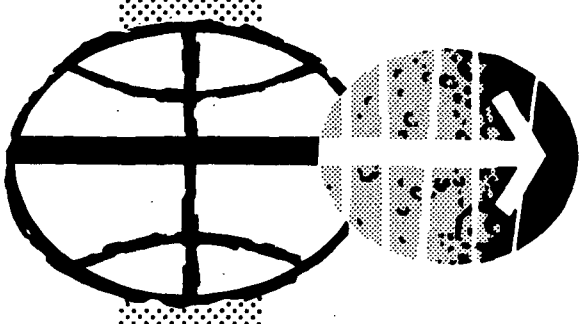
MSC-05161
SUPPLEMENT 6

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 15 MISSION REPORT
SUPPLEMENT 6

POSTFLIGHT ANALYSIS OF THE EVCS-LM COMMUNICATIONS LINK



MANNED SPACECRAFT CENTER
HOUSTON, TEXAS
JANUARY 1972

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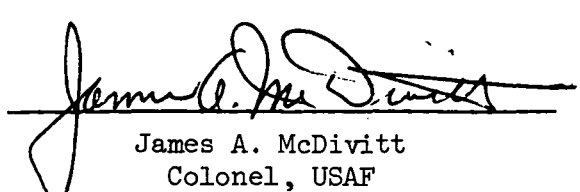
PREPARED BY

Telemetry and Communications System Division

APPROVED BY



James A. McDivitt
Colonel, USAF
Manager, Apollo Spacecraft Program

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
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POSTFLIGHT ANALYSIS OF THE EVCS-LM COMMUNICATIONS LINK FOR THE APOLLO 15 MISSION

TELEMETRY AND COMMUNICATIONS
SYSTEMS DIVISION

PREPARED BY:

C. L. Royston
Communications Systems Engineering
and Test Branch

D. S. Eggers
Electromagnetic Systems Branch

APPROVED FOR DISTRIBUTION

Leonard E. Packham
Assistant Chief, Systems
Development and Applications

Howard C. Kyle
Assistant Chief for Systems
Design and Performance

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PREFACE

This report is in response to the "LM Voice and Data Relay" test objective on page 2-9 of MSC-02575, "Mission Requirements, J-1 Type Mission, Lunar Landing." It concerns itself solely with the EVA-LM-MSFN voice and data link. The MSFN-LM-EVA link was not considered since its characteristics are such that its performance will at least equal the performance of the EVA-LM-MSFN link.

Only the VHF portion of the downlink is considered for this report since the S-band portion (LM-MSFN) has been verified on previous missions and the received S-band downlink signal strength on Apollo 15 was sufficient (-119 dBm) to provide good quality voice and data at the MSFN.

The prime link for recovery of astronaut voice and data on this mission was the EVA-LCRU-MSFN link. The EVA-LM-MSFN (LM relay) link was being tested as a possible backup to the prime mode in case of LCRU failure.

Two independent but related reports were used as the basis of this report. One report, Lockheed Electronics Company report number TCSD 1372, dated September 10, 1971, [8] presents the results of an investigation to determine the quality of the electrocardiogram (EKG) data, portable life support system (PLSS) data, and astronaut voice relayed through the LM during the three Apollo 15 extravehicular activity (EVA) periods. The other report, TRW report number 17618-H213-R0-00, dated September 17, 1971, [9] provides the results of an investigation into VHF radio propagation loss data between the EVCS (extravehicular communication system) and the LM during Apollo 15.

The objectives of this report are to verify the capability of the EVA-LM VHF link as a possible backup to the LCRU and to verify the VHF prediction techniques.

1. INTRODUCTION AND SUMMARY

The Apollo 15 landing site was in the Hadley-Apennine Mountain Area. This mission provided an opportunity to obtain VHF radio propagation loss data between the EVCS and the LM. The data from this mission are used to compare the actual performance of the EVCS to LM communications link with the preflight performance predictions for Apollo 15 [1].

From the Apollo 15 postflight analysis, it was concluded that the techniques currently being used to predict VHF transmission loss and corresponding data losses during the EVA periods provide a good estimate of the actual losses in the lunar environment [2], [3], [10]. Apollo 15 provided propagation loss data out to 5 km and when major terrain obstacles were encountered.

Figure 1-1 shows the three actual traverse routes taken by the astronauts in the Hadley region. The numbered points on the traverse routes indicate where propagation loss data were available. Figure 1-2 shows the LM/EVCS communications configuration utilized.

During the three traverses, EKG data, PLSS status data, and astronaut voice were transmitted on a VHF carrier to the LM. The LM then relayed the information to the Manned Space Flight Network (MSFN) through its S-band communication system.

It is concluded from the analysis in this report that the radio transmission loss data shows good correlation with predictions during periods when the radio line of sight was obscured. The technique of predicting shadow losses due to obstacles in the radio line-of-sight provides a good estimate of the actual shadowing loss. When the transmitter was on an upslope such as the Apennine Front, the radio transmission loss approached the free space loss values as the line-of-sight to the LM was regained.

It is also concluded that (a) the VHF receiver squelch sensitivity was set to approximately -105 dBm; (b) good quality voice and data were relayed by the LM for all VHF signal levels greater than -105 dBm; and (c) additional coverage of the EVA periods could have been obtained if the squelch sensitivity had been set lower.

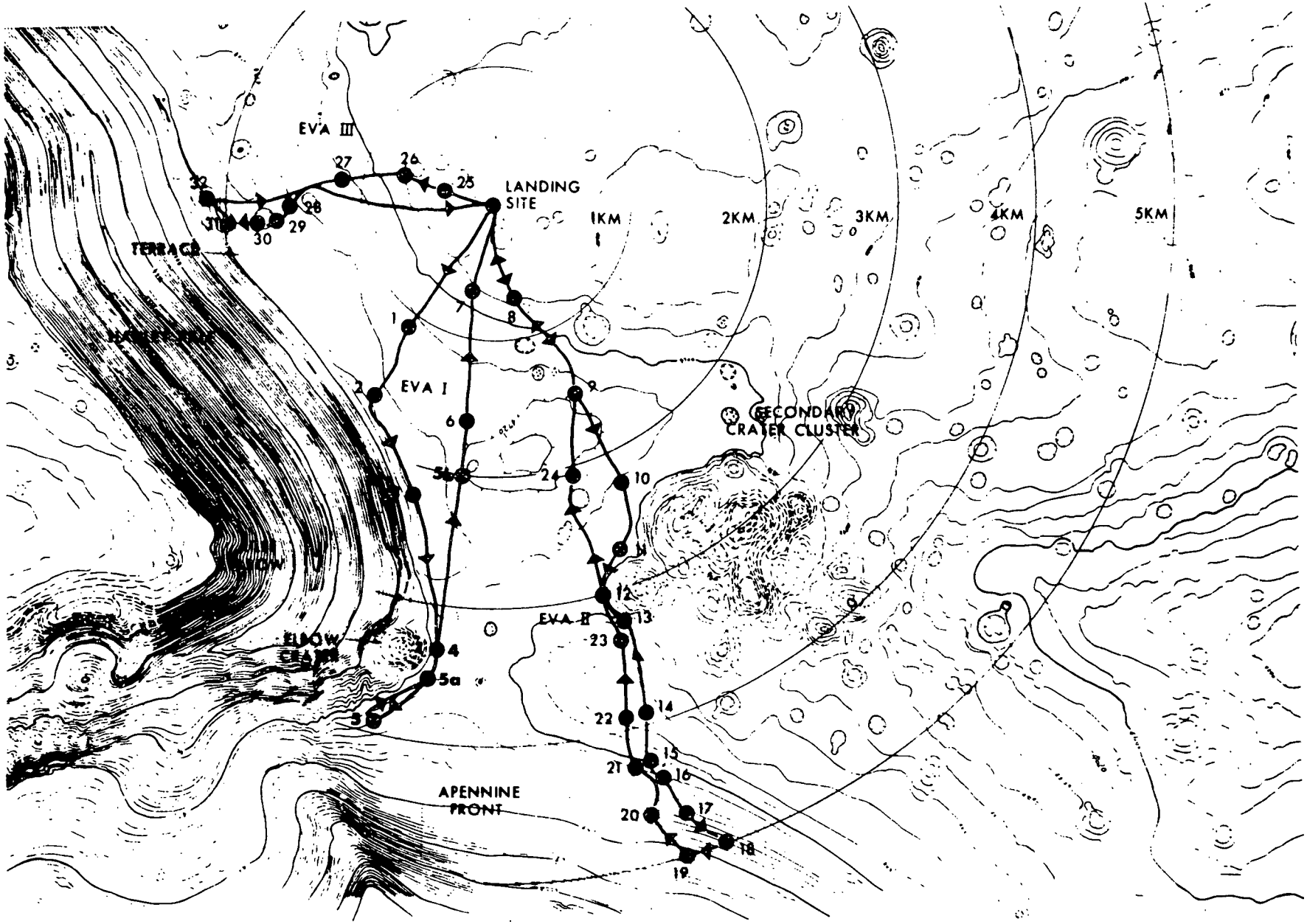

FIGURE 1-1 ACTUAL EVA TRAVERSE ROUTES FOR APOLLO 15 ON A TEN METER CONTOUR INTERVAL MAP

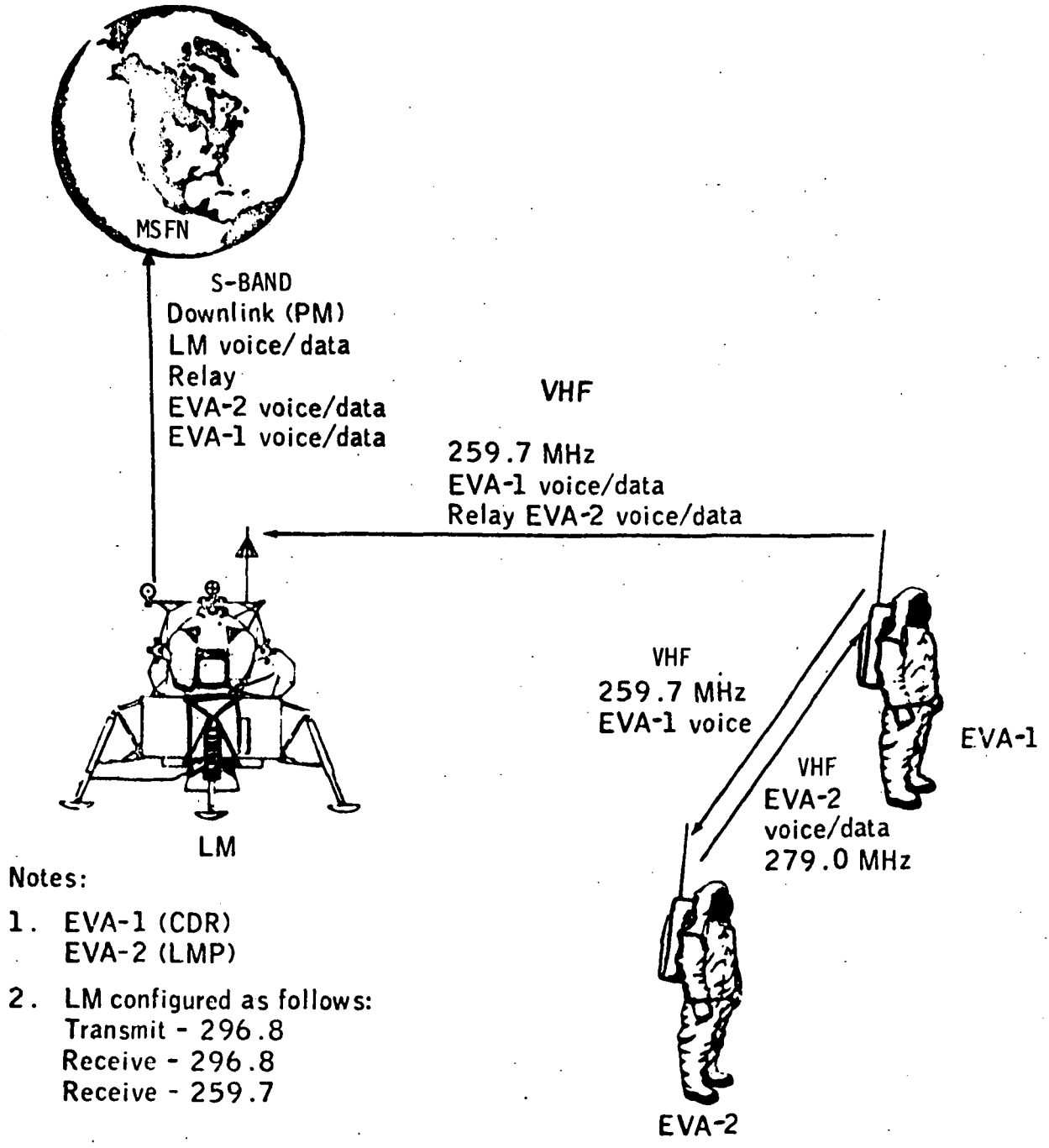

FIGURE 1-2 EVA/LM/MSFN COMMUNICATION LINK

2. LUNAR SURFACE TEST RESULTS

2.1 GENERAL

On Apollo 15 the primary mode of operation for EVA communications was for the EVCS signals to be relayed through LCRU (Lunar Communications Relay Unit) on the LRV (Lunar Rover Vehicle). The secondary mode of operation was for the EVCS signals to be relayed through the LM. During the EVA traverse periods both modes of operation were activated. This report uses the data obtained from the secondary mode of operation to verify its capability as a backup and to verify the lunar surface VHF prediction techniques.

