BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B69 10087

SUBJECT: Communications Performance of Possible Apollo (LM) USB Downlink Configurations - Case 320

DATE: October 23, 1969

FROM: N. W. Schroeder

ABSTRACT

Power margins have been calculated and the results tabulated showing the capabilities of eight available options in the configuration of the Apollo Unified S-Band (USB) LM downlink.

The results show the following:

Frequency Modulation Modes

1. Television transmitted from the LM erectable antenna to a DSN (210') station at low power is expected to be marginal; however, the voice, 51.2 kbps telemetry, and biomed data that are transmitted with it will be lost.

2. Television, telemetry (BER=10^{-4}) and Extra Vehicular Communications System (EVCS) voice with biomed data transmitted simultaneously from the LM erectable antenna to an MSFN (85') station or from the LM steerable antenna to a DSN (210') station is expected to be satisfactory only at high power.

Phase Modulation Modes

1. Low bit rate (1.6 kbps) telemetry (BER-10^{-6}), base-band voice, and key data transmitted from the LM steerable antenna to an MSFN (85') station are all expected to be satisfactory even at low power (ranging could also be accommodated,if required).

2. High bit rate (51.2 kbps) telemetry (BER=10^{-6}), and normal voice with biomed data transmitted simultaneously from the LM erectable antenna to a DSN (210') station is expected to be satisfactory even at low power.

(NASA-CR-107814) COMMUNICATIONS PERFORMANCE OF POSSIBLE APOLLO /LM/ USB DOWNLINK CONFIGURATIONS (Bellcomm, Inc.) 15 p

N79-72684

Unclas
00/32 11696

FF No. 602(A

(PAGES) (CODE)

CR#107814

(NASA CR OR TMX OR AD NUMBER) (CATEGORY)

[redacted]

FEB 1970
RECEIVED
NASA STI FACILITY
INPUT BRANCH

BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B69 10087

SUBJECT: Communications Performance of Possible Apollo (LM) USB Downlink Configurations - Case 320

DATE: October 23, 1969

FROM: N. W. Schroeder

MEMORANDUM FOR FILE

Introduction

Extended periods of lunar surface activity require optimum use of the Unified S-Band (USB) communications system to conserve electrical energy on the LM and to obtain the data required for mission operations.

To aid in identifying this optimum utilization, power margins have been calculated. The results of these calculations, the capabilities of the available options in the configuration of the Apollo USB LM downlink, are tabulated in Tables I through III. The margin equations used in the calculations are those presented in reference 1. The USB system parameters used in the calculations are contained in Table IV. The eight options of the downlink configuration that are considered here are the possible combinations of the following:

1. High or low power transmissions from the LM,

2. LM transmissions from the steerable or the erectable antenna,

3. LM transmissions to an MSFN (85') or a DSN (210') ground station.

Table I summarizes the quality expected (acceptable (+), marginal (*), and unacceptable (-)) at the ground station of the possible types of LM data when this data is transmitted via the LM downlink. Eight possible options in the configuration of this downlink are presented in the table.

Table II shows the total signal power and the signal to noise power density ratios that are expected at the input to the ground station receiver for eight options of the downlink configuration. The total received signal power is

identical in both frequency modulation (FM) modes and phase modulation (PM) modes; however, this is not true for the signal to noise density ratios. For the FM modes, the system noise temperature is constant (210°K was used here), but for the PM modes this parameter is a function of the received carrier power, see reference 1. The ratio then of total received signal power to noise density ($P_T/_{KoT}$) in the PM modes is a function of the communications mode being transmitted by the LM. Downlink modes 2 and 5 represent the maximum and minimum magnitude respectively, for this ratio; therefore the two entries in Table II for ($P_{T/KoTs}$) are bounds on this ratio.

Table III shows the minimum total received signal power and the corresponding signal power to thermal noise density ratio required for the possible types of data that can be transmitted on the LM downlink in order that all communications perform satisfactorily.

Results

The results obtained in this analysis are summarized in Table I. The entries in this table are obtained by first finding in Table III the magnitude of total received power that is required for the selected data to be usable, and then determining from Table II if sufficient total received power is available in the downlink configuration considered. Although the numerical magnitudes of the power margins are not contained in Table I, they can be readily obtained in decibels by the use of Tables II and III.

Conclusions

Frequency Modulation (FM) Modes

1. Television, when transmitted from the LM, is transmitted simultaneously with telemetry, voice and Biomed data. When this combination (LM FM Mode 10) is transmitted from the erectable antenna to a DSN (210') station at low power,

   a. the television is expected to be marginal,

   b. the 1.6 kbps telemetry is expected to be satisfactory, and

   c. the 51.2 kbps telemetry, voice, PLSS status, and biomed data will be lost.

2. When only an MSFN (85') station is available, only the erectable antenna in the high power mode will provide usable EVA biomed data.

Phase Modulation Modes

The LM low power mode will provide the following usable data:

1. A full PM mode (51.2 kbps telemetry (BER=10^{-6}) voice with Biomed data and ranging) transmitted from the LM erectable antenna to a DSN (210') station.

2. Ranging, 1.6 kbps telemetry (BER=10^{-6}), baseband voice and key data transmitted from the LM steerable antenna to an MSFN (85') station.

