

EB-67-3314-U
21 JULY 1967



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SUPPLEMENTAL REPORT ON COMMUNICATION SYSTEM PERFORMANCE DURING MISSION AS-202

(Supplements Section 7.16 of
POSTLAUNCH REPORT FOR MISSION
AS-202, MSC-A-R-66-5,
dated
October 12, 1966.)



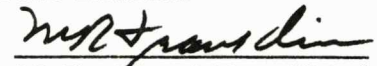
INFORMATION SYSTEMS DIVISION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

SUPPLEMENTAL REPORT ON
COMMUNICATION SYSTEM
PERFORMANCE DURING
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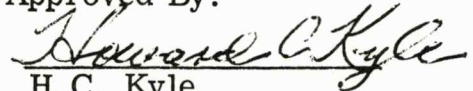
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1.0 INTRODUCTION

This report supplements the information presented in section 7.16 (Communication Subsystem) of the POSTLAUNCH REPORT FOR MISSION AS-202 (Apollo Spacecraft 011) dated October 12, 1966. This report includes the results of additional evaluation of the unified S-band (USB) system performance and special tests involving the UHF command system.

1.1 Unified S-Band System

Four USB anomalies were reported in the postlaunch report:

1. Low carrier power at MIL and BDA.
2. Inability to recognize two-way lock at CRO.
3. Degraded up-voice channel at BDA.
4. Invalid ranging data at CRO.

Since the above report was published, each of these anomalies and other questions posed in the postlaunch report have been investigated. The results of this investigation are in section 3 of this report.

1.2 UHF Command System

Special tests, which investigated the failure of the spacecraft command subsystem to accept the CM/SM separation command, were accomplished in the Electronic Systems Compatibility Laboratory (ESCL). The results of these tests and the associated conclusions follow.

2.0 SUMMARY

Each of the reported anomalies and other facets of the USB and UHF command system operation have been investigated. The results of this investigation are summarized below.

2.1 Summary of Anomalies

- a. The difference between the measured and the predicted down-link carrier powers at MIL were explained by correcting the measured data for skewing of the chart paper and utilizing the full-scale antenna patterns.
- b. Up-link received carrier power at MIL was still approximately 20 db below predicted. This anomaly is not explained; however, there are indications that the carrier power was not as low as the telemetered data suggests.
- c. Low down-link carrier power at BDA has not been explained.
- d. Inability to recognize two-way lock at CRO was attributed partially to the failure of the spacecraft AGC indicator on the MSFN-USB exciter console. (Refer to reference 3 of appendix A.)
- e. Failure to obtain two-way lock at CRO when utilizing the automatic acquisition sweep was attributed to a shorted cable shield in the acquisition circuitry. (Refer to reference 2 of appendix A.)
- f. Degraded up-voice channel performance at BDA was apparently due to low modulation indices.
- g. Invalid ranging data at CRO was attributed to failure to acquire one or more of the A, B, and C subcodes. This failure may have been caused by the fact that the exciter was not phase-locked to the synthesizer during range-code acquisition.
- h. The CM/SM separate commands transmitted by the CSQ were not accepted because the sync and data signal frequencies were outside the frequency tolerance of S/C up-data receiver decoder.

3.0 INVESTIGATION RESULTS

3.1 RF Subsystem

3.1.1 MIL

3.1.1.1 Down-Link Carrier Power

Investigation of the down-link carrier power problem at MIL revealed:

- a. The measured carrier powers shown in figure 7.16-8 of the postlaunch report were in error. This error was caused by skewing of the paper on the strip chart recorder.
- b. There are considerable differences between the one-third scale antenna patterns used for the predictions presented in the postlaunch report and the preliminary full-scale antenna patterns measured by IESD (after the postlaunch report was published) at the aspect angles that existed during the MIL coverage.

Thus, the actual carrier power recorded by MIL during its coverage was replotted considering the effects of skewing of the chart recorder paper. These new carrier powers are shown in figure 3-1. Also, new predictions of carrier powers based on full-scale antenna patterns and actual trajectory were obtained. These predictions are also shown in figure 3-1.

A study of the information presented in figure 3-1 (neglecting transients) reveals that there are two distinct time periods when the predicted and measured carrier powers do not compare. These periods are from T (launch) to T+30 seconds, and from T+100 seconds to T+120 seconds. During the remainder of the coverage, the maximum difference between measured and predicted carrier powers is 9 db. The average difference between predicted and measured carrier powers for the remainder of the MIL coverage was approximately 5 db. This difference occurs from T+235 to T+242 seconds.

The deviation between predicted and measured carrier levels for the time period T to T+30 seconds can probably be attributed to the effects of the multipath situation that exists between the launch pad and the station and possibly to the manual antenna pointing techniques utilized during this time period.

The deviation between predicted and measured carrier levels for period between T+100 and T+120 seconds can be attributed to the fact that the signals were being transmitted through the exhaust plume of the launch vehicle. The predictions do not consider the attenuation of the signal during this phase.

3.1.1.2 Up-Link Carrier Power

When the postlaunch report was published, predictions of the up-link carrier power based on the launch trajectory and spacecraft received antenna patterns were not available. Therefore, the up-link predictions shown in figure 7.16-6 of the postlaunch report were based on the difference in up-link and down-link transmitted powers and the difference in up-link and down-link carrier suppressions.

After the postlaunch report was prepared, preliminary full-scale antenna patterns and the launch trajectory have been utilized to generate new up-link predictions. These predictions and the measured up-link carrier power are presented in figure 3-2. Since the predictions are based on a constant ground-transmitter power of 7 kilowatts, and the actual transmitted power was varied between 700 watts and 7 kilowatts over the time period from launch to T+300 seconds, comparison of the predicted and measured carrier power is limited to the period between T+300 and T+420 seconds.

This comparison shows that the predicted carrier power is, in general, 20 db greater than the measured carrier power.

However, indications exist that the received up-link carrier power was not as weak as shown in figure 3-2. These indications are: (1) the difference in measured up-link and down-link carrier power, and (2) the measured postdetection signal-to-noise ratio of the turned-around voice subcarrier.

As stated in the postlaunch report, the difference in up-link and down-link carrier powers should be approximately 33 db for the conditions that existed at MIL during the launch phase. However, as can be seen by comparing the information shown in figures 3-1 and 3-2, the difference in the two carrier powers is only 16 to 20 db. For example, the received down-link carrier power at T+340 seconds was -117 dbm, the received up-link carrier power was -100 dbm, the difference being 17 db. Utilizing the predicted difference; i. e., 33 db, and the down-link carrier power of -117 dbm an up-link carrier power of -84 dbm would be expected.

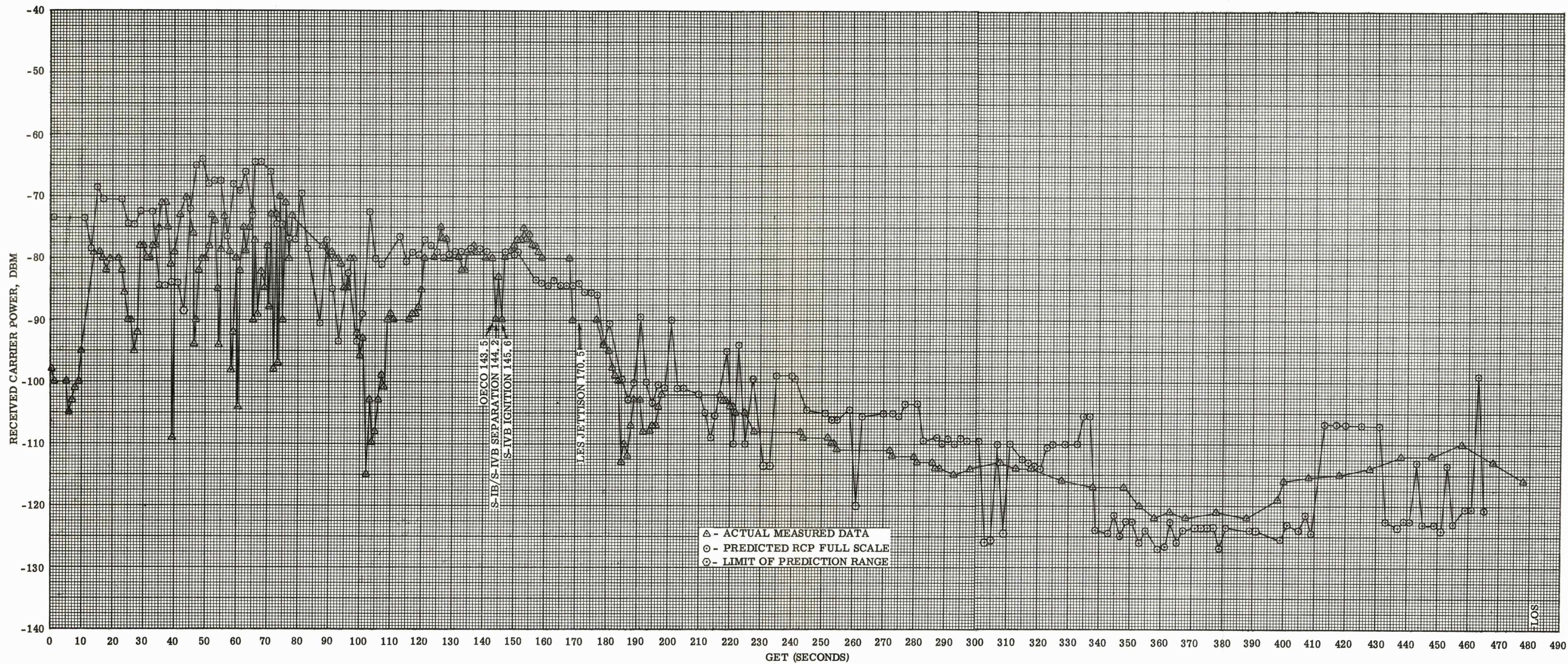


Figure 3-1. Comparison of Measured and Predicted Down-Link Carrier Powers for MIL Coverage of AS-202