2.1.1 Data Sources

The Apollo 15 data, [4], used in this report were obtained from the Instrumentation Integration Branch in the Test Division of NASA/MSC. The data were in the form of strip chart recordings of the LM VHF receiver B automatic gain control (AGC) voltage as a function of mission time. Extensive use of astronaut voice logs were used to establish the approximate locations of the astronauts as a function of mission times. Also, the LRV navigational system information voiced back to earth and the astronauts descriptions of the local terrain during their traverses were very valuable in determining their locations and tasks at each work station.

Computer tabulations of the LM 259.7 MHz VHF receiver AGC were used to further refine the values obtained from the strip chart recordings. Also, partial panoramic photographs of the surrounding terrain at each work station were available to determine the surface features that may have affected the radio propagation loss.

The maps of the Hadley Rille region used in this report were obtained from the Geodesy and Photometry Branch in the Mapping Sciences Laboratory of NASA/MSC.

2.1.2 Assumptions

The analysis presented in this report is based on the following assumptions:

1. The terrain profiles for the Hadley-Apennine landing site are constructed from the 1:15,840 scale contour map shown in figure 1-1. This map is used for simulator models and has 20 meter basic contour lines (form lines), with ten meter line interpolation. This map is the highest resolution data available in the form of a contour map for the Hadley Apennine

landing site. The limitations of this map are as follows: horizontal distance errors on the map between control points are generally less than 7%. However, errors can be as great at 15% between other points. Due to the limitations of the Lunar Orbiter V medium resolution photography used in the compilation of the 1:15,840 scale contour map, a 20 meter undulation over a 200 meter distance is not even detectable, unless light angles are just right [5].

2. The approximate EVA traverse routes are derived from the LRV navigational system range and bearing readouts recorded on the astronaut logs.

3. The LM EVA antenna is 8.24 meters (27 feet) above the ground and the EVCS antenna is 1.83 meters (6 feet) above the ground.

4. The analysis described in this report is based on an empirical technique that utilizes measured VHF data over irregular terrain. This technique has been described in a previous report [3]; it will not be repeated here.

2.2 Received Power at LM Receiver

The LM VHF receiver AGC voltage levels are converted into received signal power by using calibration data obtained during VHF receiver checkout. Tables 2-1 through 2-3 are summaries of the data excerpted from the telemetry data during EVA's I, II, and III, respectively. These tables list the distance from the LM, the received signal power, and transmission loss over the lunar surface for each location on the traverse routes. In addition, the tables give the approximate mission elapsed time for the location on the traverse route. This mission time is in Apollo Elapsed Time (AET) and is defined as elapsed time from range zero, where range zero is defined as the integral second prior to liftoff.

2.3 VHF Performance Evaluation

2.3.1 General

This section examines the results of an investigation to determine the quality of EKG data, PLSS data, and astronaut voice relayed through the LM to the MSFN during the three EVA periods. The voice and data quality are compared to expected performance based on laboratory test results [11], and premission predictions relating expected voice and data quality to received VHF signal level.

The performance of the VHF link was investigated throughout each EVA period, with special attention given to three specific time intervals within each period. An attempt was made to include as many variations (lunar terrain, proximity to the LM, and LRV motion) as possible.

TABLE 2-1 RECEIVED POWER AND TRANSMISSION LOSS DURING EVA I

Point Along Traverse	Mission Elapsed Time (AET)		Distance From LM (km)	Received Power at LM Receiver (dBm)			Transmission Loss Over Lunar Surface (dB)		
	From	To		High	Low	Quiescent	High	Low	Quiescent
1	121:52:36	121:53:00	1.1	-75.0	-80.9	-77.0	-96.8	-102.7	-98.8
2	121:57:00	121:57:24	1.7	-82.1	-86.5	-85.0	-103.9	-108.3	-106.8
3	122:03:48	122:04:00	2.3	-104.2	L	L	-126.0	L	L
4	122:10:36	122:11:00	3.2	-94.3	-101.0	-96.0	-116.1	-122.8	-117.8
5	122:43:24	122:46:00	3.9	-86.2	-105.9	-95.0	-108.0	-127.7	-116.8
4	123:33:00	123:33:24	3.3	-98.5	-103.3	-102.0	-120.3	-125.1	-123.8
6	123:49:12	123:49:48	1.6	-96.4	-104.2	-97.0	-118.2	-126.0	-118.8
7	123:55:00	123:55:20	0.7	-85.6	-91.8	-87.0	-107.4	-113.6	-108.8

L - Denotes the cases when the AGC data is off scale low; lowest value of received power that can be recorded is -106.0 dBm, which corresponds to -127.8 dB transmission loss.

TABLE 2-2 RECEIVED POWER AND TRANSMISSION LOSS DURING EVA II

Point Along Traverse	Mission Elapsed Time (AET)		Distance From LM (km)	Received Power at LM Receiver (dBm)			Transmission Loss Over Lunar Surface (dB)		
	From	To		High	Low	Quiescent	High	Low	Quiescent
10	143:28:12	143:28:36	2.2	-87.7	-92.0	-90.0	-109.5	-113.8	-111.8
11	143:31:40	143:32:00	2.7	-94.8	-103.0	-97.0	-116.6	-124.8	-118.8
12	143:35:12	143:35:36	3.0	-94.0	-99.8	-96.0	-115.8	-121.6	-117.8
13	143:37:12	143:37:48	3.3	-95.6	-103.5	-99.0	-117.4	-125.3	-120.8
14	143:42:48	143:43:12	3.9	-102.4	L	L	-124.2	L	L
14	143:43:36	143:44:00	4.0	-98.4	-103.5	-100.0	-120.2	-125.3	-121.8
15	143:45:36	143:46:00	4.3	-86.5	-90.5	-88.0	-108.3	-112.3	-109.8
16	143:47:30	143:47:50	4.4	-81.3	-86.2	-84.0	-103.1	-108.0	-105.8
17	143:49:30	143:50:00	4.7	-77.0	-78.8	-77.0	-98.8	-100.6	-98.8
18	143:52:30	143:54:00	5.0	-72.5	-80.1	-77.0	-94.3	-101.9	-98.8
19	145:00:48	145:01:15	5.0	-73.0	-78.4	-75.0	-94.8	-100.2	-96.8
20	145:26:30	145:27:00	4.7	-78.4	-80.1	-79.9	-100.2	-101.9	-101.7

TABLE 2-2 RECEIVED POWER AND TRANSMISSION LOSS DURING EVA II (CONTINUED)

Point Along Traverse	Mission Elapsed Time (AET)		Distance From LM (km)	Received Power at LM Receiver (dBm)			Transmission Loss Over Lunar Surface (dB)		
	From	To		High	Low	Quiescent	High	Low	Quiescent
21	146:20:12	146:20:48	4.3	-88.2	-92.0	-90.2	-110.0	-113.8	-112.0
22	146:23:48	146:24:12	3.9	-104.6	L	L	-126.4	L	L
23	146:28:36	146:29:10	3.4	-90.0	-101.2	-93.0	-111.8	-123.0	-114.8
24	146:55:48	146:56:05	2.0	-91.6	-96.1	-92.0	-113.4	-117.9	-113.8
9	146:59:00	146:59:30	1.5	-89.5	-94.1	-92.0	-111.3	-115.9	-113.8
8	147:04:12	147:04:30	0.7	-74.0	-78.0	-76.0	-95.8	-99.8	-97.8

L - Denotes the cases when the AGC data is off scale low; lowest value of received power that can be recorded is -106.0 dBm, which corresponds to -127.8 dB transmission loss.

TABLE 2-3 RECEIVED POWER AND TRANSMISSION LOSS DURING EVA III

Point Along Traverse	Mission Elapsed Time (AET)		Distance From LM (km)	Received Power at LM Receiver (dBm)			Transmission Loss Over Lunar Surface (dB)		
	From	To		High	Low	Quiescent	High	Low	Quiescent
25	164:49:00	164:50:00	0.38	-50.8	-60.4	-55.8	-69.6	-79.2	-74.6
26	164:52:20	164:53:00	0.77	-74.6	-82.5	-78.0	-93.4	-101.3	-96.8
27	164:56:00	164:57:00	1.3	-85.6	-94.8	-90.0	-104.4	-113.6	-108.8
28	164:59:00	164:59:30	1.6	-83.6	-90.2	-85.7	-102.4	-109.0	-104.5
29	164:59:50	165:00:10	1.7	-96.0	-100.5	-97.5	-114.8	-119.3	-116.3
30	165:00:20	165:01:20	1.8	-88.2	-92.2	-89.2	-107.0	-111.0	-108.0
31	165:21:00	165:23:00	2.0	-104.8	L	L	-123.6	L	L
32	166:16:00	166:17:00	2.2	-102.6	L	L	-121.4	L	L

L - Denotes the cases when the AGC data is off scale low; lowest value of received power that can be recorded is -106.0 dBm, which corresponds to -127.8 dB transmission loss.

Tables 2-4, 2-5, and 2-6 pinpoint the location of the LRV during the time intervals selected for investigation and also summarize the results. During each of these intervals, the voice quality, PLSS status percent data loss, and VHF received signal level at the LM were determined. A subjective voice quality analysis was performed and the PLSS 1 (commander) and PLSS 2 percent data losses were determined. Abrupt losses of PLSS data occurred at -105 dBm received VHF signal level; therefore, the data indicates the VHF receiver squelch sensitivity had been set to -105 dBm during pre-EVA preparation. Since no data was lost at signal levels above -105 dBm, the relationship between percent data loss and VHF signal level was not determined. The percent data loss results shown in tables 2-4, 2-5, and 2-6 are not truly indicative of low signal level performance, but only in-lock/out-of-lock conditions as determined by the squelch circuit.

