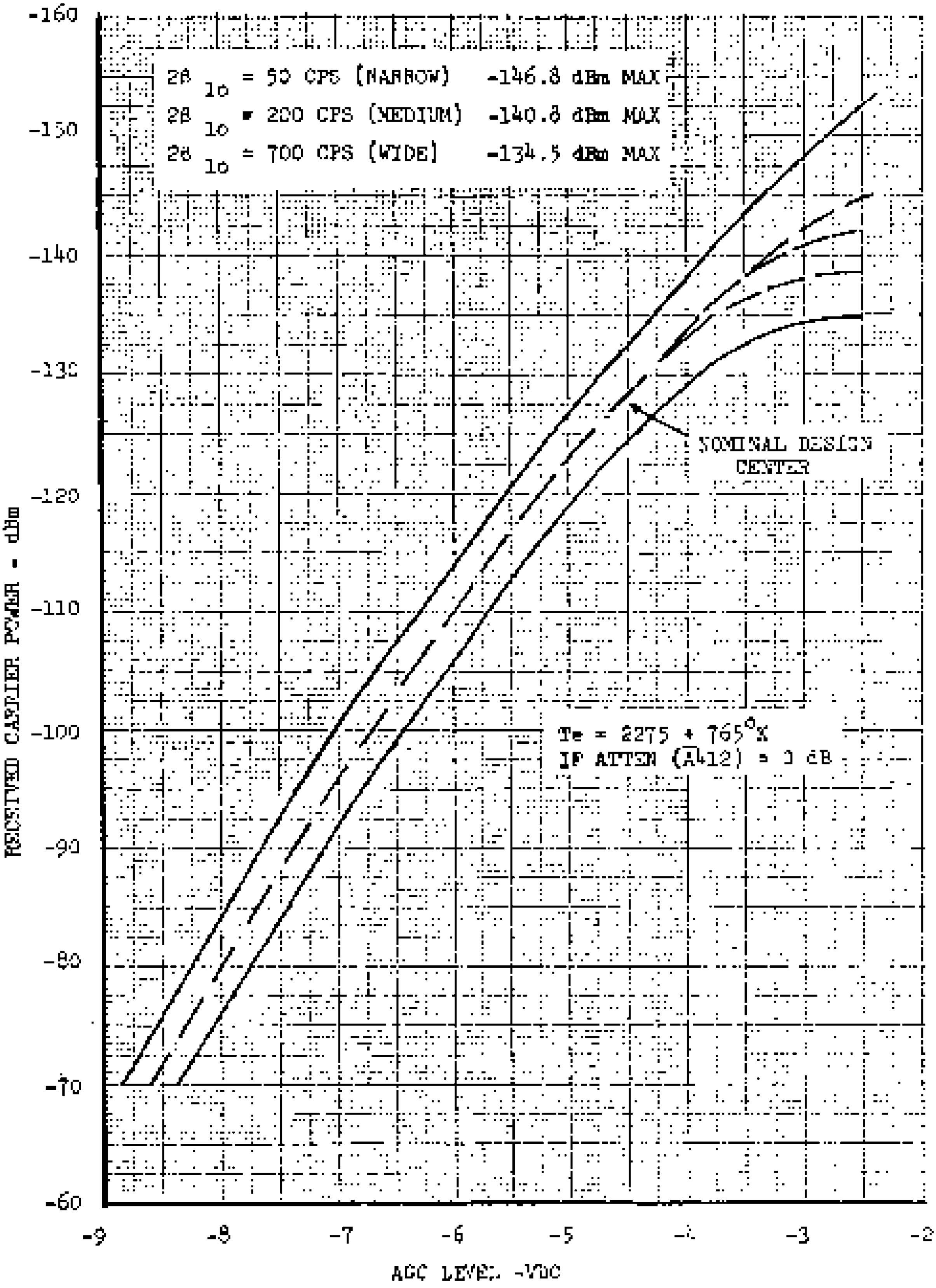


FIGURE 1B AGC CHARACTERISTICS-MSFN MODE

7. Acquire lock and measure the receiver AGC volts.

   NOTE: If the AGC voltage is greater than -6.00 volts, add attenuation in 1 dB increments with variable attenuator (A406) for -6.00 volts. If the AGC voltage is less than -6.00 volts, change the 50-MHz IF mixer modules with the angle channel receiver and select the module that produces an AGC closest to -6.00 volts).

8. Measure AGC voltage versus received signal level from -70 dBm to threshold. Compare the test results with the AGC characteristics graph, Figure 11 page 45 of JPL SPEC DNR-1276-CTL B. Test results should be very close to nominal design center in the -90 dBm to -130 dBm range.

9. Reconnect the coaxial cable to the parametric amplifier input.

10. Set the switched and variable attenuators to cancel the parametric amplifier gain.

11. Reacquire lock and set signal level for -110 dBm. Readjust the variable attenuator A406 +1 dB to set AGC voltage to -6.00 volts. If greater than ±1 dB is required, the attenuator setting was not properly set to compensate for parametric amplifer gain.

12. Repeat the AGC curve for -70 dBm to threshold. (The data will repeat for all strong signal levels.) Voltage versus signal level will increase as level approaches threshold.

APPENDIX B

REFERENCES

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3. Apollo 10 Flight Plan, AS-505/CSM-106/LM4, April 17, 1969.

4. Communications Systems Performance And Coverage Analysis For Apollo 10, Addendum 2, May 14, 1969.

5. Spacecraft Operational Trajectory For Mission G, Revision 1 Apollo 11, Volume 1, MSC Internal Note No. 69-FM-186 and MSC Internal Note EE-R-69-3.

6. Apollo Communications Systems, CSM High Gain Antenna/LM Steerable Antenna Look Angle Conversions, May 7, 1969.

7. Volume II, LM Data Book, June 1968.

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9. Block III-C, Ground Equipment, S-Band RF Receiver/Exciter Subsystem Detail Specification, JPL Document No. DSR-1276-DTL B, 30 September, 1968.