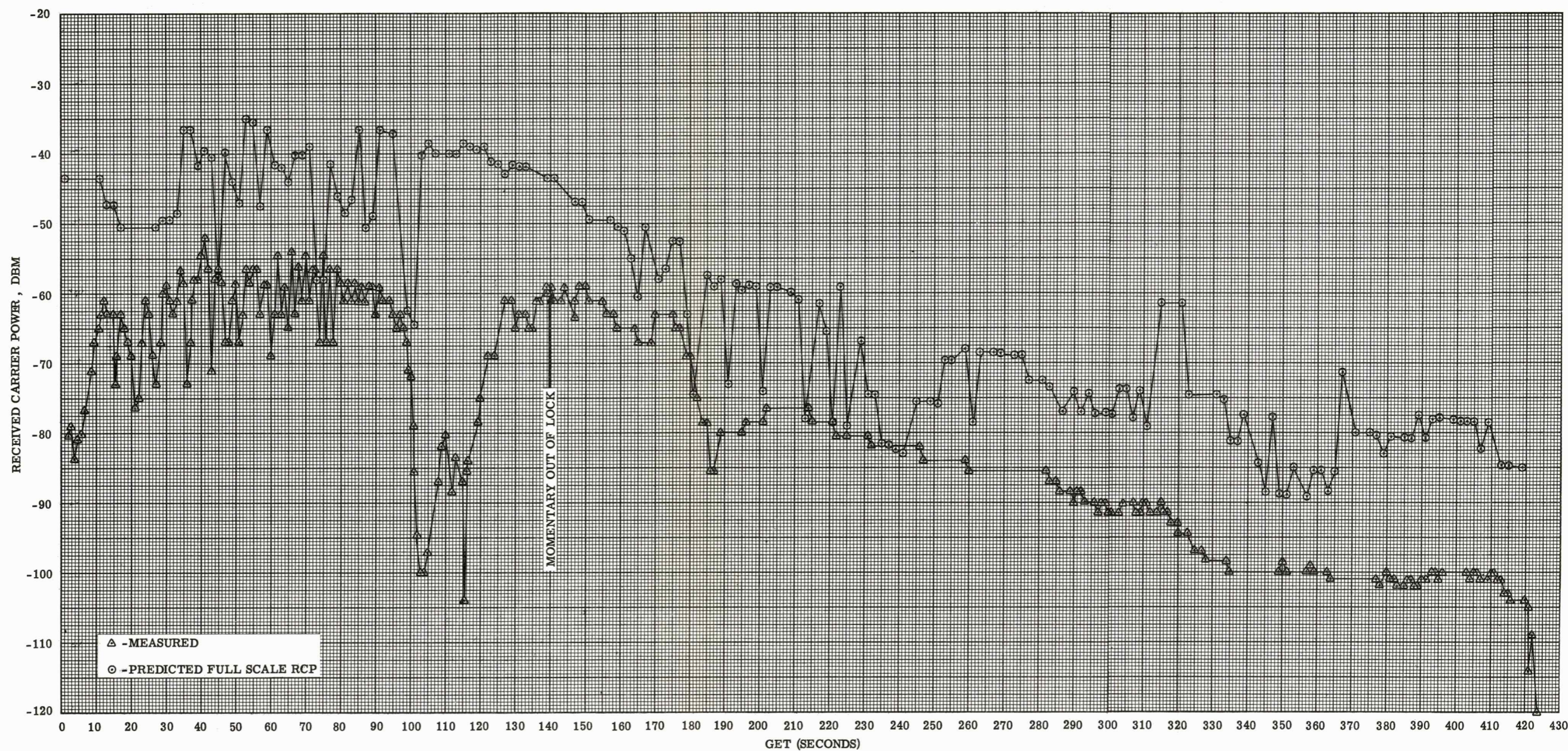


Figure 3-2. Comparison of Measured and Predicted Up-Link Carrier Powers for MIL Coverage of AS-202

As will be shown in section 3.2, the up-voice evaluation on AS-202 data was limited to measurement of the signal-to-noise ratio of the turned-around, up-voice tone received at the ground station. The data presented in the section 3.2 shows that the postdetection signal-to-noise ratio remained fairly constant from T+135 to T+385 seconds, and the measured ratio was approximately +35 db in a 1.396-KHz noise bandwidth. In particular, the measured postdetection signal-to-noise ratio was +36 db at T+340 seconds. (See figure 3-3.) The decommutated VHF telemetry data indicates that the up-link carrier power was -100 dbm at T+340 seconds, and the MSFN strip chart recordings indicate that the received down-link carrier power at T+340 seconds was -117 dbm. As will be shown in the following analysis, the measured postdetection signal-to-noise ratio, the measured up-link carrier power, and the measured down-link carrier power at T+340 seconds are not compatible.

The ranging channel equations presented in the following material were obtained from reference 1 of appendix A. These equations are presented here without derivation to help clarify the subsequent discussion.

$$\alpha = \frac{\sqrt{2}}{2} \text{ LBG} \left[\frac{S/N}{1+S/N} \right]^{1/2} \text{ SIN } (\alpha) J_0 (M_1) J_0 (M_2) \quad (1)$$

$$\beta = \sqrt{2} \text{ LBG} \left[\frac{S/N}{1+S/N} \right]^{1/2} \text{ COS } (\alpha) J_1 (M_1) J_0 (M_2) \quad (2)$$

$$\gamma = \sqrt{2} \text{ LBG} \left[\frac{S/N}{1+S/N} \right]^{1/2} \text{ COS } (\alpha) J_0 (M_1) J_1 (M_2) \quad (3)$$

where:

α = down-link PRN ranging index in radians.

L = amplitude parameter of the limiter preceding the transponder wide-band phase detector.

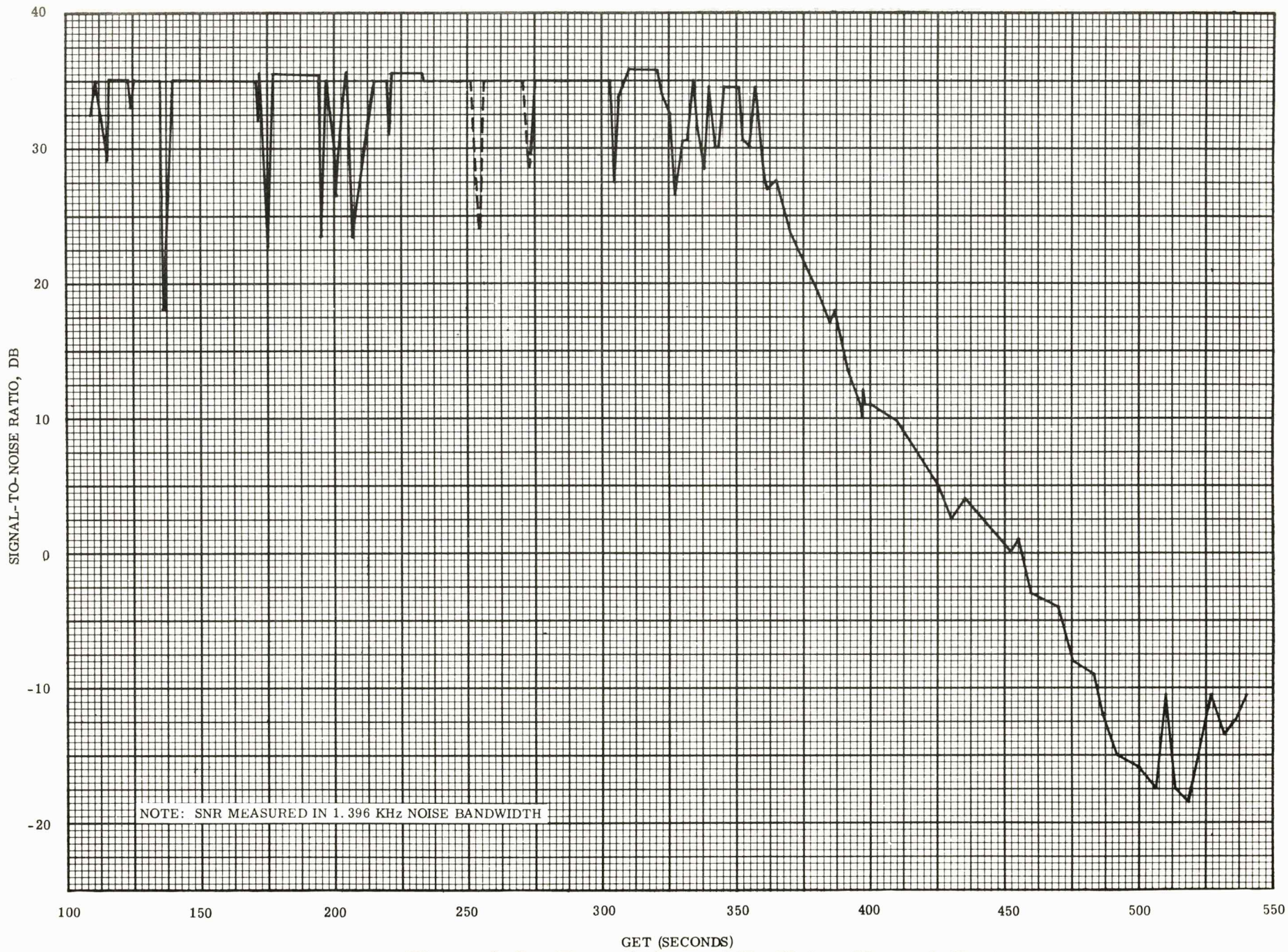


Figure 3-3. Turned-Around Up-Voice Channel Post Detection Signal-to-Noise Ratio Measurement Results for MIL Coverage of AS-202

B = amplitude parameter of the wide-band phase detector.

G = amplitude parameter of the video channel in the transponder.

S/N = signal-to-noise ratio at the input to the wide-band limiter preceding the phase detector.

θ = modulation index of the PRN ranging signal on the up-link in radians.

M_1 = modulation index of the up-voice subcarrier in radians.

M_2 = modulation index of the up-data subcarrier in radians.

β = modulation index of the up-link voice subcarrier remodulated onto the down-link (with PRN Signal) in radians.

γ = modulation index of the up-data subcarrier remodulated onto the down-link (with PRN Signal) in radians.

For high signal levels into the ranging channel, i. e., if S/N is much greater than 1, equations 1, 2, and 3 can be rewritten as follows:

$$\alpha = A \sin(\theta) J_0(M_1) J_0(M_2) \quad (4)$$

$$\beta = 2A \cos(\theta) J_1(M_1) J_0(M_2) \quad (5)$$

$$\gamma = 2A \cos(\theta) J_0(M_1) J_1(M_2) \quad (6)$$

where:

$$A = \frac{\sqrt{2}}{2} \text{ LBG}$$

and

$$\left[\frac{S/N}{1+S/N} \right]^{1/2} \approx 1$$

The turn-around ratio for the Block I USBE installed in Spacecraft 011 was 1.16:1. That is, the ratio of the down-link modulation index for the range code to the up-link modulation index for the range code is 1.16:1 when the up-link carrier is modulated by ranging only. Utilizing this parameter and equation 4, A is 1.18 for the D-6 USBE.

Calibration data derived from Motorola module tests for the D-6 USBE indicates that the 3-db IF bandwidth at the input to the limiter was 7.9 MHz. The USBE receiver noise figure of the qualification test unit was 10.9 db. Assuming that the noise bandwidth of the IF bandpass filter is equal to the 3-db bandwidth and that the noise figure of D-6 was equal to the noise figure of the qualification unit, the noise power at the input to the limiter can be calculated as follows:

$$\begin{aligned} N &= -174.0 \text{ dbm/cps} + 10.9 \text{ db} + 10 \log (7.9 \times 10^6) \\ &= -94.1 \text{ dbm} \end{aligned}$$

As previously stated, the measured up-link carrier power at T+340 seconds was -100 dbm. The total received signal power at this time can be determined using equation 7.

$$P_c/P_t = \cos^2 \theta J_0^2 (M_1) J_0^2 (M_2) \quad (7)$$

where:

P_c = received carrier power.

P_t = total received signal power.

θ = range code modulation index.

M_1 = peak deviation of carrier due to the up-voice subcarrier.

M_2 = peak deviation of the carrier due to up-data subcarrier.

At the time of interest, MIL was transmitting up-link mode 1-F and $\theta = 0.3$ radians, $M_1 = 0.61$ radians, and $M_2 = 0.61$ radians.