TABLE 2-4

VHF COVERAGE DURING EVA-1

INTERVAL	LRV POINT LOCATION ON FIGURE 2-1	TIME PERIOD (AET)	ELAPSED TIME (SECONDS)	TOTAL TIME THAT VHF <-105 dBm (SECONDS)	VHF SIGNAL STRENGTH RANGE	PERCENT OF TIME VHF <-105 dBm	PERCENT DATA LOSS		PLSS 2 DECOM OUT OF LOCK (SECONDS)	VOICE QUALITY	REMARKS
							PLSS 1	PLSS 2			
EVA 1 (total)	N/A	119:39:17 to 126:11:59	23,562	846	<-106 dBm to >-14 dBm	3.6	N/A	N/A	N/A	N/A	
LRV TRAVERSE DURING EVA 1	N/A	121:44:00 to 124:02:00	8,280	846	<-106 dBm to >-14 dBm	10.2	N/A	N/A	N/A	N/A	
1 (a)	4	122:13:00 to 122:18:00	300	16	< -106 dBm to -91 dBm	5.3	1.6	1.6	N/A	Excellent	LRV stationary 3.2 km from LM
1 (b)	5	122:50:00 to 123:00:00	600	19	<-106 dBm to -83 dBm	3.2	2.4	2.9	20	Excellent	LRV stationary 3.9 km from LM
1 (c)	5a to 5b	123:29:00 to 123:39:00	600	300	<-106 dBm to -98 dBm	50	52.3	54.9	336	Unusable to excellent	LRV in motion 2.0 to 3.6 km from LM
1 (d)	Landing Site	124:00:00 to 124:10:00	600	0	<-34 dBm	0	0	0	0	Excellent	LM vicinity

TABLE 2-5

VHF COVERAGE DURING EVA II

INTERVAL	LRV POINT LOCATION ON FIGURE 2-1	TIME PERIOD (AET)	ELAPSED TIME (SECONDS)	TOTAL TIME THAT VHF -105 dBm (SECONDS)	VHF SIGNAL STRENGTH RANGE	PERCENT OF TIME VHF <-105 dBm	PERCENT DATA LOSS		PLSS 2 DECOM OUT OF LOCK (SECONDS)	VOICE QUALITY	REMARKS
							PLSS 1	PLSS 2			
EVA II (total)	N/A	142:14:48 to 149:27:02	25,200	277	<-106 dBm to >-14 dBm	1.1	N/A	N/A	N/A	N/A	--
LRV TRAVERSE DURING EVA II	N/A	143:10:00 to 147:10:00	14,400	277	<-106 dBm to >14 dBm	1.9	N/A	N/A	N/A	N/A	--
II (a)	18	144:00:00 to 144:10:00	600	0	<-87 dBm to >-70 dBm	0	0	0	0	Excellent	LRV stationary 5.0 km from LM
II (b)	20	145:50:00 to 146:00:00	600	0	<-92 dBm to >-73 dBm	0	0	0	0	Excellent	LRV stationary 4.7 km from LM
II (c)	9 to Landing Site	147:00:00 to 147:10:00	600	0	-96 dBm to >-14 dBm	0	0	0	0	Excellent	LRV in motion from 0 to 1.5 km from LM

TABLE 2-6

VHF COVERAGE DURING EVA III

INTERVAL	LRV POINT LOCATION ON FIG. 2-1	TIME PERIOD (AEC)	ELAPSED TIME (SECONDS)	TOTAL TIME THAT VHF <-105 dBm (SECONDS)	VHF SIGNAL STRENGTH RANGE	PERCENT OF TIME VHF <-105 dBm	PERCENT DATA LOSS		PLSS 2 DECOM OUT OF LOCK (SECONDS)	VOICE QUALITY	REMARKS
							PLSS 1	PLSS 2			
EVA III (total)	N/A	163:18:14 to 168:08:04	17,390	4,260	<-106 dBm to >-14 dBm	24.5	N/A	N/A	N/A	N/A	--
LRV Traverse During EVA III	N/A	164:00:00 to 166:45:00	10,500	4,260	<-106 dBm to >-14 dBm	40.6	N/A	N/A	N/A	N/A	--
III (a)	Landing Site	164:20:00 to 164:30:00	600	0	-44 dBm to -34 dBm	0	0	0	0	Excellent	LRV stationary at ALSEP site (100 meters from LM).
III (b)	31	165:50:00 to 166:00:00	600	600	<-106 dBm	100	100	100	600	Unusable	LRV stationary 2.0 km from LM (Receiver squelched during total interval.)
III (c)	32	166:18:00 to 166:26:00	480	475	<-106 dBm to >-103 dBm	99	100	100	480	Unusable	LM Stationary 2.2 km from LM (Receiver squelched during total interval.)

Laboratory test data [11] and premission predictions [10] showed that excellent voice and good quality data would be relayed from VHF signal levels greater than -105 dBm. Therefore, the performance during the mission was consistent with laboratory test results and predictions. The laboratory test data and predictions also showed that the communications coverage afforded by the EVCS-LM VHF link could have been increased with a more sensitive squelch setting. The possible increase in coverage cannot be determined because the lowest value of received power which can be determined is limited to -106 dBm by the range of the telemetry measurement.

2.3.2 EVA I

Table 2-4 shows a summary of the EVA I evaluation results.

During interval I(a), the PLSS 1 and PLSS 2 data losses averaged 1.6% (for each). The VHF signal level was -105 dBm or less approximately 5.3% of the time. The periods of low VHF signal level were generally of short duration (less than 8 seconds). The voice quality was excellent when the received signal level was greater than -105 dBm. The LRV was stopped at location 4 on figure 1-1 approximately 3.2 km from the LM.

During interval I(b), the PLSS 1 and PLSS 2 data losses averaged 2.4% and 2.9%, respectively. The VHF signal level was -105 dBm or less approximately 3.2% of the time with the longest period being 7 seconds. Voice quality was excellent when the received signal level was greater than -105 dBm. The LRV was stopped at location 5 on figure 1-1 approximately 3.9 km from the LM.

During interval I(c), the PLSS 1 and PLSS 2 data losses averaged 52.3% and 54.9%, respectively. The VHF signal level was -105 dBm or less approximately 50% of the time with low VHF signal level experienced during several periods of more than 10 seconds and one period of 50 seconds. The voice quality was excellent during periods of signal level greater than -105 dBm, but voice was not relayed by the LM during the remainder of the interval. The LRV was in motion between points 5a and 5b on figure 1-1, and its distance from the LM ranged from approximately 2.0 to 3.6 km.

An additional time interval, I(d), was evaluated with the LRV in the vicinity of the LM. During this interval, there were no data losses for either PLSS 1 or PLSS 2 and the VHF signal level was not less than -34 dBm. The voice quality was excellent throughout.

During the entire EVA I period, the VHF signal level was at or below -105 dBm approximately 3.6% of the time. The longest continuous period of low VHF signal level was 73 seconds.

2.3.3 EVA II

Table 2-5 shows a summary of the EVA II evaluation results.

During intervals II(a), II(b), and II(c) there was no data loss for either PLSS 1 or PLSS 2. The VHF signal level did not drop below -96 dBm and the voice quality was excellent throughout. During II(a) the LRV was stopped at location 18 on figure 1-1 about 5.0 km from the LM. During interval II(b) the LRV was stopped at location 20 about 4.7 km from the LM. During interval II(c), the LRV was in motion ranging from LM vicinity to about 1.5 km away (location 9).

2.3.4 EVA III

Table 2-6 shows a summary of the EVA III evaluation results.

During interval III(a) there was no data loss for either PLSS 1 or PLSS 2. The VHF signal level varied between -44 and -34 dBm and the voice quality was excellent throughout. The LRV was stopped at the ALSEP site approximately 100 meters from the LM.

During interval III(b) the PLSS 1 and PLSS 2 data losses were both 100%. The VHF signal level was below -105 dBm the entire time and no voice was relayed by the LM. The LRV was stopped at location 31 on figure 1-1 approximately 2.0 km from the LM.

During interval III(c) the PLSS 1 and PLSS 2 data losses were both 100%. The VHF signal level was -105 dBm or less approximately 99% of the time and the voice was not relayed by the LM. The LRV was stopped at location 32 on figure 1-1 approximately 2.2 km from the LM.

During the entire EVA III time period, the VHF signal level was at or below -105 dBm approximately 24.5% of the time. Throughout the time period from 165:19:00 to 166:29:00 AET, the VHF signal level was generally below -105 dBm. This accounts for a major portion of the 24.5%.

2.4 Radio Transmission Loss Over the Lunar Surface

The receiver signal power is measured at the input to the diplexer of the LM VHF receiver. Table 2-7 is a list of parameters for the EVCS used in this report. The EVCS transmitter power and cable loss parameters are those measured during equipment checkout tests. The antenna gains are taken from references 6 and 7 for the LM EVA antenna and EVCS backpack antenna, respectively. The EVCS backpack antenna gain is taken from pattern data and corresponds to average gain for the standing position.

TABLE 2-7

EVCS PARAMETERS

1.	EVCS-1 transmitter power at input terminal of antenna	+25.7 dBm
2.	EVCS-1 antenna gain	-2.0 dB
3.	LM EVA antenna gain	
	EVA I and II traverses	0.0 dB
	EVA III traverse	-3.0 dB
4.	Cable loss between LM EVA antenna and diplexer	-1.9 dB

The radio transmission loss can be calculated by the following formula:

$$P_r = L_c + G_r - L_t + G_t + P_t \qquad (1)$$

where

P_r = received signal power at LM diplexer in dBm

L_c = cable loss between LM diplexer and EVA antenna in dB

G_r = LM EVA antenna gain

L_t = radio transmission loss over the lunar surface in dB

G_t = EVCS backpack antenna gain in dB

P_t = EVCS transmitter power at the antenna input terminal in dBm

Substituting the values in table 2-7, the transmission loss, L_t, for EVA's I and II is equal to

$$L_t = 21.8 - P_r \qquad (2)$$

The transmission loss values in the last three columns of tables 2-1 and 2-2 are computed with Equation 2 for EVA's I and II.

Substituting the values in table 2-7, the transmission loss, L_t, for EVA III is equal to

$$L_t = 18.8 - P_r \qquad (3)$$

The transmission loss values in the last three columns of table 2-3 are computed with equation 3 for EVA III.

2.5 Comparison of Predicted and Actual Radio Transmission Loss

The contour map shown in figure 2-1 shows the actual traverse routes taken by the Apollo 15 astronauts. The EVA I traverse is covered by three radials, EVA II by four radials, and EVA III by four radials.

The comparisons of the predicted and actual radio transmission losses over the lunar surface for EVA's I, II, and III are shown in figures 2-2 through 2-12. These figures in general show a good correlation between the predicted and actual transmission loss values. The actual transmission loss fluctuations are shown by a bar indicating the high, low, and quiescent transmission loss values. The predicted transmission loss is shown as a range (shaded area) between the loss that would be expected in free space and the loss that would be expected over flat terrain. The actual transmission loss would be expected to fall somewhere between the two lines except in areas of antenna shadowing due to lunar terrain obstructions and/or LRV equipment. Bounds on the shadow losses due to lunar terrain obstructions are also presented.

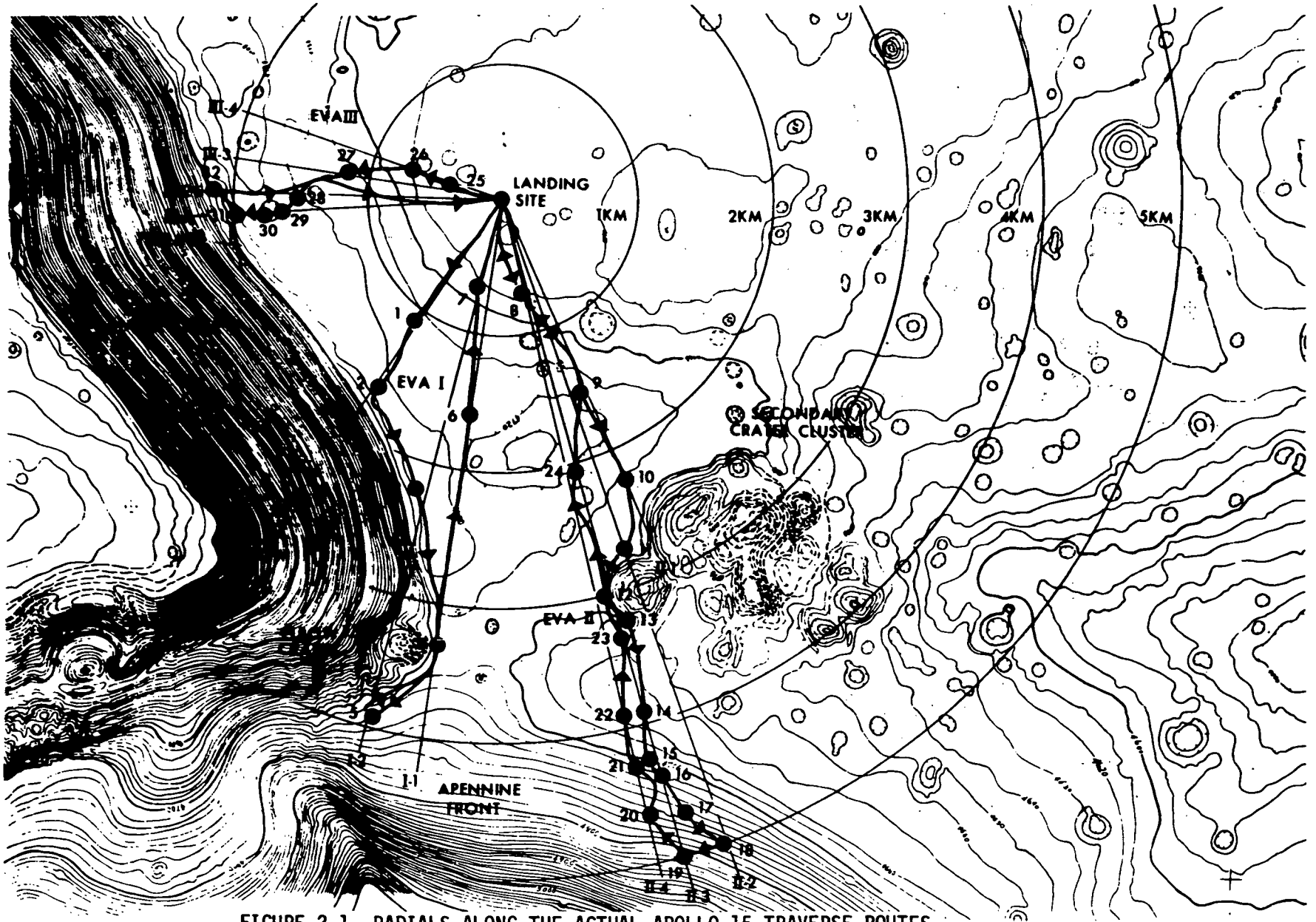

FIGURE 2-1 RADIALS ALONG THE ACTUAL APOLLO 15 TRAVERSE ROUTES

2.5.1 EVA I Traverse Analysis

The predicted and actual radio transmission loss values are compared in figures 2-2 through 2-4 for EVA I. Radials I-1 through I-3 pass through seven areas where telemetry data can be correlated with the positions on the traverse route (see figure 2-1).

Data points for areas 1, 2, 4, and 5 all fall within the expected areas of loss fluctuations. However, data points for areas 3, 6, and 7 fall below the areas of predicted loss fluctuations. The additional transmission losses for area 3 are most likely due to the differences between the contour map and the actual lunar terrain in the Hadley Rille lip area. The data points for areas 6 and 7 were recorded on the return leg of the traverse. The additional transmission losses for areas 6 and 7 are probably due to the blockage and shadowing caused by the LCRU equipment attached to the front of the LRV. No pattern data were available on the EVCS backpack antenna with the astronauts riding on the LRV. The gain value used for the EVCS backpack antenna gain factor corresponds to the average gain in the standing position.