Therefore:

$$10 \log PC - 10 \log Pt = -2.0 \text{ db}$$

and

$$Pt = -100 \text{ dbm} - (-2.0 \text{ db}) = -98 \text{ dbm}$$

The S/N at the input to the limiter is equal to Pt (dbm) - N (dbm) = 4 db or 0.4. The modulation indices of the turned-around, up-link modulation can now be determined utilizing equations 8, 9, and 10.

$$\alpha = A \left[\frac{S/N}{1+S/N} \right]^{1/2} \sin \theta J_0 (M_1) J_0 (M_2) \quad (8)$$

$$\beta = 2A \left[\frac{S/N}{1+S/N} \right]^{1/2} \cos \theta J_1 (M_1) J_0 (M_2) \quad (9)$$

$$\gamma = 2A \left[\frac{S/N}{1+S/N} \right]^{1/2} \cos \theta J_0 (M_1) J_1 (M_2) \quad (10)$$

For the received up-link signal power of -98 dbm,

$$\left[\frac{S/N}{1+S/N} \right]^{1/2} = \sqrt{0.285} = 0.535.$$

Therefore:

$$\alpha = 0.155 \text{ radians peak}$$

and

$$\beta = \zeta = 0.102 \text{ radians peak.}$$

The down-link carrier suppression due to the down-link modulation, i. e., the turned-around, up-link modulation, the turned-around gaussian noise, and the telemetry and voice subcarriers, can be determined utilizing equation 11.

$$\frac{P_c}{P_t} = \cos^2 J_0^2(M_3) J_0^2(M_4) J_0^2(\gamma) J_0^2(\vartheta) J_0^2(\xi) \quad (11)$$

where:

P_c = carrier power.

P_t = total power.

M_3 = down-link telemetry modulation index = 1.1 radians.

M_4 = down-link voice modulation index = 0.84 radians.

ξ = down-link modulation index of turned around gaussian noise

$$= \frac{\sqrt{2} \text{ LBG}}{2} \left(\frac{1}{1+S/N} \right)^{1/2} \frac{2B_v}{B_{IF}}$$

where:

$$\frac{\sqrt{2} \text{ LBG}}{2} \approx A = 1.18$$

B_v = ranging channel noise bandwidth = 1.2 MHz

For the conditions previously specified, that is, up-link carrier power of -100 dbm and S/N = 0.4,

$$\xi = (1.18) \left(\frac{1}{1+0.4} \right)^{1/2} \frac{(2) (1.2 \times 10^6)}{7.9 \times 10^6}$$

$$= 0.304 \text{ radians.}$$

Thus:

$$\frac{P_c}{P_t} = \cos^2 (0.155) J_0^2 (1.1) J_0^2 (0.84) J_0^2 (0.102) J_0^2 (0.304)$$

$$= -4.86 \text{ db}$$

At T+340 seconds, the received down-link carrier power was -117 dbm; therefore, the total received signal power was -117 dbm - (-4.86 db) = -112.2 dbm.

The relationship between the power in the up-voice subcarrier and the total received signal power at MIL is given by equation 12.

$$\frac{P_{sc1}}{P_t} = 2 \cos^2 J_0^2 (M_3) J_0^2 (M_4) J_0^2 (\gamma) J_1^2 (\beta) J_0^2 (\xi) \quad (12)$$

Evaluating equation 12 using the values previously specified yields

$$\frac{P_{sc1}}{P_t} = -27.81 \text{ db. Therefore, the received power in the up-voice}$$

subcarrier is $-112.2 + (-27.8) = -140.0 \text{ dbm.}$

As will be shown in section 3.2, the up-voice, signal-to-noise ratios were measured at the output of a 30-KHz discriminator. The pre-detection noise bandwidth of the discriminator was 18.3 KHz. Assuming a constant ground system temperature of 240° K, the noise spectral density would be -174.8 dbm/Hz, and the noise power in the above predetection bandwidth would be -132.2 dbm.

Therefore, the calculated predetection signal-to-noise ratio would be $-140 - (-132.2) = -7.8$ db. Since the calculated predetection signal-to-noise ratio is negative, the calculated output signal-to-noise would be very small. However, as shown in figure 3-3, the measured output signal-to-noise ratio was +36 db at T+340 seconds. Thus, the up-link carrier power, down-link carrier power, and up-voice signal-to-noise ratio measured at T+340 seconds are not compatible.

A comparison of the measured and predicted down-link carrier powers (figure 3-1) at T+340 seconds shows that the measured carrier power was approximately 7 db greater than predicted. A similar comparison of the measured and predicted up-link carrier powers (figure 3-2) shows that the measured up-link carrier power was approximately 20 db weaker than predicted. Therefore, it was decided to calculate the up-voice, signal-to-noise ratio based on the predicted up-link and the measured down-link carrier powers.

Utilizing the equations presented above, the calculated up-voice discriminator predetection signal-to-noise ratio, based on an up-link carrier power of -80 dbm, a down-link carrier power of -117 dbm, signal combination 1-F on the up-link, signal combination B-1 on the down-link, and the assumptions presented previously, is 8.1 db.

Assuming that the discriminator is still operating in the linear region, the calculated postdetection signal-to-noise ratio can be determined using equation 13.

$$S/N \text{ out} = S/N \text{ in} + 10 \log \left[\frac{(3) (\Delta f_p)^2 (B_1)}{(2) (B_2)^3} \right] \quad (13)$$

where:

S/N out = postdetection signal-to-noise.

S/N in = predetection signal-to-noise

Δf_p = peak frequency deviation of up-voice subcarrier =
7.5 KHz

B_1 = discriminator predetection noise bandwidth = 18.3 KHz

B_2 = postdetection bandwidth = 1.396 KHz

Thus:

$$S/N \text{ out} = 8.1 + 10 \log \left[\frac{(3) (7.5 \times 10^3)^2 (18.3 \times 10^3)}{2 (1.396 \times 10^3)^3} \right]$$

$S/N \text{ out} = +35.6 \text{ db.}$

This calculated signal-to-noise ratio agrees very favorable with the measured signal-to-noise ratio of +36 db.

Since suppression of the turn-around modulation indices and the turn-around noise do not become factors that must be considered until the up-link carrier power is below -90 dbm, both of the indications presented above point out that the up-link carrier power received during the MIL coverage was probably greater than -90 dbm at T+340 seconds.

The calibration curve utilized in computing the up-link carrier power from the VHF PCM data is shown in figure 3-4. As shown, very small changes in the AGC voltage correspond to large changes in received carrier power as long as the carrier power is greater than -100 dbm. Considering this curve and an overall PCM system accuracy of ± 3 percent, it can be seen that if the received carrier power was -90 dbm, the tolerances on the measurements would be approximately +15 and -10 db. Therefore, it is conceivable that the actual carrier power could be 10 db greater than the PCM data indicates.

3.1.2 BDA

3.1.2.1 Down-Link Carrier Power

The received carrier power observed by BDA and the predicted carrier power based on full-scale antenna patterns, actual spacecraft-to-ground station look angles, and slant ranges are shown

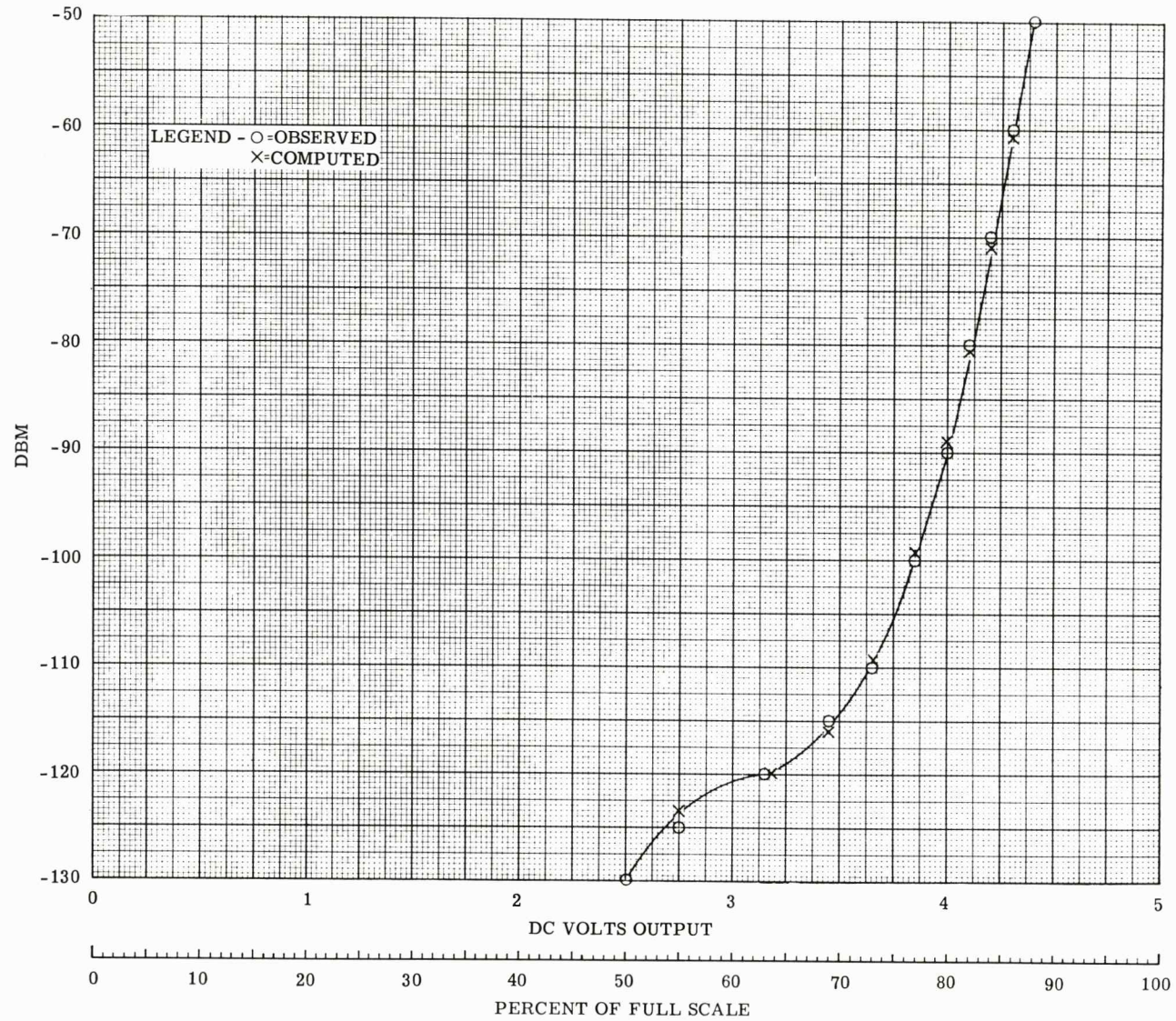


Figure 3-4. USBE Receiver AGC Voltage for SC-11 (Measurement CT0147U)
Calibration Curve

in figure 3-5. As shown, the measured and predicted carrier powers agreed within 8 db from T+300 to T+363 seconds and from T+465 to T+583 seconds.

However, a major discrepancy between predicted and measured carrier powers existed during the time period from T+363 to T+465 seconds. As shown in figure 3-5 the down-link carrier power received at BDA dropped from -110 dbm at T+363 seconds to such a low value that the receivers dropped out of lock at T+405 seconds. Figure 3-5 also shows that this out-of-lock condition was not predicted. Consequently, this discrepancy has not been explained.

BDA reestablished two-way lock at T+460 seconds and maintained this condition until T+590 seconds. At T+590 seconds down-link lock was lost. The decrease in signal level and resulting loss of down-link lock at this time can be attributed to the spacecraft moving out of the antenna beam width while the antenna was being manually moved through the keyhole area.

It should be noted that the event recorder at BDA failed prior to the pass; therefore, data that might have provided an insight into the discrepancy reported above was not available.

3.1.2.2 Up-Link Carrier Power

Plots of the measured up-link carrier power received at the USBE during the pass over BDA and predictions* of the same are shown in figure 3-6. As shown, BDA established two-way lock at T+420 seconds and maintained this lock until loss of signal (LOS) at T+790 seconds.

The average difference between predicted and measured carrier powers from acquisition to T+470 seconds can probably be attributed to the fact that the S-band antenna was slaved to the FPS-16 radar. When autotrack mode was selected at T+470 seconds, the received carrier power immediately increased approximately 7 db, and to within 5 db of the predictions. (See figure 3-6.)

*Due to problems associated with the full-scale antenna pattern tape, these predictions are based on one-third scale patterns.

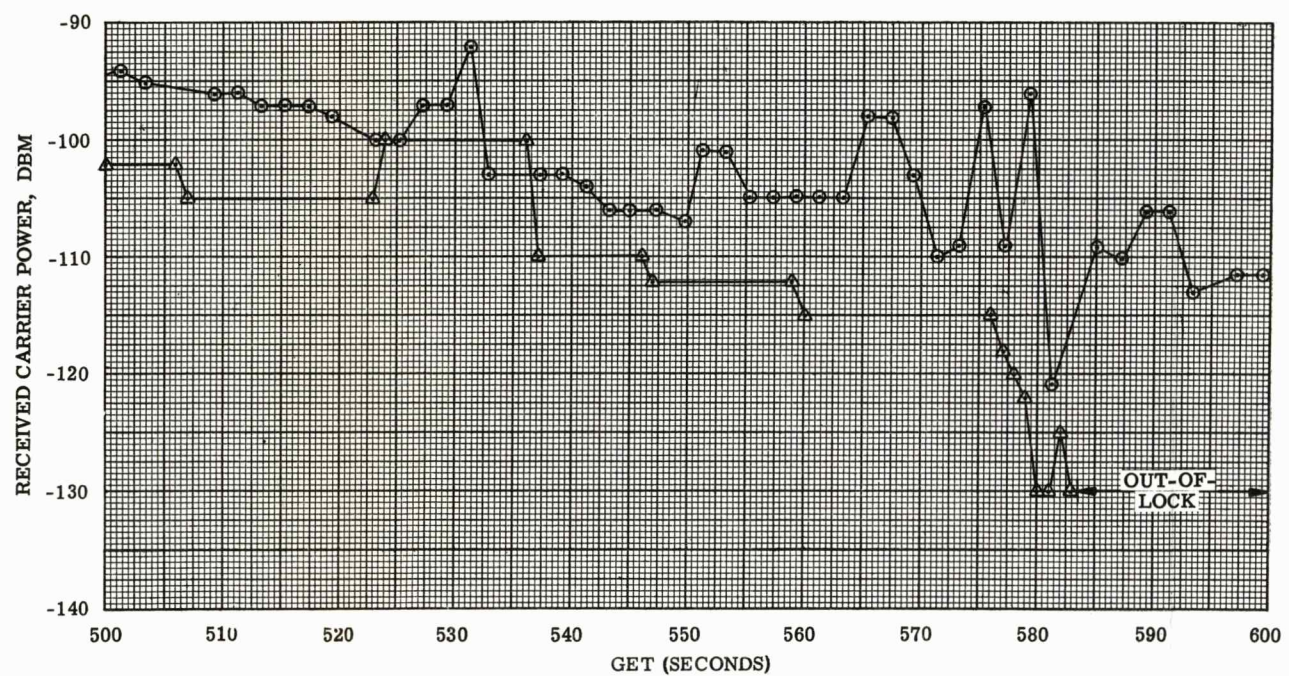
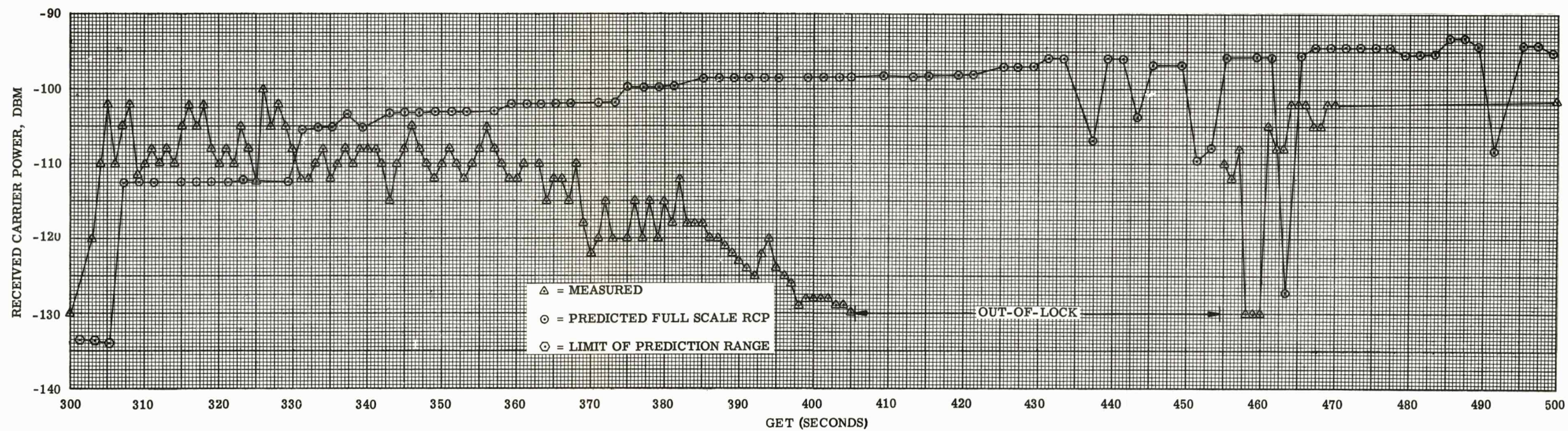


Figure 3-5. Comparison of Measured and Predicted Down-Link Carrier Powers for BDA Coverage of AS-202

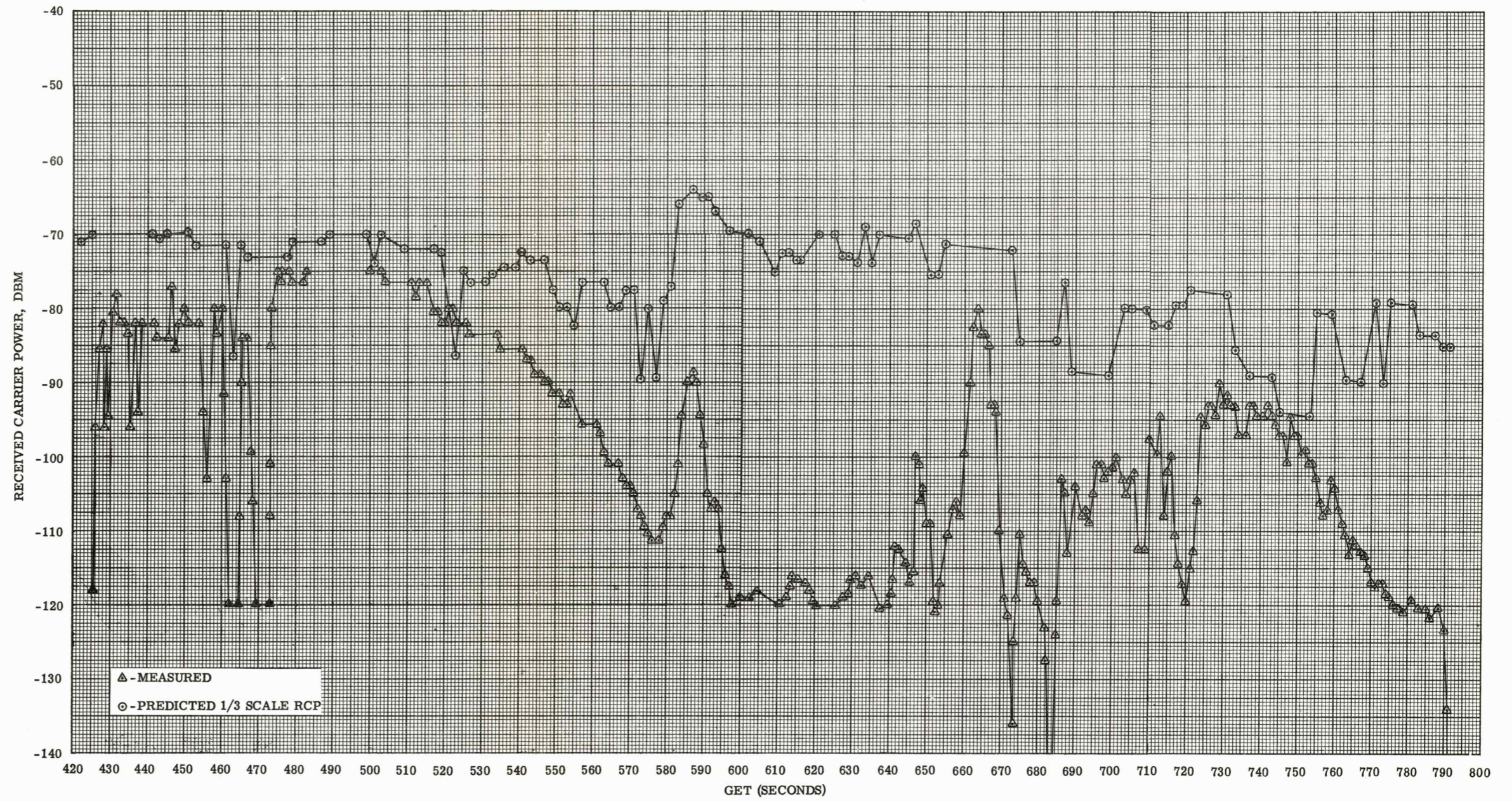


Figure 3-6. Comparison of Measured and Predicted Up-Link Carrier Powers for BDA Coverage of AS-202

At T+515 seconds, the received up-link carrier power began decreasing and continued to decrease until T+575 seconds. This decrease in carrier power was not predicted and has not been explained.

The ground station reached prelimits of keyhole at approximately T+585 seconds and was slaved to the AA NR-3. Even though up-link lock was maintained during this time, the measured carrier power was approximately 50 db lower than predicted. This indicates that the spacecraft was displaced from the antenna boresight.

A valid comparison of the predicted and measured carrier powers could not be accomplished for the remainder of the pass because of switching between autotrack and the slave modes at the ground station antenna.

3.1.3 CRO

3.1.3.1 Down-Link Carrier Power

The postlaunch report explained most of the S-band problems encountered during the pass over CRO. The major problem that was not explained was the sharp dip in received carrier power between T+3770 and T+3840 seconds. (See figure 3-7 of this report and figure 7.16-17 of the postlaunch report.)

In figure 7.16-17 of the postlaunch report, the measured carrier power was compared to predictions based on the one-third-scale antenna patterns and a right circular polarized (RCP) ground station antenna. Since the postlaunch report was published, additional information indicates that although CRO had selected RCP at the switch panel, the main antenna was in a left circular polarized (LCP) configuration.

Thus, new predictions based on one-third-scale spacecraft antenna patterns and a LCP ground antenna were necessary. These predictions are also shown in figure 3-7. The information presented in this figure shows that the previously unexplained dip in received carrier power at CRO is accounted for by the fact that the ground station antenna was in an LCP configuration.