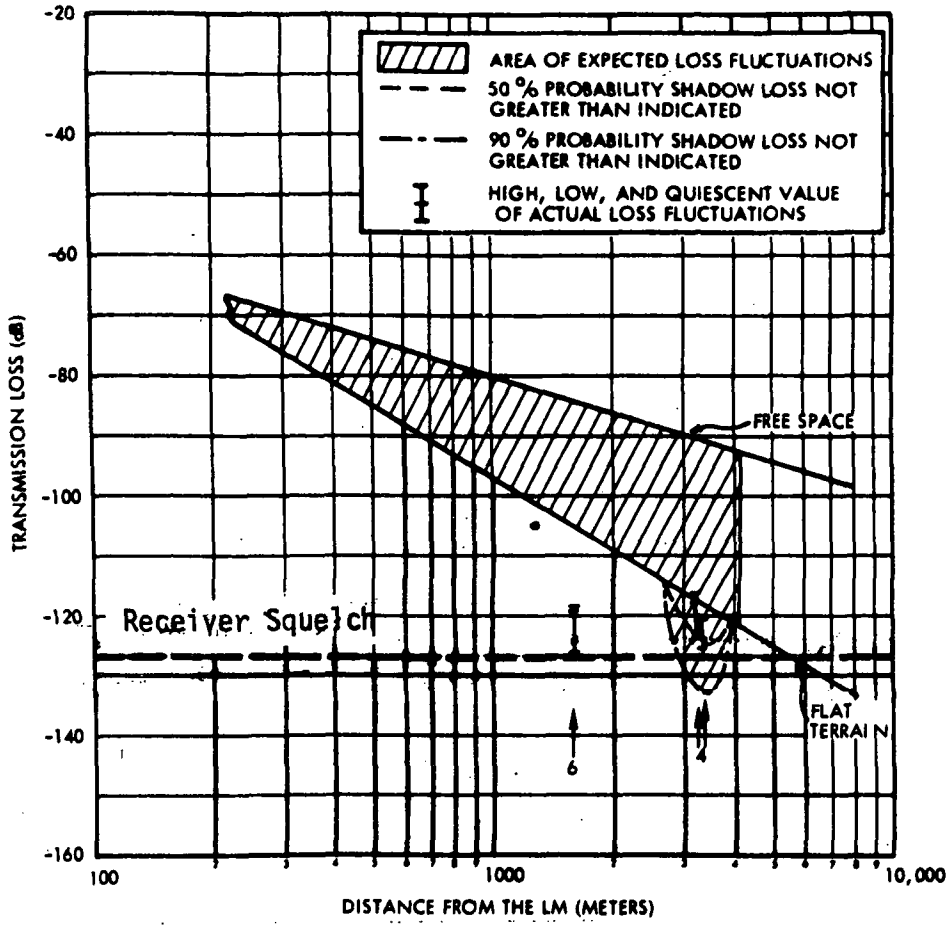

FIGURE 2-2A TRANSMISSION LOSS ON RADIAL I-1 AT 259.7 MHz

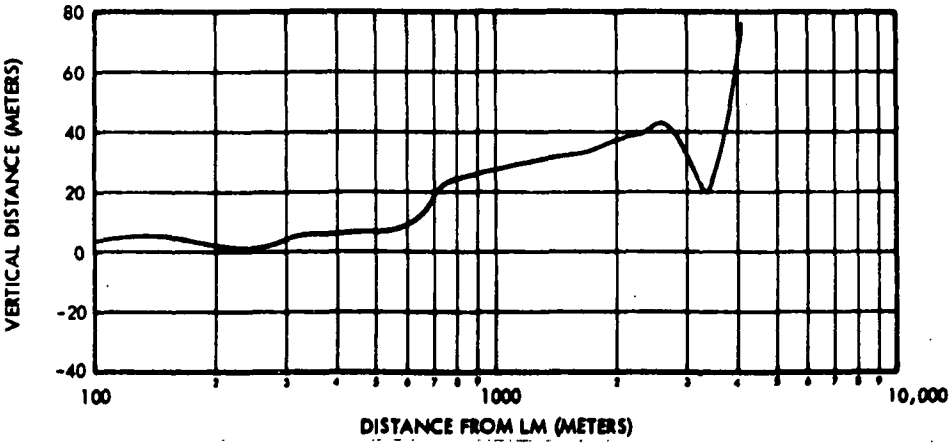

FIGURE 2-2B RADIAL I-1 LUNAR PROFILE, HADLEY-APENNINE SITE

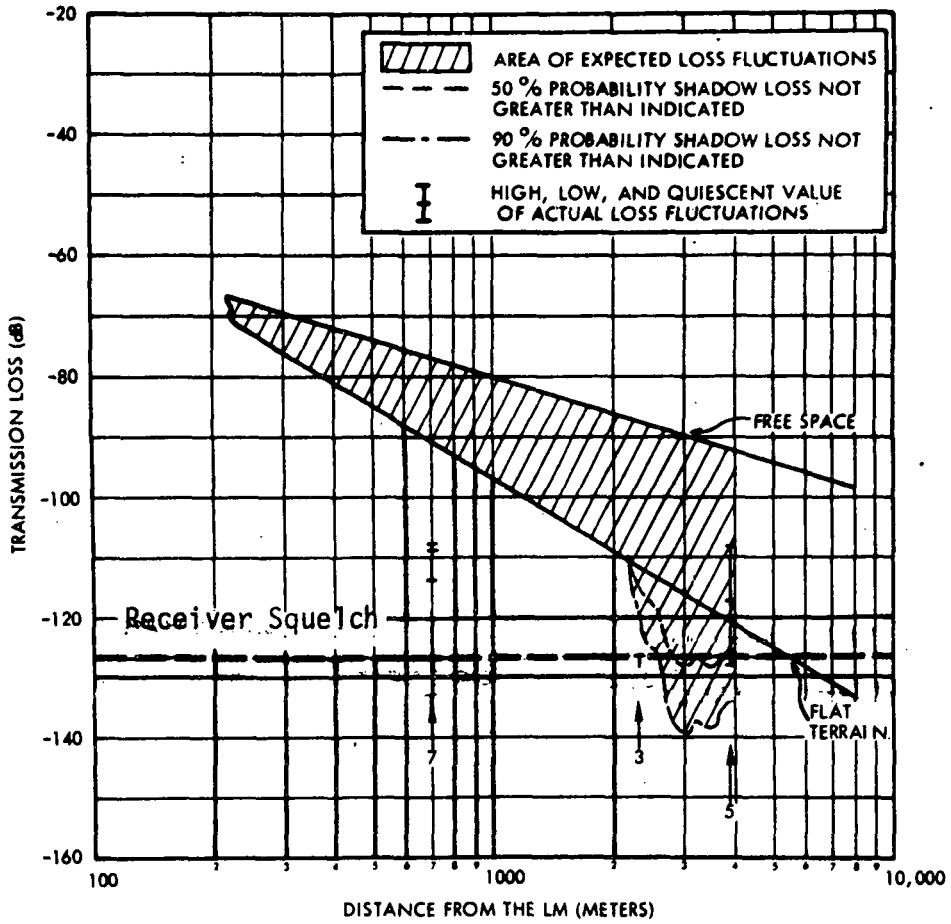

FIGURE 2-3A TRANSMISSION LOSS ON RADIAL I-2 AT 259.7 MHz

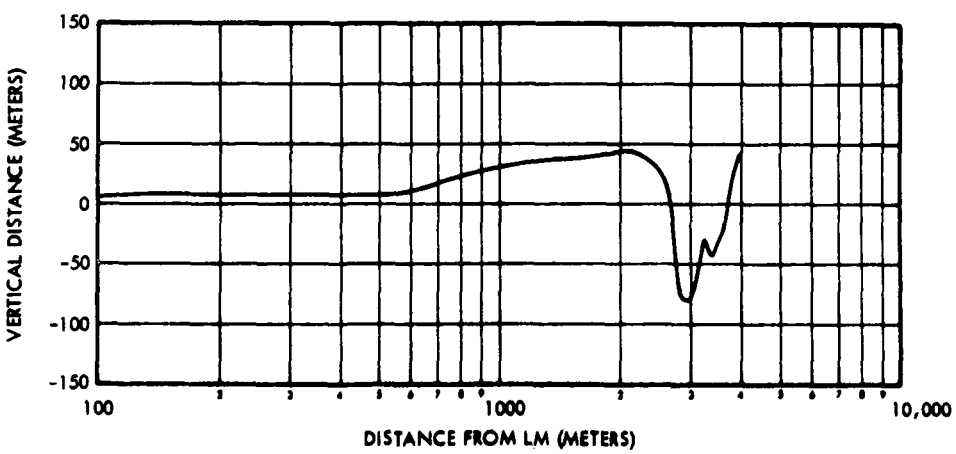

FIGURE 2-3B RADIAL I-2 LUNAR PROFILE, HADLEY-APENNINE SITE

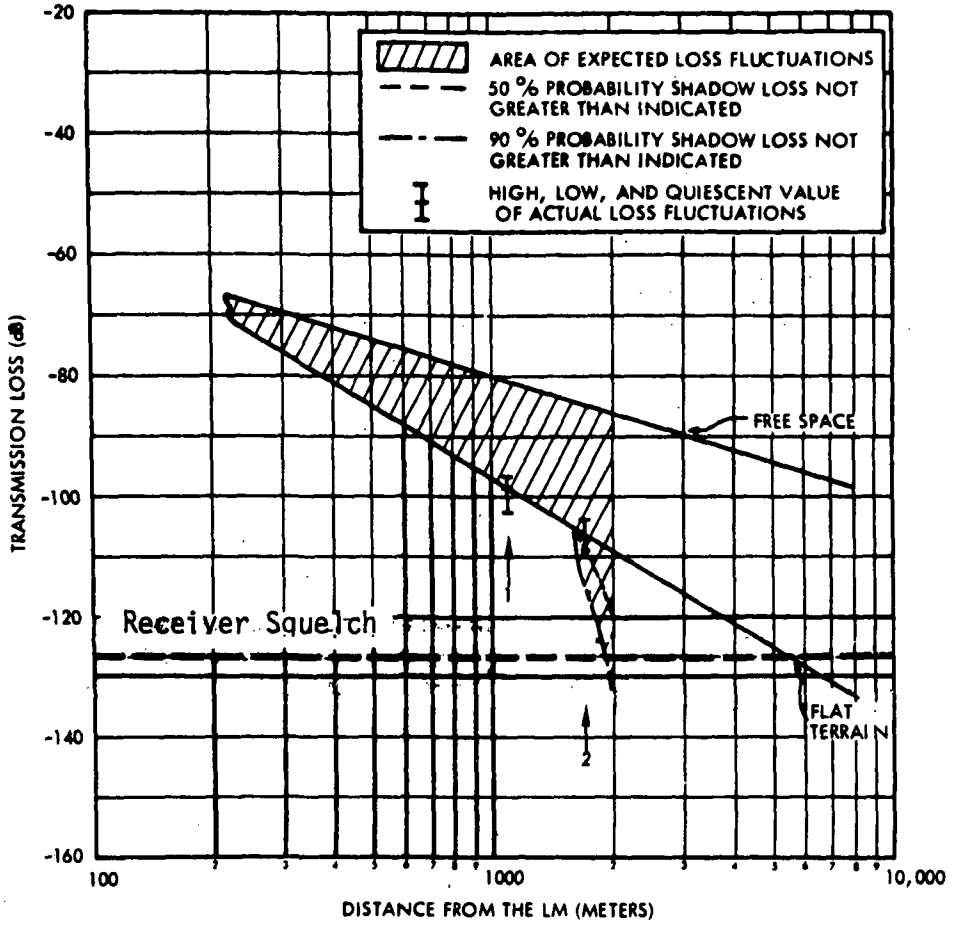

FIGURE 2-4A TRANSMISSION LOSS ON RADIAL I-3 AT 259.7 MHz

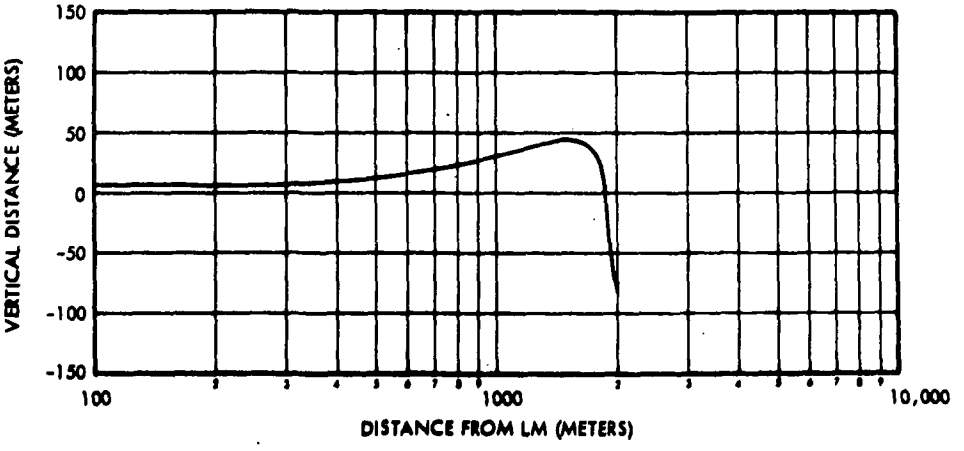

FIGURE 2-4B RADIAL I-3 LUNAR PROFILE, HADLEY-APENNINE SITE

2.5.2 EVA II Traverse Analysis

The predicted and actual radio transmission loss values are compared in figures 2-5 through 2-8 for EVA II. Radials II-1 through II-4 pass through the areas where the telemetry data can be correlated with the positions on the traverse route. Seventeen data points are located on this traverse route and are numbered from 8 through 24. Out of the 17 data points only two do not fall within the areas of expected loss fluctuations. These are the points for areas 8 and 9. The data points for areas 8 and 9 were also recorded on the return leg of the traverse. The additional transmission losses for areas 8 and 9 are probably due to the combination of the EVCS backpack antenna pattern being modified when the astronauts are on the LRV and the blockage caused by the LCRU equipment attached to the front of the LRV.