3.1.3.2 Up-Link Carrier Power

As stated in the postlaunch report, good correlation between predicted and measured carrier powers existed when the up-link was in lock. This correlation was not changed when new predictions based on an LCP ground station antenna configuration were generated.

3.2 Up-Voice Channel

The configuration of the spacecraft unified S-band equipment (USBE) is such that the baseband up-link modulation is turned around and remodulated on the down-link when the USBE ranging switch is in the RNG position. Prior to launch of Spacecraft 011, the ranging switch was placed in the above position and remained there throughout the mission. Thus, the up-link voice signals (1-KHz tone) transmitted by each of the participating MSFN sites were recovered from recordings of the received down-link signals. Also, since the voice signals utilized during the subject mission were pure tones, an estimate of the expected voice performance was obtained by measuring the postdetection signal-to-noise ratios of the recovered signals. The following material presents the results of the above measurements.

3.2.1 MIL

The signal-to-noise ratio of the turned around up-voice tone as received by MIL was measured utilizing the test configuration shown in figure 3-8. As shown, the recorded data was reproduced by the CEC VR-3600 recorder in the ESCL. The reproduced waveform was then demodulated utilizing a Block I E-Model 30-KHz discriminator and the detected signal and noise were bandlimited by a Dynatronics low-pass filter. The low-pass filter had a noise bandwidth of 1396 Hz. The composite signal (signal plus noise) out of the low-pass filter was then connected to a wave analyzer and a distortion analyzer. The wave analyzer was utilized as a narrow bandpass filter tuned to the tone frequency (1 KHz), and the output, which represents the signal voltage, was recorded on one channel of a strip chart recorder. The distortion analyzer was utilized as a narrowband notch filter tuned to 1 KHz such that the output represented the noise voltage. The noise voltage was then applied to another channel on the strip chart recorder. Also, as shown in the figure, GMT was recorded. The data recorded on the strip chart recorder was then analyzed and converted to a signal-to-noise ratio as a function of elapsed time.

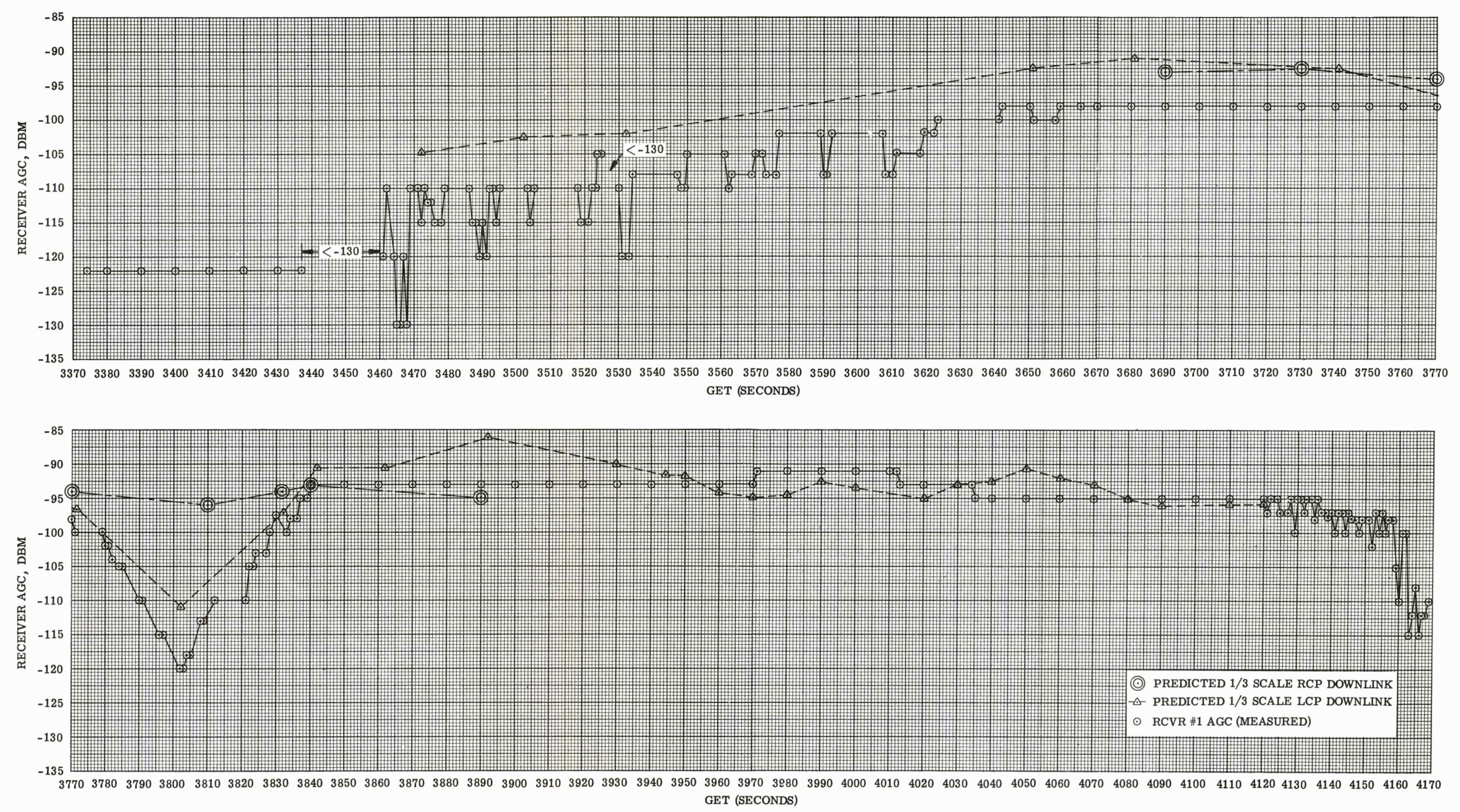


Figure 3-7. Comparison of Measured and Predicted Down-Link Carrier Powers for CRO Coverage of AS-202

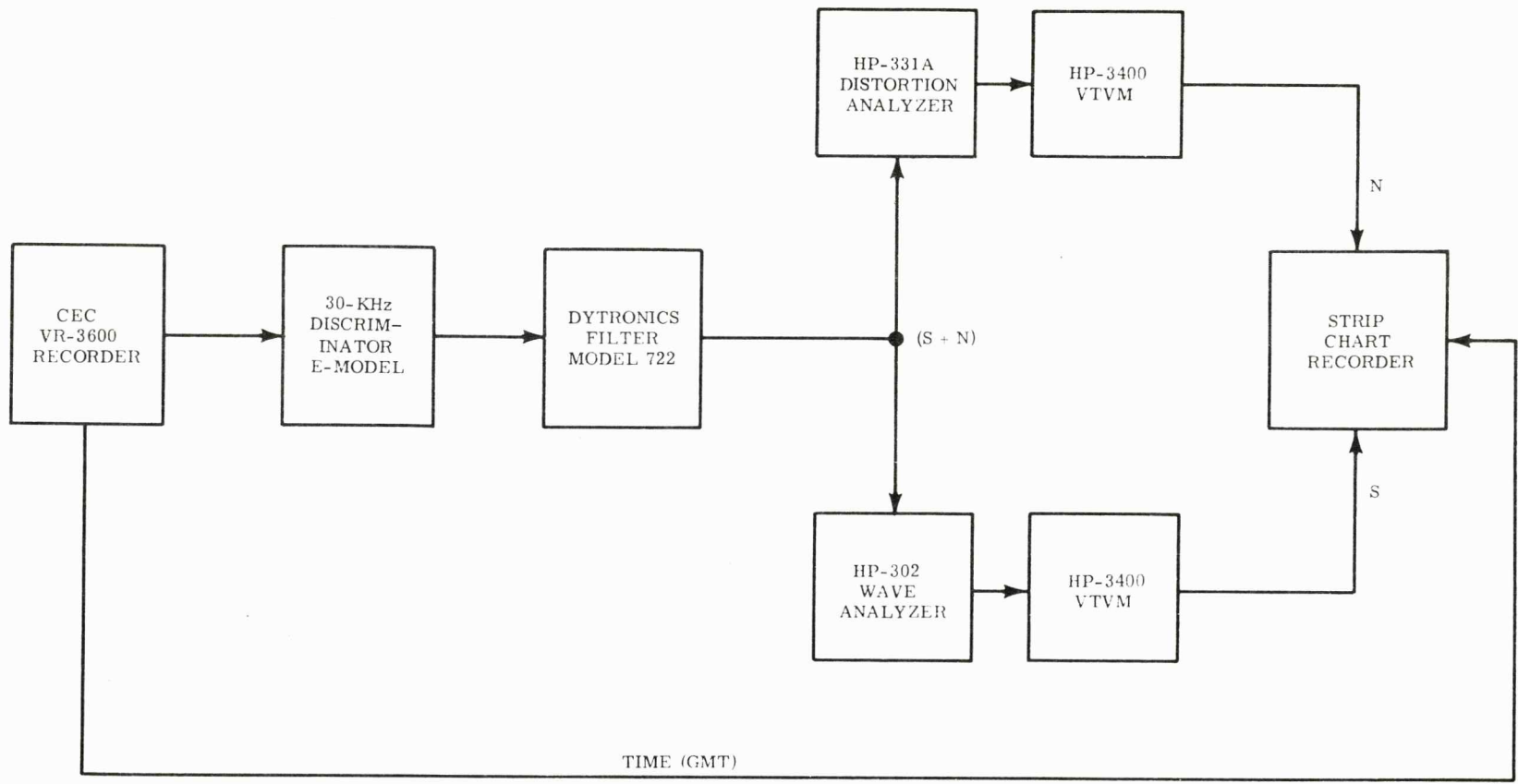


Figure 3-8. Test Configuration for Up-Voice Channel Signal-to-Noise Ratio Measurements

The results of the signal-to-noise measurements performed and the data recorded at MIL are shown in figure 3-3. As shown, the measured signal-to-noise ratio was approximately +35 db for the period from T+135 to T+385 seconds. During the period from T+385 to T+420 seconds, the signal-to-noise ratio decreased from +35 db to +11.5 db.

Audio tests in the ESCL have been performed utilizing signal-to-noise ratios measured in an F1A filter to establish expected word intelligibility. The signal-to-noise ratios measurements derived from the MIL tape can be referred to an F1A bandwidth using the following relationship:

$$\text{SNR (F1A)} = \text{SNR} - 10 \log \frac{(B_2)^3}{(B_1)^3}$$

where:

SNR = signal-to-noise ratios as shown in figure 3-3.

B_1 = noise bandwidth of Dynatronics filter (1396 Hz)

B_2 = noise bandwidth of F1A filter (2,200 Hz)

Thus for a SNR of 35 db, the SNR (F1A) would be 29.1 db. The results of audio tests conducted in the ESCL indicate that the word intelligibility corresponding to a SNR (F1A) of 29.1 db is greater than 80 percent. Since the measured signal-to-noise ratios shown in figure 3-3 represent the signal-to-noise ratio of turned-around, up-voice modulation as received at MIL, it can be stated that the word intelligibility of the turned-around up-link voice signals would have been greater than 80 percent for the time period from T+135 to T+385 seconds. Therefore, it is safe to assume that the word intelligibility in the spacecraft would have been greater than 80 percent over the same time period.

Since the up-link carrier power from launch to T+135 seconds was approximately equal to the carrier power between T+135 and T+385 seconds, it can also be assumed that the word intelligibility from launch to T+135 seconds would also have been greater than 80 percent.