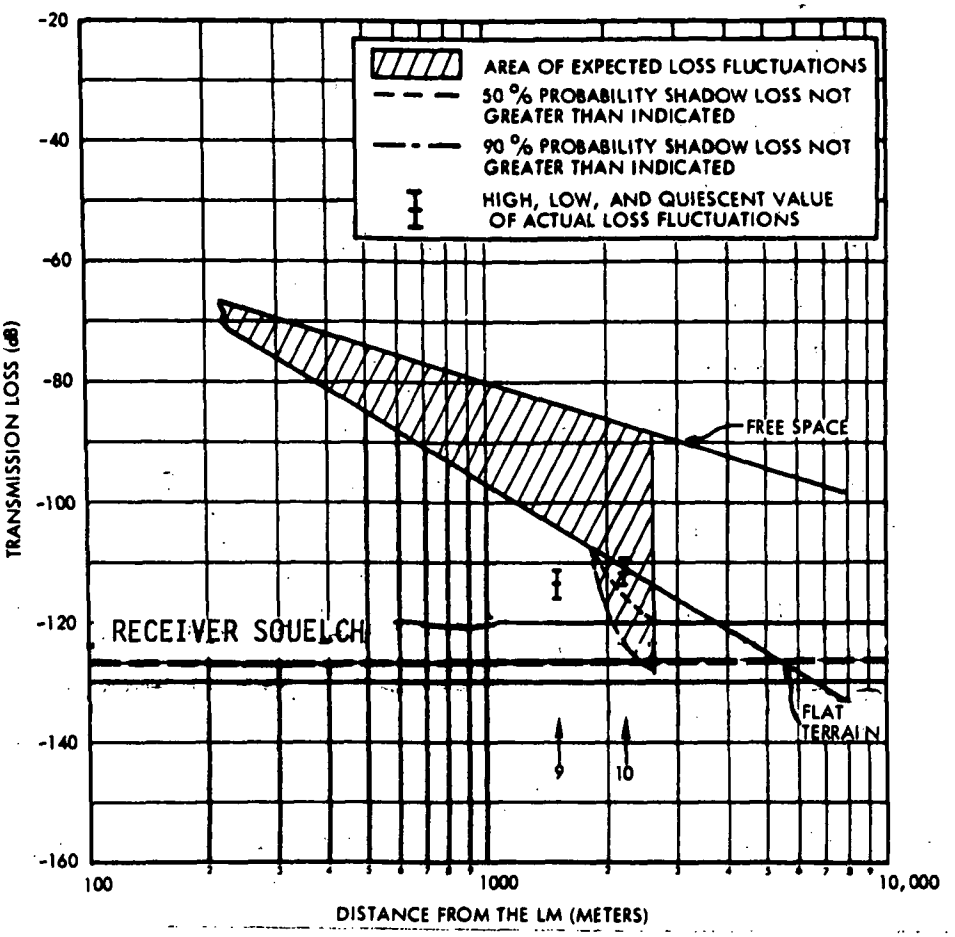

FIGURE 2-5A TRANSMISSION LOSS ON RADIAL II-1 AT 259.7 MHz

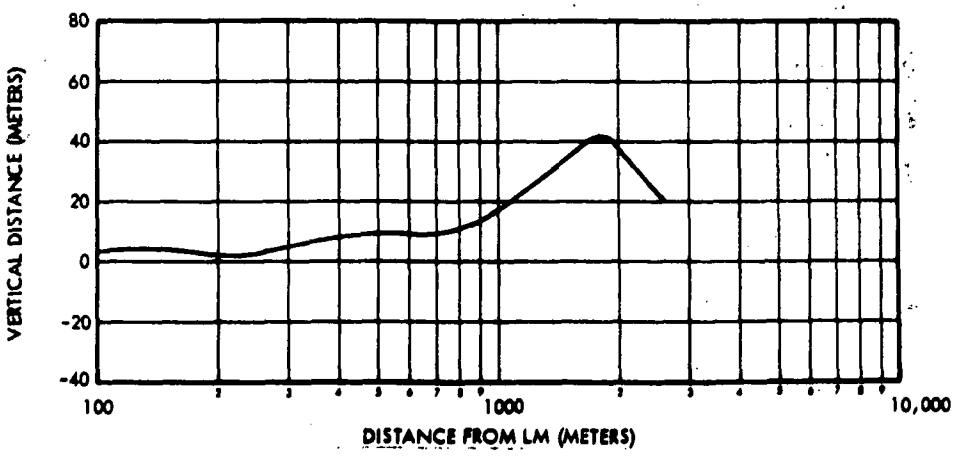

FIGURE 2-5B RADIAL II-1 LUNAR PROFILE, HADLEY-APENNINE SITE

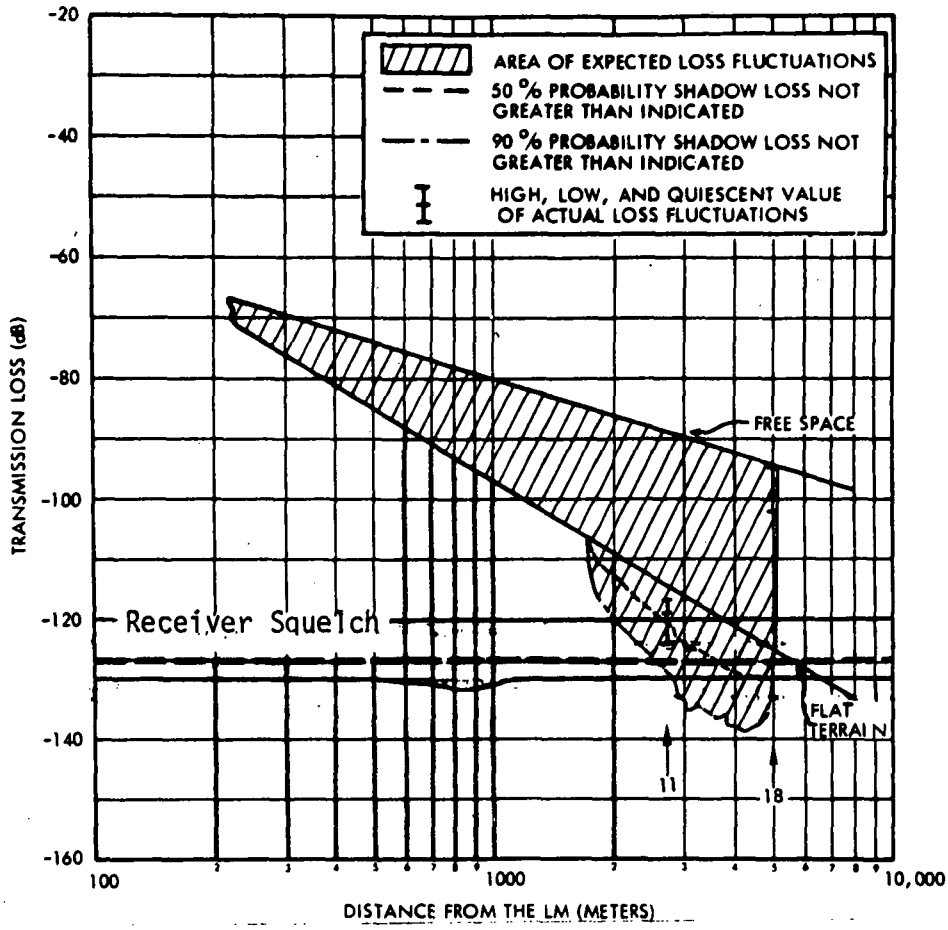

FIGURE 2-6A TRANSMISSION LOSS ON RADIAL II-2 AT 259.7 MHz

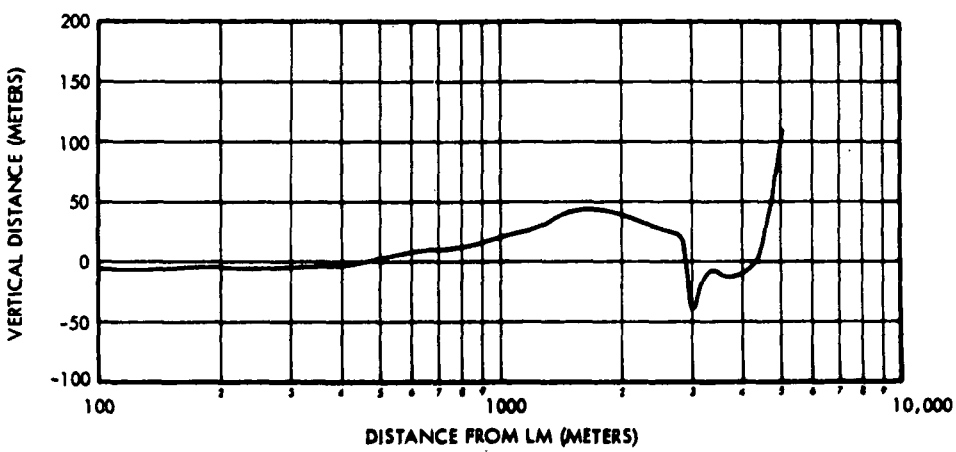

FIGURE 2-6B RADIAL II-2 LUNAR PROFILE, HADLEY-APENNINE SITE

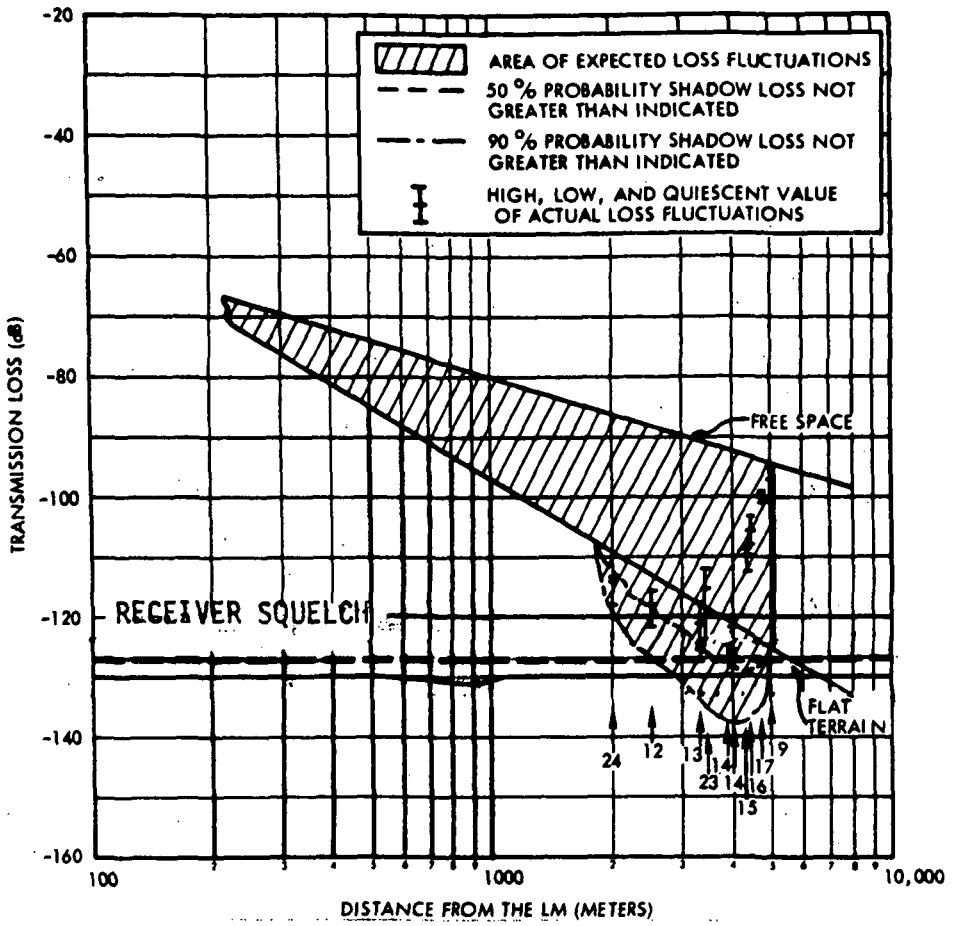

FIGURE 2-7A TRANSMISSION LOSS ON RADIAL II-3 AT 259.7 MHz

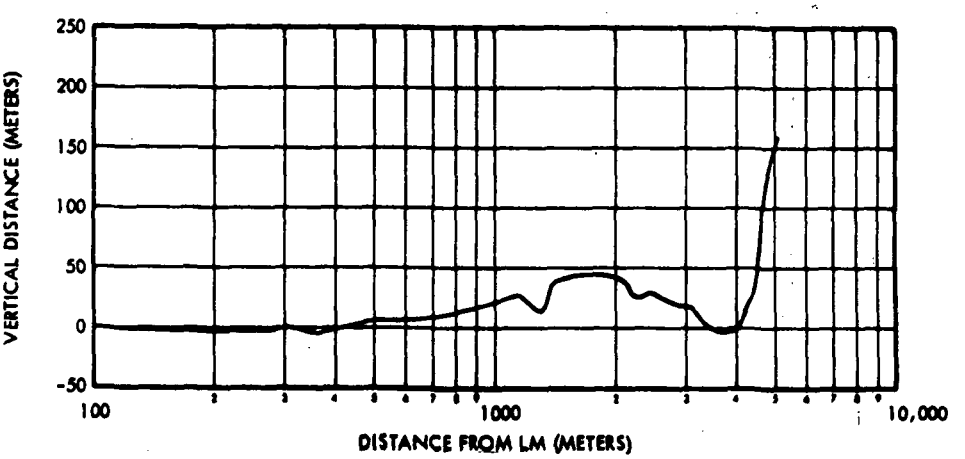

FIGURE 2-7B RADIAL II-3 LUNAR PROFILE HADLEY-APENNINE SITE

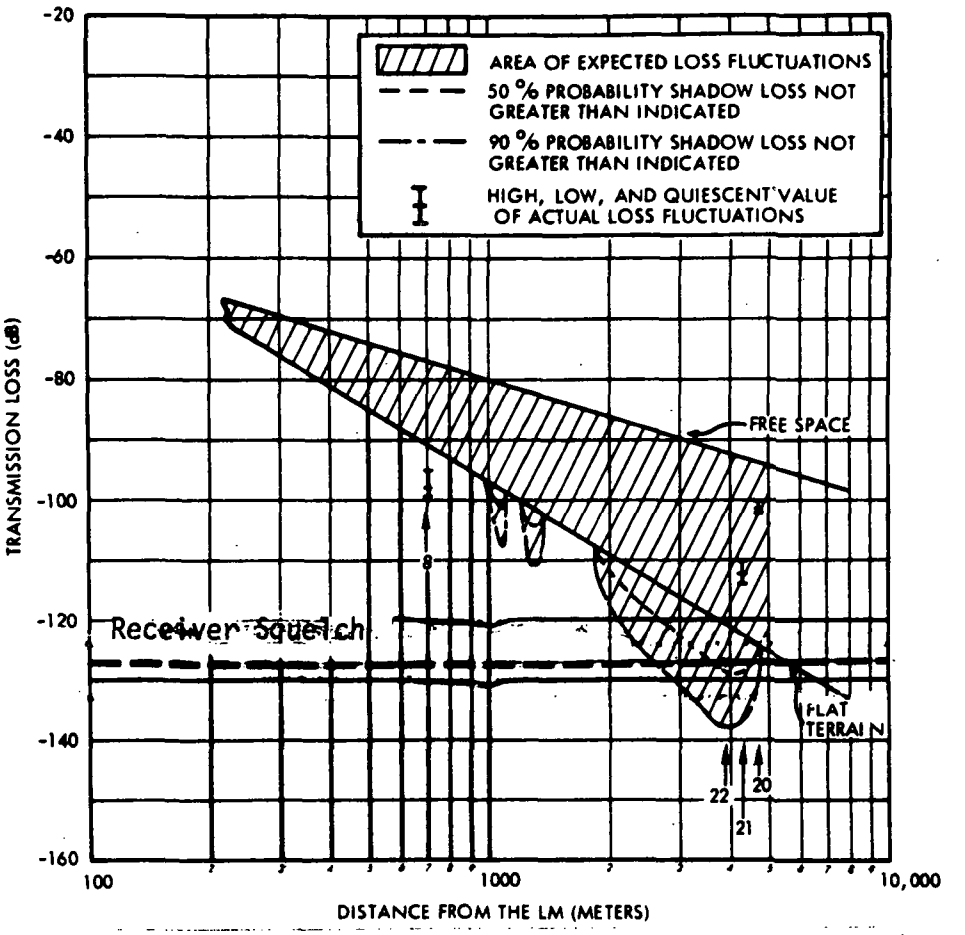

FIGURE 2-8A TRANSMISSION LOSS ON RADIAL II-4 AT 259.7 MHz

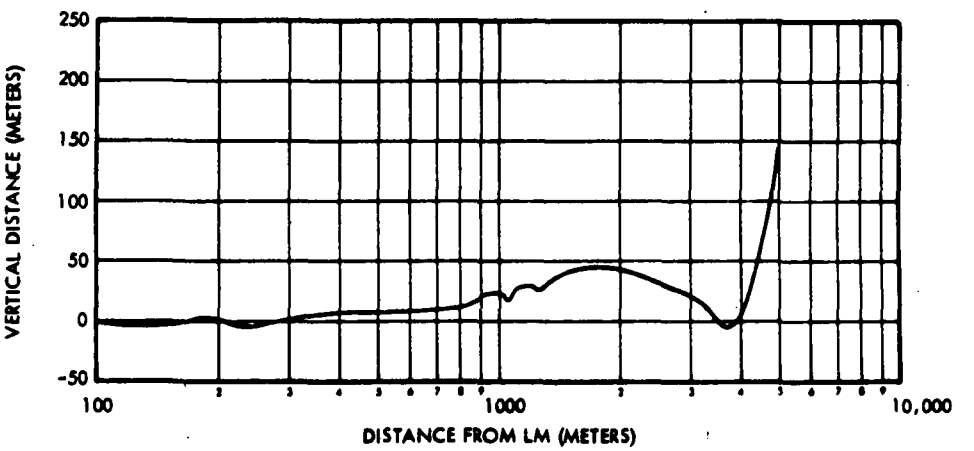

FIGURE 2-8B RADIAL II-4 LUNAR PROFILE, HADLEY-APENNINE SITE

2.5.3 EVA III Traverse Analysis

Figures 2-9 through 2-12 show the predicted and actual radio transmission loss values for the EVA III traverse. Radials III-1 through III-4 pass through eight areas where telemetry data can be correlated with the positions on the traverse route. These points are numbered 25 through 32. Out of the eight data points, only points 26 and 27 do not fall within the areas of expected loss fluctuations. The astronauts had reported that the terrain around points 26 and 27 were very hummocky or undulating. However, no evidence of the depressions is shown on the contour map from which the predicted transmission loss values are made. An examination of the terrain around points 26 and 27 shows a number of small craters that appear on the photomap but not on the contour map. Therefore, the most probable cause of the additional transmission losses for points 26 and 27 are the depression located in those areas but which do not show on the contour map.