3.2.2 BDA

Attempts to measure the up-voice, signal-to-noise ratios as recorded at BDA using the technique described above were not successful.

Observation of the baseband spectrum reproduced from the BDA wide-band recording revealed that the 30-KHz subcarrier level was extremely low while the down-link subcarrier levels were normal. Although the carrier levels at BDA were lower than predicted, they were not low enough to cause suppression of the up-link subcarriers during a majority of the pass. Thus, it must be assumed that the up-voice modulation indices for the 30-KHz subcarrier were low.

3.2.3 CRO

Attempts to measure the up-voice, signal-to-noise ratios from the CRO recordings were also unsuccessful. Examination of the data reproduced from the recordings showed that the 30-KHz subcarrier was received during the times that it was applied to the up-link. However, a tone could not be detected at the output of the 30-KHz discriminator. Thus, it must be assumed that the 30-KHz subcarrier was not modulated by a 1-KHz tone at CRO.

3.3 Ranging Channel Performance

Investigation of the ranging channel performance was limited to: (1) a comparison of the slant range measured utilizing the S-band system and slant ranges derived from the spacecraft trajectory, and (2) an examination of the reported anomaly, i. e., the invalid ranging data obtained at CRO. Note that the accuracy of the USB ranging system has not been established using AS-202 data.

3.3.1 MIL

Range-code acquisition was performed at MIL prior to lift-off, and continuous S-band ranging information was received until T+303.5 seconds. This ranging information was recorded on a wide-band magnetic tape. The slant range from MIL to the spacecraft was obtained from the magnetic tape, utilizing the facilities offered by the ESCL, and this slant range was compared to the slant range information derived from the C-band radar. The results of this

comparison is shown in figure 3-9. As shown, the difference in the two ranges varied from -0.65 nautical miles at lift-off to +3.7 nautical miles at T+300 seconds.

A graphical analysis utilizing the locations of the launch pad, the C-band radar site, and the S-band site indicated that the differences in slant range at lift-off and at T+165.6 seconds are explained by considering the locations of the two sites. Based on a limited evaluation, it can be stated that the S-band ranging channel performed as expected during the MIL coverage.

3.3.2 BDA

A comparison of the slant ranges derived from the BDA S-band and C-band data is shown in figure 3-10. As shown, the S-band slant range was 0.28 nautical miles less than the C-band range at T+533 seconds and 0.65 nautical miles greater at T+592 seconds. Although this difference in slant range has not been investigated, it is felt that the difference is due to the difference in locations of the C-band and S-band sites.

3.3.3 CRO

CRO established two-way lock at an elapsed time of T+3981 seconds. Range-code modulation was initiated and the ranging receiver locked at an elapsed time of 3982 seconds. At this time the conditions that existed were:

- a. Up-link received carrier level = -56 dbm.
- b. Down-link received carrier level = -91 dbm.
- c. Up-link mode 1-A (ranging only at 0.3 radians).
- d. Synthesizer loop filter switch in OPERATE.
- e. Synthesizer loop out-of-lock.
- f. Integration switch setting of 2^6
- g. Lunar range code.

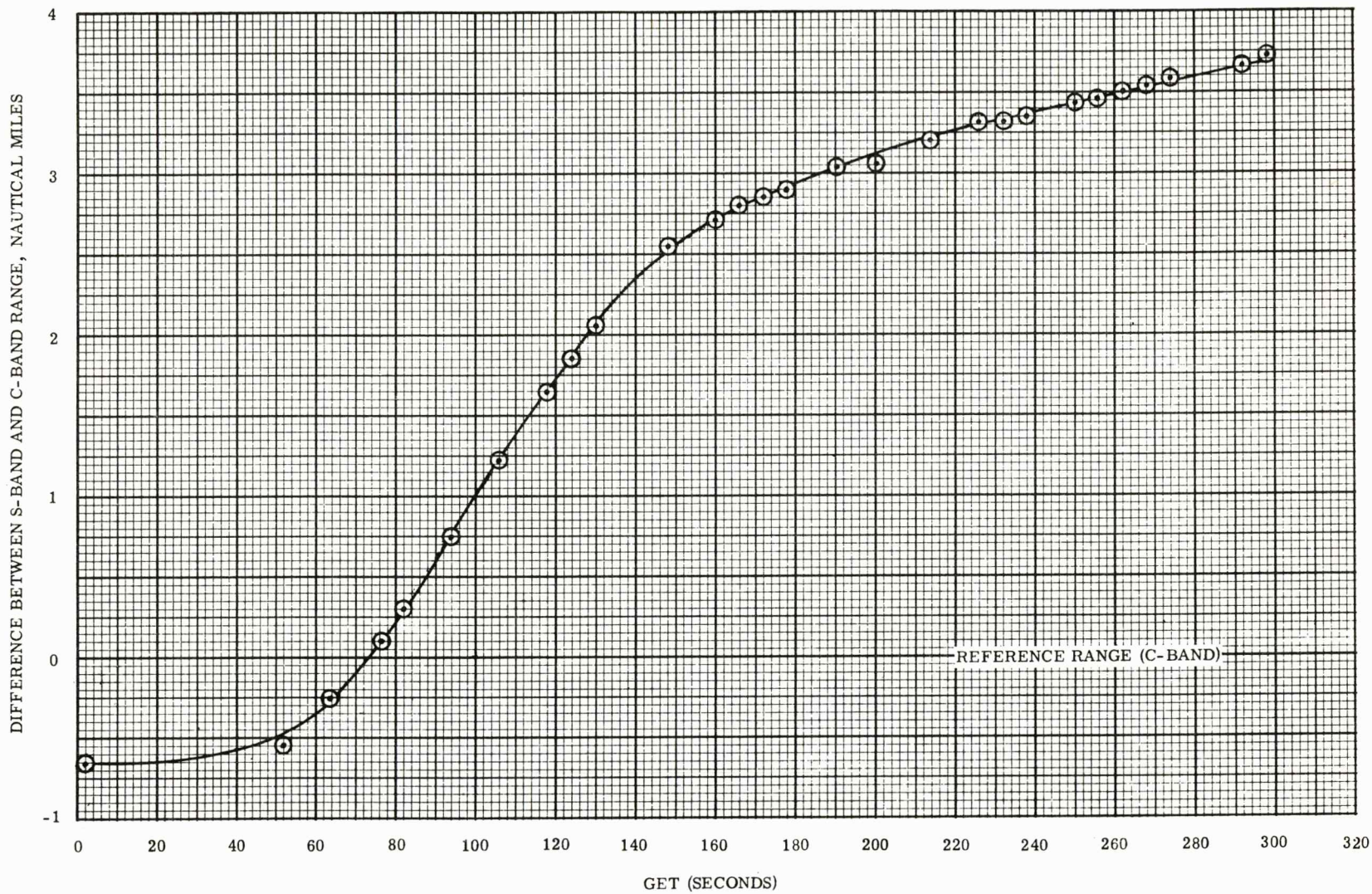


Figure 3-9. Comparison of C-Band and S-Band Slant Ranges for MIL Coverage of AS-202

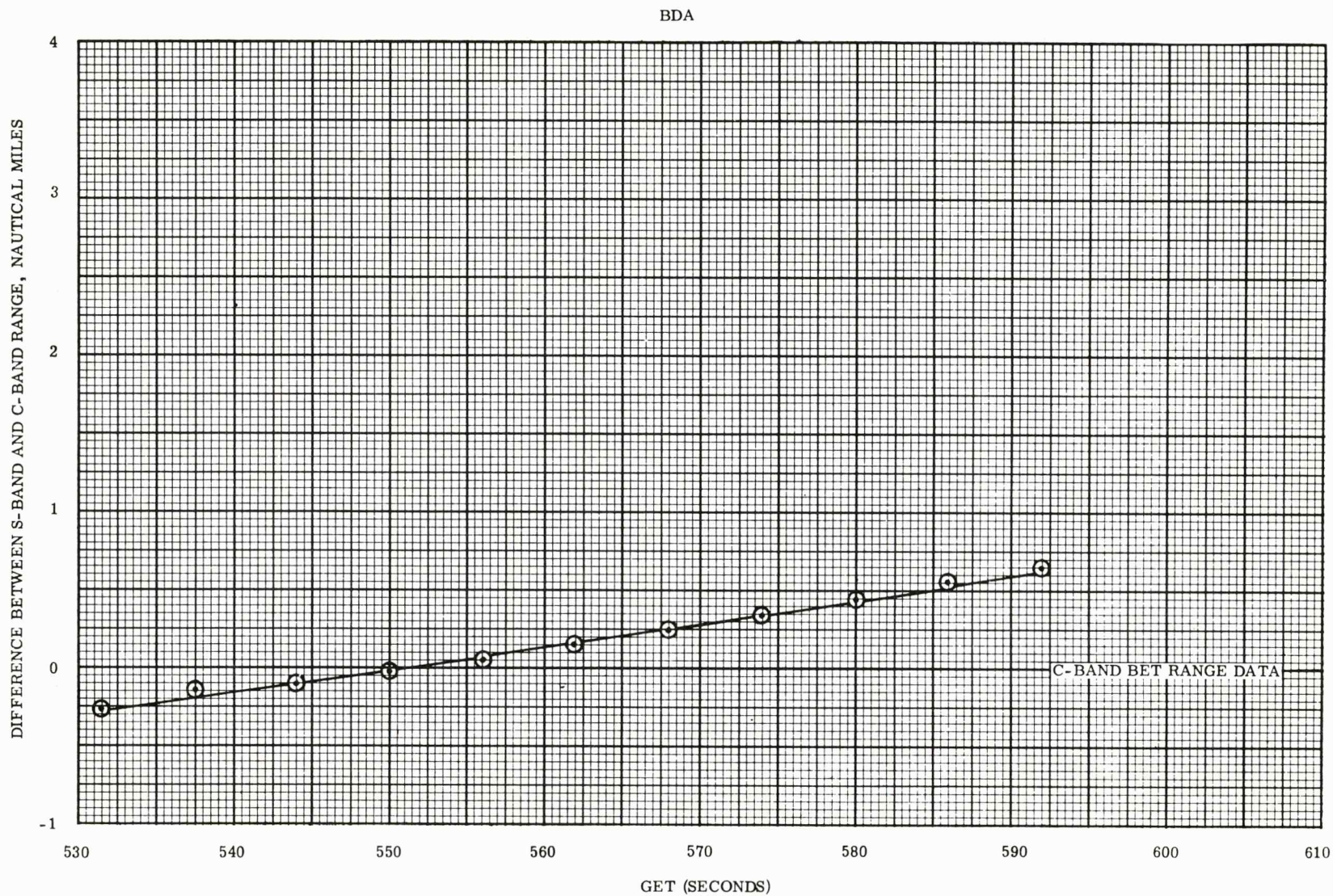


Figure 3-10. Comparison of C-Band and S-Band Slant Ranges for BDA Coverage of AS-202

When the range receiver was locked, the Mark I ranging subsystem was in the reset state. For this state, the nominal correlation voltage is 0.53 volt. However, as shown in figure 3-11, the correlation voltage observed at CRO was actually 0.75 volt.

The ranging system calibrations were performed using the translator, which effectively has a turn-around ratio of 1:1, and the USBE had a measured turn-around ratio of 1.16:1. Also, the ranging calibrations are performed at a received carrier power of -110 dbm, which is considerably weaker than the actual signal carrier power at the above time. Thus, the higher level output from the range receiver coherent amplitude detector can be justified by considering the differences in the actual and calibration configurations.