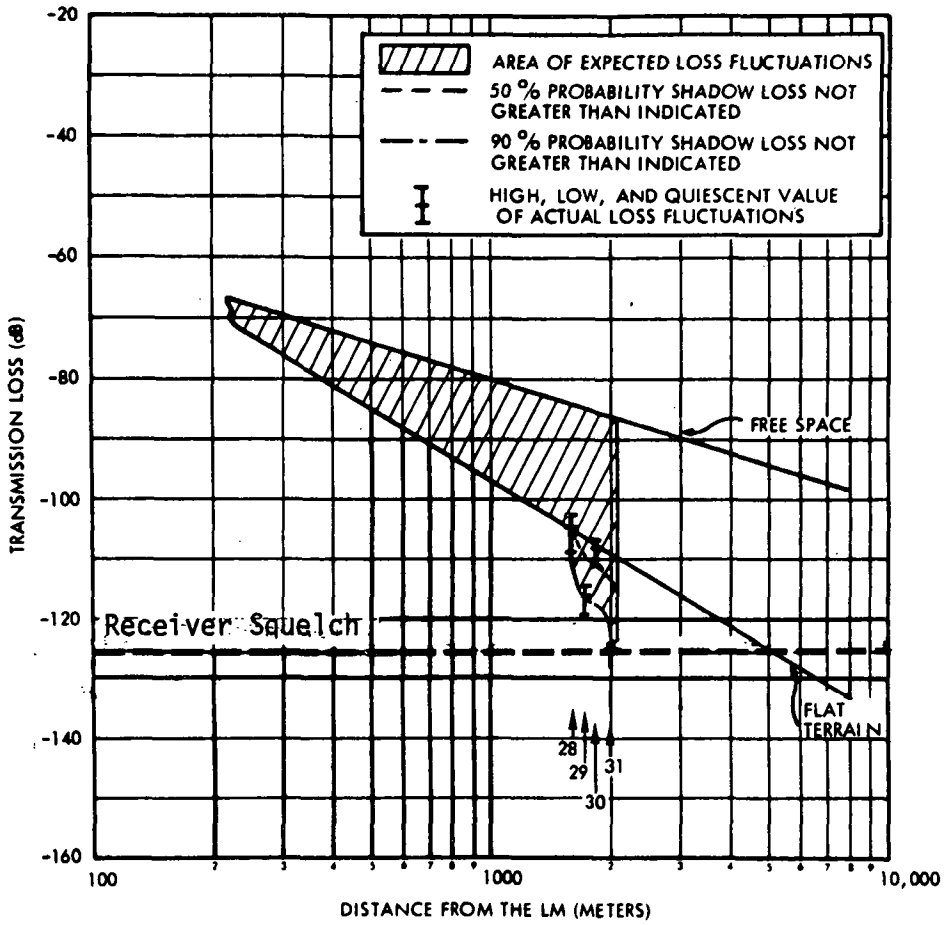

FIGURE 2-9A TRANSMISSION LOSS ON RADIAL III-1 AT 259.7 MHz

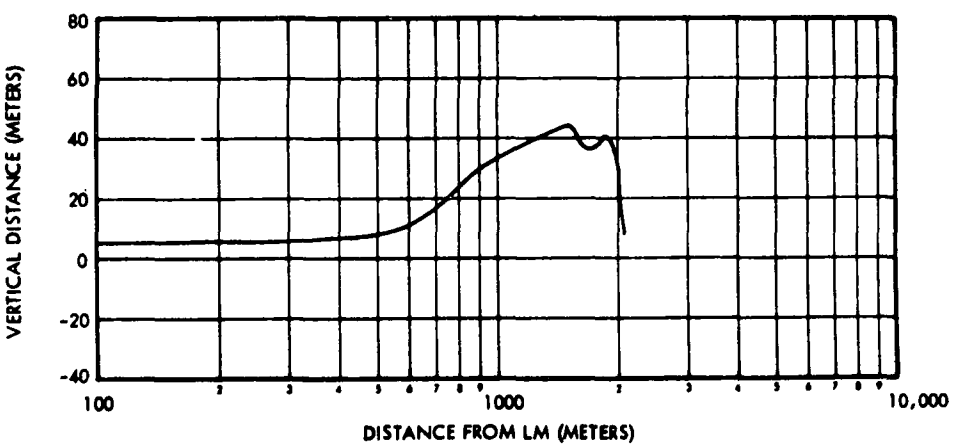

FIGURE 2-9B RADIAL III-1 LUNAR PROFILE, HADLEY-APENNINE SITE

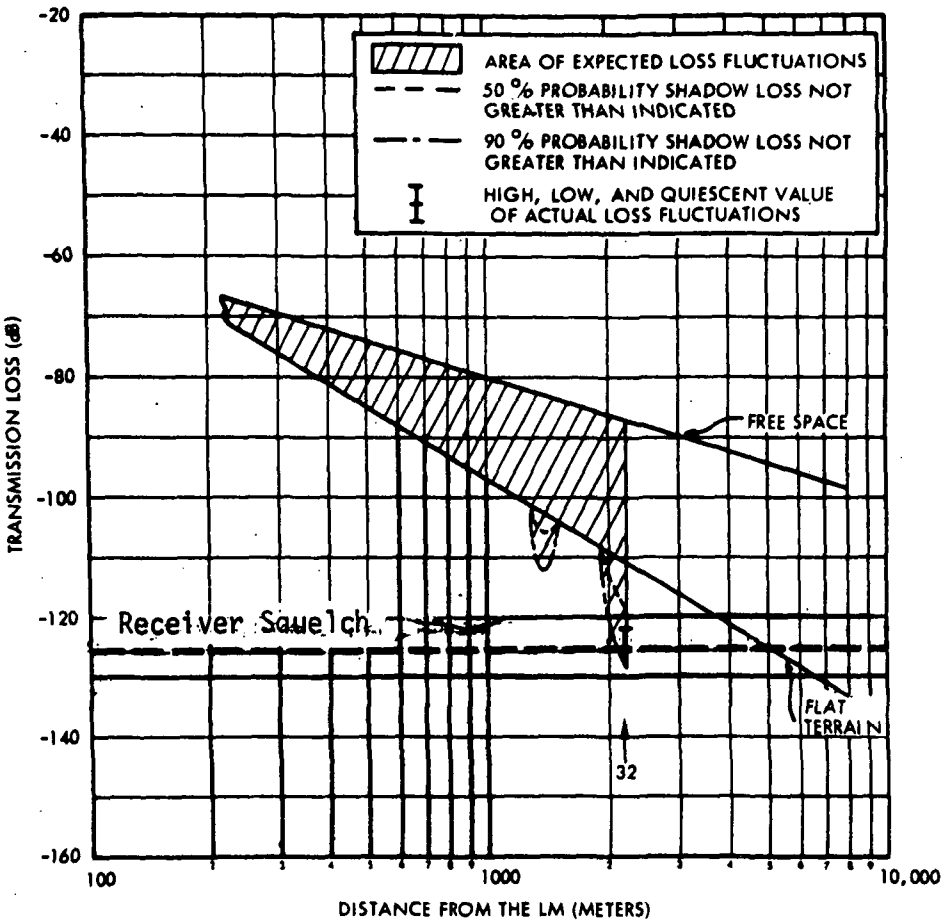

FIGURE 2-10A TRANSMISSION LOSS ON RADIAL III-2 AT 259.7 MHz

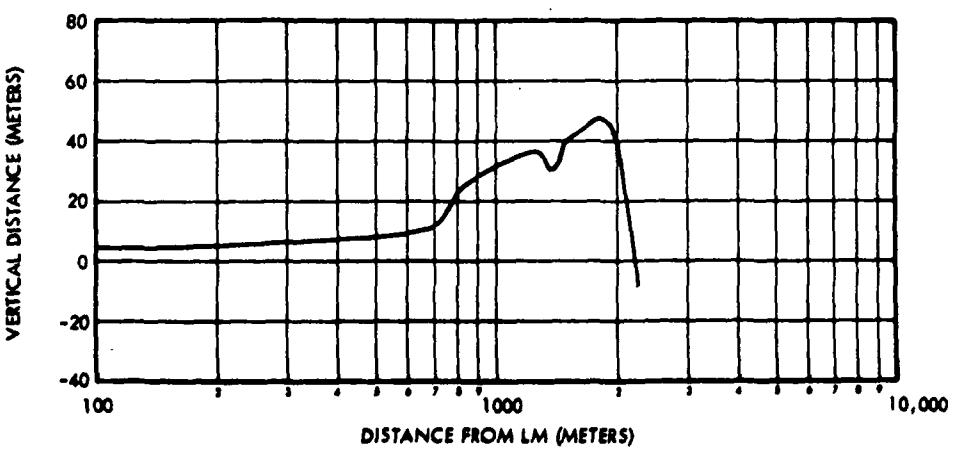

FIGURE 2-10B RADIAL III-2 LUNAR PROFILE, HADLEY-APENNINE SITE

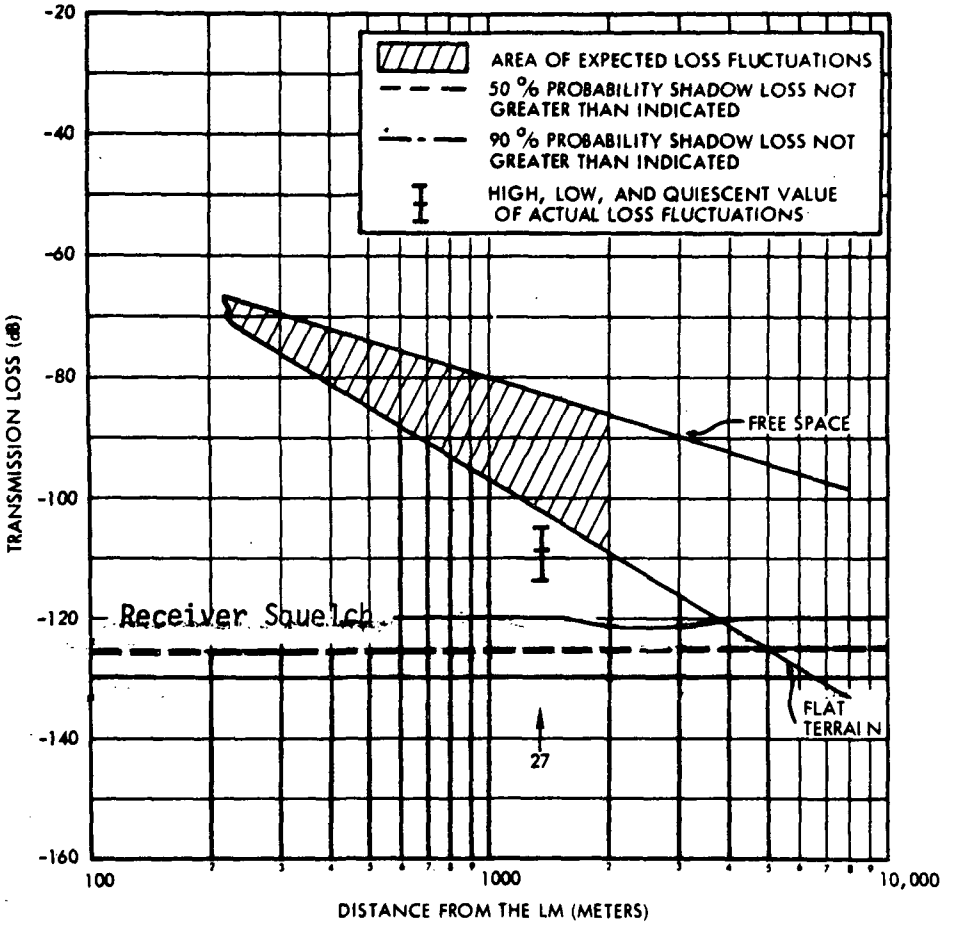

FIGURE 2-11A TRANSMISSION LOSS ON RADIAL III-3 AT 259.7 MHz

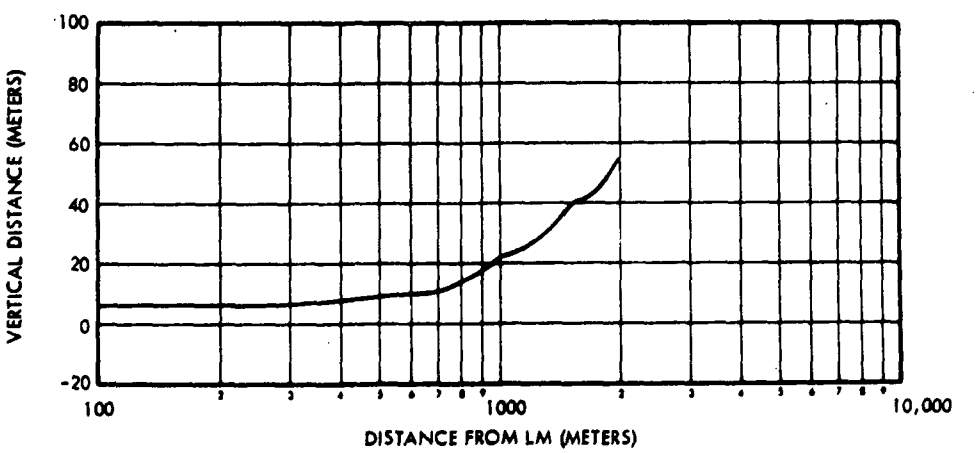

FIGURE 2-11B RADIAL III-3 LUNAR PROFILE, HADLEY-APENNINE SITE

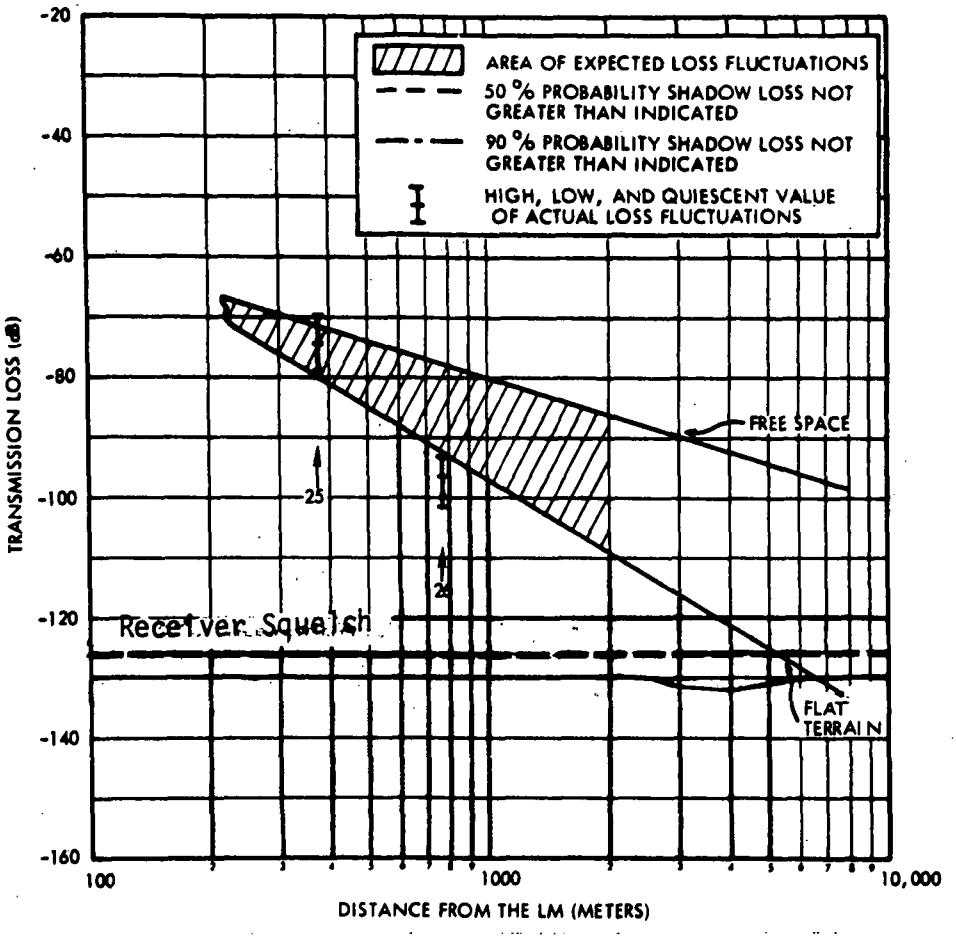

FIGURE 2-12A TRANSMISSION LOSS ON RADIAL III-4 AT 259.7 MHz

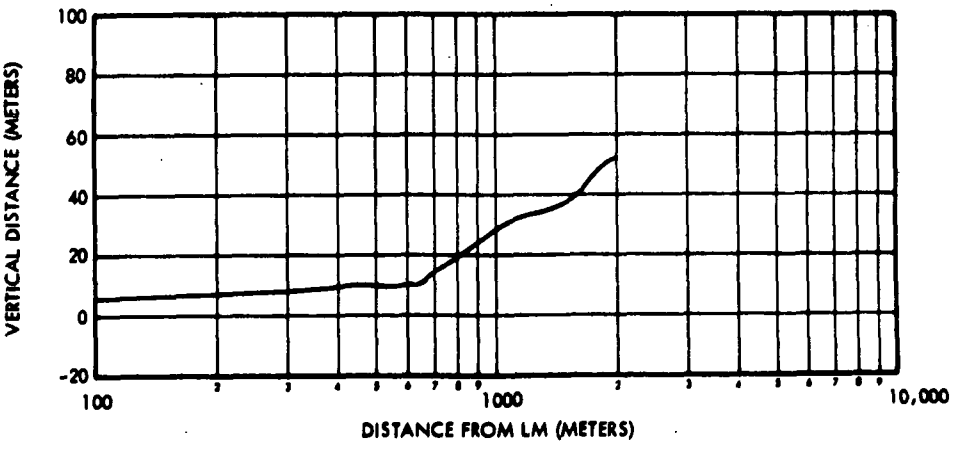

FIGURE 2-12B RADIAL III-4 LUNAR PROFILE HADLEY-APENNINE SITE

3. CONCLUSIONS AND RECOMMENDATIONS

A summary of the LRV locations where the actual and predicted VHF transmission losses were compared are shown in figure 3-1. For the three EVA traverses a total of 32 areas are shown where data points are available. Most of the areas shown on this map have radio transmission loss fluctuations which fell within the range of the preflight predicted values.

Seven areas had measured transmission loss data exceeding the predicted loss values. These points are areas 3, 6, 7, 8, 9, 26, and 27. The additional transmission losses for areas 6, 7, 8, and 9 are most probably due to the combination of the EVCS backpack antenna pattern being degraded when the astronauts were on the LRV, and the blockage and shadowing loss caused by the LCRU equipment attached to the front of the LRV since these points were recorded on the return leg of the traverse.

A comparison of the photomap and the contour map shows that the contour map only represents the larger scale features in the landing site area. The photomap shows many smaller scale features that are not represented on the contour map. Therefore, the additional transmission losses for areas 3, 26, and 27 are most likely due to the limitations of the contour maps available for this analysis.

In general, the data showed good correlation during periods when the radio line of sight was obscured. The data also showed that during the traverse up the Apennine Front, the radio transmission loss approached that of free space loss as the line of sight to the LM was regained.

The quality of the EVCS data and voice transmitted by the VHF link was commensurate with the received VHF signal level down to approximately -105 dBm, when all EVCS voice and data dropped out. This indicates that the VHF receiver squelch sensitivity was set to approximately -105 dBm.

Additional coverage of EVA periods could have been obtained if the squelch sensitivity had been set at a lower signal level. Therefore, it is recommended that the pre-EVA procedures for Apollo missions 16 and 17 be changed. For these missions, the thumbwheel setting for receiver squelch with no input signal should be determined in accordance with existing procedures. The thumbwheel setting should then be backed off one position in place of the one-and-one-half positions in the existing procedures. Incorporation of this recommendation in the crew procedures will increase the availability of voice and data relayed by the LM during the EVA periods.

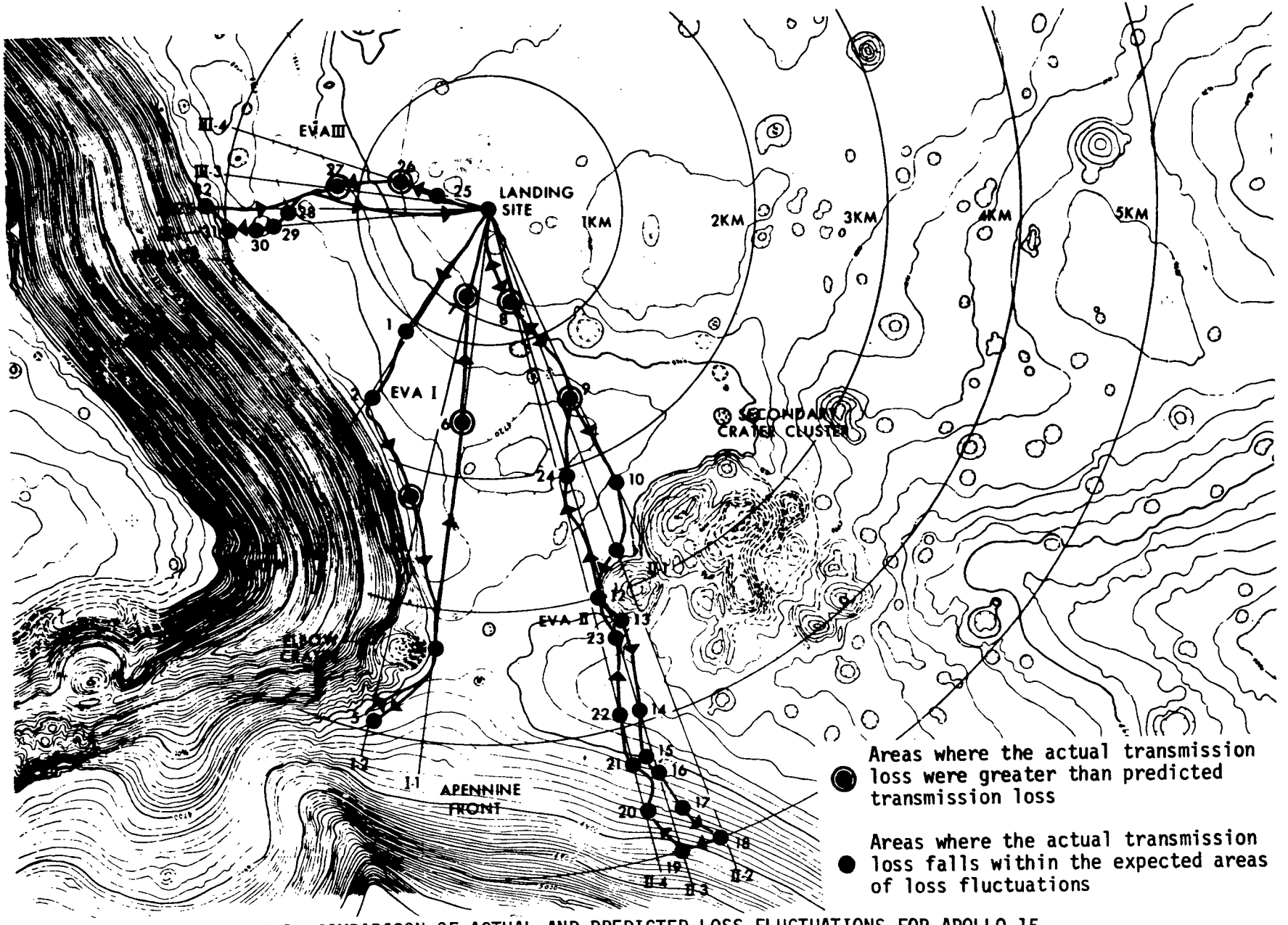

FIGURE 3-1 COMPARISON OF ACTUAL AND PREDICTED LOSS FLUCTUATIONS FOR APOLLO 15

ABBREVIATIONS

AET - Apollo Elapsed Time

AGC - Automatic Gain Control

CDR - Commander

dBm - Decibels above or below a reference level of 1 milliwatt

EKG - Electrocardiogram

EVA - Extravehicular Activity

EVA I - First Extravehicular Activity

EVA II - Second Extravehicular Activity

EVA III - Third Extravehicular Activity

EVCS - Extravehicular Communications System

Km - Kilometer

LCRU - Lunar Communications Relay Unit

LM - Lumar Module

LMP - Lunar Module Pilot

LRV - Lunar Roving Vehicle

MSFN - Manned Space Flight Network

PLSS - Portable Life Support System

PLSS I - Commander's Portable Life Support System

PLSS II - Lunar Module Pilot's Portable Life Support System

TCSD - Telemetry and Communications Systems Division

VHF - Very High Frequency

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