Code acquisition was initiated at T+3985.5 seconds and normal x - subcode acquisition is evidenced by a 6-db drop in correlation voltage and subsequent return to 0.75 volt. Acquisition of the A, B, and C subcodes can not be verified from the chart recording because the change in correlation voltage levels occurs too fast for the pen to follow. However, if each of these subcodes had been acquired correctly, the correlation voltage would have been 1.39 volts when the acquisition was completed, i. e., when the ranging subsystem entered state P7. As shown in figure 3-11, the correlation voltage for state P7 was 1.0 volt. Therefore, the invalid ranging data at CRO was due to failure to acquire one or more of the above subcodes, i. e., a false acquisition.

It is known that the existing conditions, i. e., synthesizer loop filter switch in the OPERATE position and the loop out-of-lock, can cause significant amounts of frequency modulation on the exciter VCO. Since the range-code clock frequency is derived from the exciter VCO, the range-code clock frequency would also be varying and the false range code acquisition can possibly be attributed to these variations.

Note that attempting range-code acquisition with the synthesizer loop out-of-lock is not a standard operating procedure.

3.4 Spacecraft SPE Variations

During the portion of the CRO coverage from T+3981 to T+4004 seconds, large variations in the telemetered static phase error

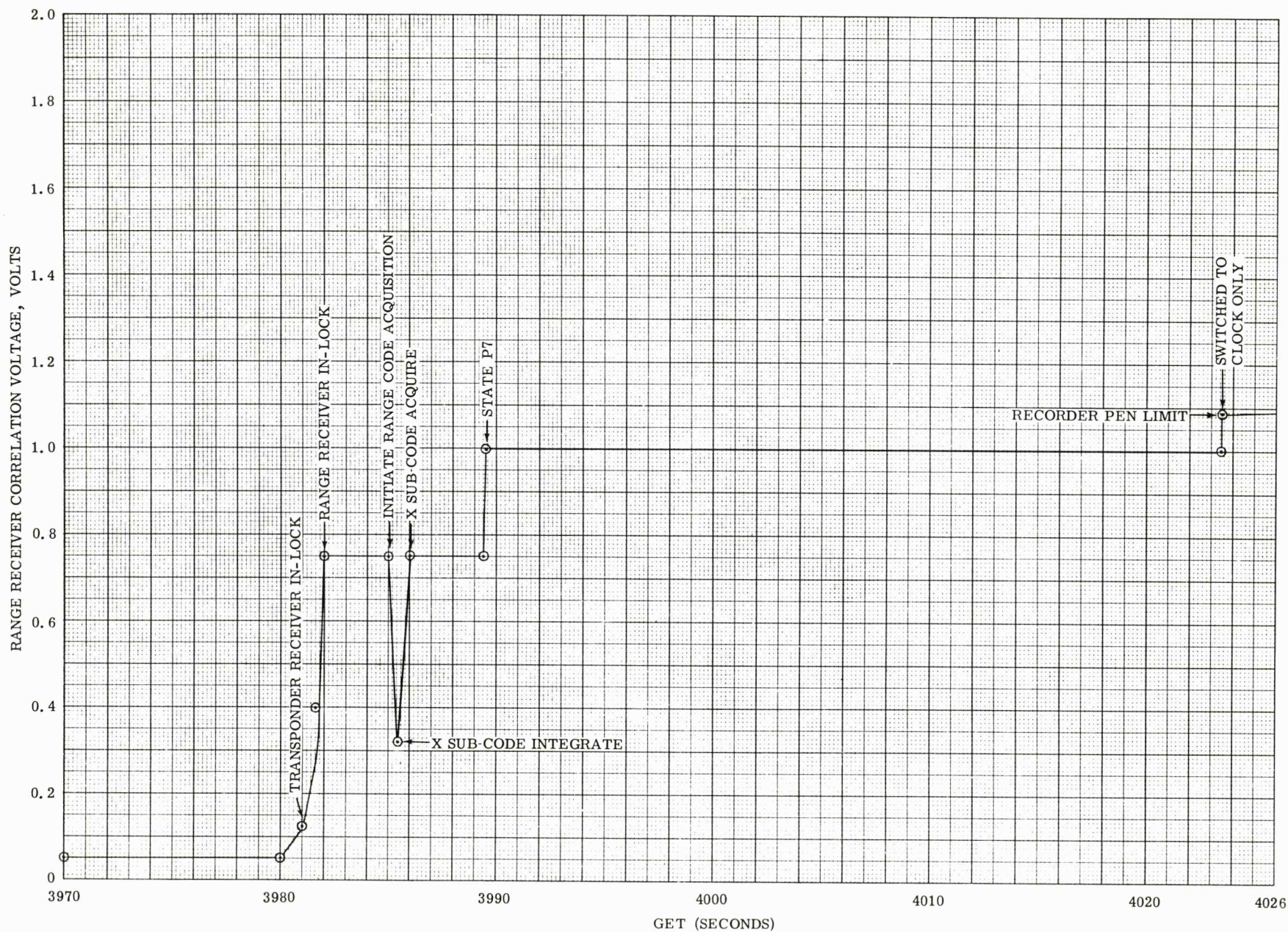


Figure 3-11. Ranging Receiver Correlation Voltage
for CRO Coverage of AS-202

(SPE) were observed. At T+4004 seconds the variations ceased and the measurement settled to the expected value. As indicated in the postlaunch report, the nonstandard conditions, i. e., the synthesizer loop filter switch in the "OPERATE" position and the loop in an unlocked condition, that existed during the above time interval were the suspected cause of these variations. Thus, a series of tests was performed to verify this phenomena.

These tests were performed as follows:

- a. The equipment was configured as shown in figure 3-12.
- b. The exciter VCO frequency was adjusted to 21.941836 MHz, and the synthesizer frequency was set to 21.941732 MHz (nominal CSM up-link frequency).
- c. The peak-to-peak voltage and the frequency of the sine wave appearing at test point 1 was measured.
- d. Step c was repeated as the exciter VCO frequency was varied to 21.942564 MHz in 104-Hz steps.

The results of the above tests indicated:

- a. The described condition produces frequency modulation of the up-link carrier.
- b. The modulation frequency appeared at test point 1.
- c. The variations of the SPE were sinusoidal, and the frequency of the variations was equal to the difference between the VCO and synthesizer frequencies.
- d. The amplitude of the SPE variations was dependent on the difference frequency. As shown in table 3-1, the amplitude increased as the difference frequency decreased.
- e. The static phase error (SPE) variations were not present when the exciter VCO was locked to the synthesizer.

TABLE 3-1. SPE VARIATION TEST RESULTS

Exciter VCO Frequency (MHz)	Synthesizer Frequency (MHz)	Difference Frequency (Hz)	AC Variation (Volts Peak-to-Peak)
21.941836	21.941732	104	1.0
21.941940	21.941732	206	0.9
21.942044	21.941732	310	0.8
21.942148	21.941732	414	0.7
21.942252	21.941732	518	0.55
21.942356	21.941732	622	0.44
21.942460	21.941732	726	0.35
21.942564	21.941732	828	0.3

Thus, it can be concluded that the variations of SPE from T+3981 to T+4004 seconds were due to the up-link carrier frequency variations which resulted from the difference in the VCO and synthesizer frequencies.

3.5 S/C 011 Postrecovery Tests

After recovery, two sets of USB tests were conducted at the contractor facilities. The summary reports resulting from these tests are presented in appendix B.

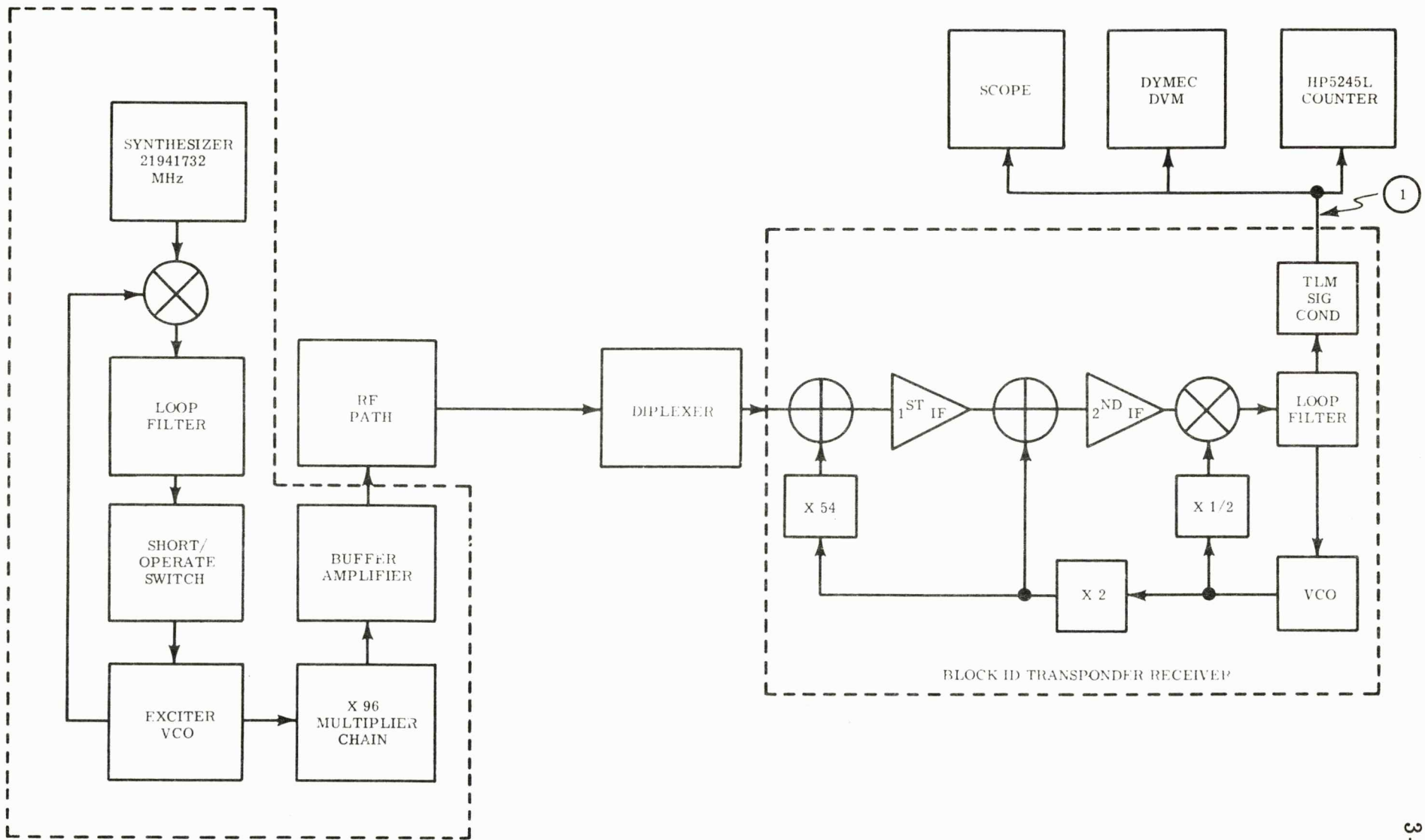


Figure 3-12. Test Configuration for USBE SPE Variation Measurements

4.0 CSQ COMMAND ANOMALY

During the AS-202 mission, the CSQ transmitted the CM/SM separate command eight (8) times and did not receive a validation for any of the transmissions. An investigation of this anomaly was initiated immediately after receipt of the command tapes. The results of the tests conducted at MSC, using the CSQ tape, are:

- a. Playback of the CSQ command recording verified that the bit structure of the transmitted commands was correct.
- b. When data from the CSQ command tape was utilized to modulate a UHF command transmitter, the command was not accepted by the up-data link (UDL) decoder. Tests were performed for signal levels up to -50 dbm.
- c. The frequencies of the PSK signals derived from the tape were low. The sync signal frequency was 962 Hz, and the data signal frequency was approximately 1925 Hz.
- d. A phase delay of approximately 50 microseconds existed between the sync signals and the data signals. The data signal was leading the sync signal.
- e. The amplitude of the data signal appeared to be about 20 percent lower than the sync signal.

After obtaining the above data, the test phase was continued by determining the susceptibility of the UDL equipment to various phase delays and frequency offsets. The results of these tests were:

- a. Phase delay detected on the CSQ tape was not large enough to cause the anomaly.
- b. UDL decoder operation was degraded when the sync-signal and the data-signal frequencies are varied from the nominal 1 and 2 KHz, respectively.
- c. Operation of the model D-4 UDL was negated when the sync and data frequencies were lowered to 995 and 1990 Hz, respectively. The operation was also negated when the frequencies were increased to 1010 and 2020 Hz, respectively.

- d. Operation of the model D-2 UDL was negated when the sync and data frequencies were lowered to 992 and 1984 Hz, respectively, or increased to 1021 and 2042 Hz, respectively.
- e. The rest frequencies of the digital command system (DCS), located in the ESCL and operating in the test mode (internal timing), were 962 and 1923 Hz. Note that these frequencies are approximately equal to the frequencies derived from the CSQ tape.

The test results presented above indicate that the frequency tolerance on the up-data sync signal is approximately 1 KHz $\begin{matrix} +12 \text{ to } 21 \text{ Hz} \\ -5 \text{ to } 8 \text{ Hz} \end{matrix}$. Since the frequency of the sync signal recorded by the CSQ was outside of this tolerance, the CSQ command anomaly was caused by improper PSK signal frequencies. Also, the test results indicate the CSQ DCS was possibly operating in the test mode.

APPENDIX A

REFERENCES

1. Selden, R. L.: Definition and Measurement of the Unified S-Band Transponder Ranging Channel, TM-66-2021-1. Bellcomm, Inc., March 1, 1966.
2. Performance Evaluation of the Unified S-Band Ground System for AS-202. Goddard Space Flight Center, October 14, 1966.
3. Postlaunch Report for Mission AS-202 (Apollo Spacecraft 011). Manned Spacecraft Center, October 12, 1966.

APPENDIX B
ENGINEERING SUMMARY REPORTS

REPORT NO. SID 66-1774
DATE 14 NOV 66

ENGINEERING SUMMARY REPORT

TITLE USBE ANOMOLY TEST, S/C 011 POST RECOVERY

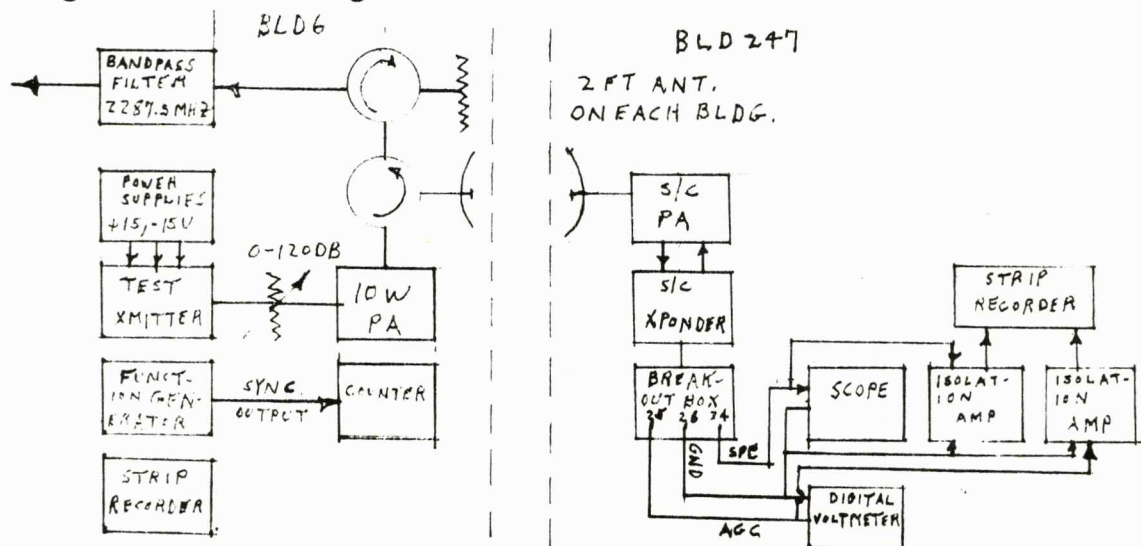
REFERENCES ATR #521086, T.P.S. PRT- S/C 011 037

OBJECTIVES OF INVESTIGATION

The purpose of this test sequence is to obtain the following measurements:
VSWR of the S-Band Scimitar Antenna, AGC vs. R.F. Level at input of the USBE,
Power Levels at the antenna terminals and USBE acquisition rates.

PROCEDURE

The detail test procedure is described in TPS #037. The block diagram below depicts the general test configuration used for these measurements.



SIMPLIFIED TEST CONFIGURATION BLOCK DIAGRAM

DISCUSSION OF RESULTS:

- (A) The S-Band Scimitar Antenna VSWR was grossly measured as 2.4/1 at 2287.5 MC.
- (B) An R.F. level vs. AGC voltage curve was taken. The data compared favorably with the KSC pre-flight data. The worst case point was measured at -120 dbm which showed the post-flight data to be 6 db worse than the pre-flight data. The two sets of data are shown below in Table I.
- (C) R.F. power levels, as measured at the antenna terminals, and corrected for spacecraft system loss was 10.4 watts from the power amplifier, and 400 milliwatts from the transponder.
- (D) Acquisition Rates - Maximum acquisition rate was defined for these tests as the maximum rate at which the transponder would maintain lock during all portions of repeated sweep cycles. The maximum acquisition rate was measured at -60 dbm and -100 dbm signal level input to the transponder. The limit for both signal levels was between 50 kc/sec² and 60 kc/sec². Actual value between these limits will be determined in an ATEE Lab test.

TABLE I		
RF LEVEL	VS	AGC VOLTAGE
RF LEVEL IN DBM	AGC VOLTAGE IN VDC	
	PRE-FLIGHT	POST-FLIGHT
-60	4.3	4.275
-70	4.2	4.180
-80	4.1	4.120
-90	4.0	3.880
-100	3.85	3.625
-110	3.65	3.325
-115	3.45	3.075
-120	3.15	2.75

TENTATIVE CONCLUSIONS:

The data indicates the system performance agrees with pre-flight specifications. The slight difference (6 db) between pre-flight AGC measurements and post-flight measurements were made at 120 dbm, which indicates some system degradation but not enough to mean anything on an orbital mission. The acquisition rate of the USBE indicates that the initial rate of 35 kc/sec² used by Carnarvon was more than adequate to achieve two way lock. The antenna VSWR was grossly measured only because the vehicle was not in a proper environment for the measurement, however, the VSWR as measured seems adequate.

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REPORT NO. SID 66-1773

DATE 14NOV66

ENGINEERING SUMMARY REPORT

TITLE S/C 011 Post Flight USB Reference System Test

REFERENCES USB ICD Blk. I MH01-13013-414, ATR 521070, TPS-PRT-SC/011-015, SID 65-1510

OBJECTIVES OF INVESTIGATION

Verify that system parameters are nominal for various USB coherent modes of operation.

PROCEDURE

The detailed test procedure is described in TPS-015. A simplified block diagram of the test set-up is shown below in Figure I.

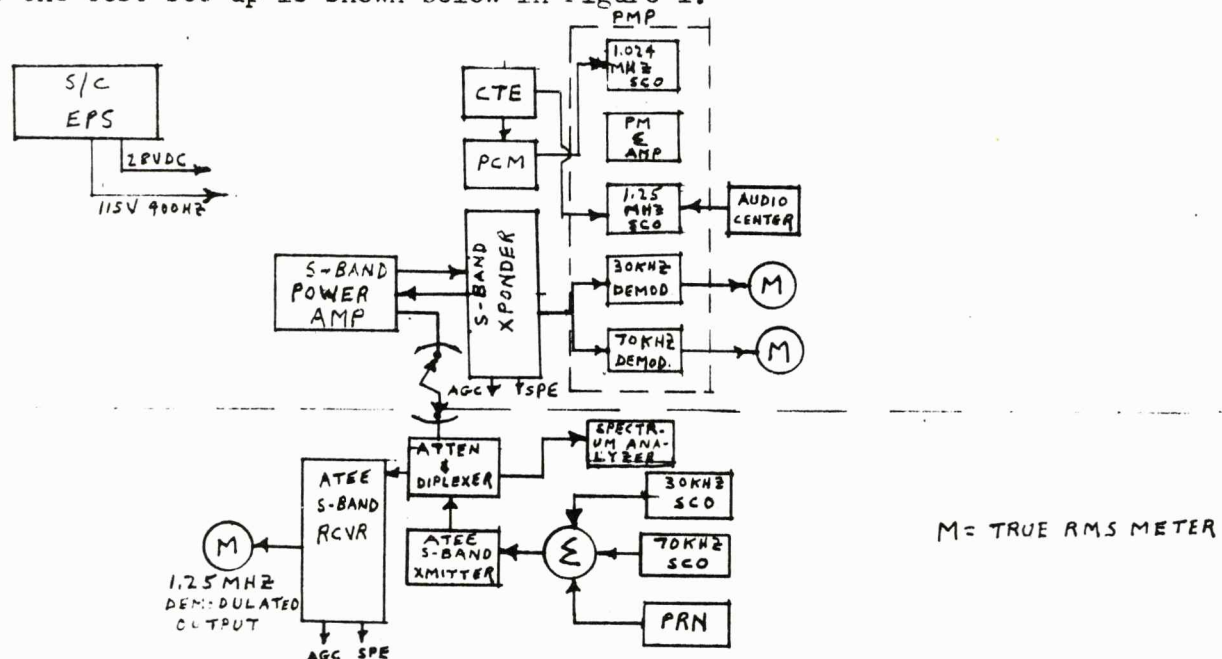


FIG. I

DISCUSSION OF RESULTS:

- A. The R.F. power levels, as measured at the antenna terminals, and corrected for S/C system loss was 10.4 watts in the high power mode and 400 MW in the bypass mode.
- B. The output frequency was 2287.51 MHZ.
- C. The AGC vs. RF level characteristics were grossly obtained and will be accurately calibrated during anomaly tests per ATR 521086.
- D. Static phase error did not exceed 5 degrees peak at the ATEE receiver under all test conditions. The maximum phase error obtained at the transponder was 16 degrees peak.
- E. Worse case S/N ratios measured at the various demodulator outputs were:
- (1) 1.25 MHZ = 6.8 db
 - (2) 30 KHZ = 12.1 db
 - (3) 70 KHZ = 6.2 db

TENTATIVE CONCLUSIONS:

The data indicates that the USB system performance was nominal for all the PM coherent modes when subjected to the test conditions as set forth in TPS-015.

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