N. W. Schroeder

2034-NWS-mbr

N. W. Schroeder

Attachment
Tables I thru IV

REFERENCES

1. Schroeder, N. W., "Communications Margins for Apollo Univied S-Band Links with Phase Modulation," Bellcomm TM 68-2034-17, December 31, 1968.

2. Hood, B. H., "A Communications Performance Evaluation for the Reference Lunar Landing Mission," Information Systems Division, Houston, Texas, EB 69-2004 (u), January, 1969.

3. Eggleston, T. W., Loch, F. J., and Porter, J. A., "Communications Systems Performance and Coverage Analysis for Apollo 11 (G Type Mission) Volume IV," Information Systems Division, Houston, Texas, EB-R-69-7, June 26, 1969.

TABLE I

SUMMARY OF EXPECTED DATA QUALITY USING POSSIBLE APOLLO (LM) USB DOWNLINK CONFIGURATIONS†

DOWNLINK SERVICES TRANSMITTED	HIGH POWER (LM TRANSMITTER POWER = 18.6 WATTS)				LOW POWER (LM TRANSMITTER POWER = .345 WATTS)			
	LM ERECTABLE DSN (210′)	LM STEERABLE DSN (210′)	LM ERECTABLE MSFN (85′)	LM STEERABLE MSFN (85′)	LM ERECTABLE DSN (210′)	LM STEERABLE DSN (210′)	LM ERECTABLE MSFN (85′)	LM STEERABLE MSFN (85′)
FREQUENCY MODULATION MODES								
LM Voice with BIOMED - with TV	+	*	*	–	–	–	–	–
LM Voice with BIOMED - no TV	+	*	*	–	–	–	–	–
LM (Dual EVA) EVCS Voice, PLSS status & EVA BIOMED - with TV	+	+	+	–	–	–	–	–
LM (Dual EVA) EVCS Voice, PLSS status & EVA BIOMED - no TV	+	+	+	–	–	–	–	–
LM (Single EVA) EVCS Voice, PLSS status & EVA BIOMED - with TV	+	+	+	–	–	–	–	–
LM (Single EVA) EVCS Voice, PLSS status & EVA BIOMED - no TV	+	+	+	*	–	–	–	–
51.2 KBPS TLM - with TV	+	+	+	–	–	–	–	–
51.2 KBPS TLM - no TV	+	+	+	*	*	–	–	–
TV	+	+	+	*	*	–	–	–
1.6 KBPS TLM - with TV	+	+	+	+	+	–	–	–
1.6 KBPS TLM - no TV	+	+	+	+	+	*	*	–
PHASE MODULATION MODES								
51.2 KBPS TLM - with full PM mode	+	+	+	+	+	–	–	–
51.2 KBPS TLM - with normal Voice/HL BIOMED	+	+	+	+	+	–	*	–
LM Voice/HL BIOMED - with full PM mode	+	+	+	+	+	*	*	–
LM Voice/HL BIOMED - with 51.2 KBPS TLM	+	+	+	+	+	+	+	–
LM Voice/HL BIOMED - with 1.6 KBPS TLM	**LOW POWER ONLY**				+	+	+	–
1.6 KBPS TLM - with LM Voice/HL BIOMED	**LOW POWER ONLY**				+	+	+	+
Ranging - with full PM mode	+	+	+	+	+	+	+	+
1.6 KBPS TLM - with LM B.U. Voice	+	+	+	+	+	+	+	+
LM B.U. Voice - with 1.6 KBPS TLM	+	+	+	+	+	+	+	+
1.6 KBPS TLM only	+	+	+	+	+	+	+	+
LM B.U. Voice only	+	+	+	+	+	+	+	+
KEY only	+	+	+	+	+	+	+	+

†Note: Calculations are based on worst case parameters available from Apollo 11 mission

+Power margin is more positive than 1 dB (performance is acceptable)

–Power margin is more negative than –1 dB (performance is not acceptable)

*Power margin is between +1 and –1 dB. (performance is marginal)

TABLE II

TOTAL RECEIVED SIGNAL POWER
TO
THERMAL NOISE POWER DENSITY RATIOS
EXPECTED FOR LM TO MSFN (85') AND DSN (210') LINKS
AT LUNAR RANGE ($R=215 \times 10^3$ N.Mi)

Link Antenna		Total Received Signal Power	Frequency Modulation	Phase Modulation	
Ground Station	LM	P_T in dBW.	P_T/KoT in dB.*	$P_T/KoTs$ in dB.**	
				Uplink Mode 6+ Downlink Mode 2	Downlink Mode 5+
LM Transmitting Power = 18.6 watts					
DSN (210')	Erectable	-115.3 dBW	90.1 dB	80.2 dB	74.9 dB
DSN (210')	Steerable	-123.6	81.8	78.2	74.2
MSFN (85')	Erectable	-123.3	82.1	78.6	74.2
MSFN (85')	Steerable	-131.6	73.8	72.9	71.3
LM Transmitting Power = .345 watts					
DSN (210')	Erectable	-132.6	72.8	62.1	60.7
DSN (210')	Steerable	-140.9	64.5	64.4	64.1
MSFN (85')	Erectable	-140.6	64.8	64.4	64.2
MSFN (85')	Steerable	-148.9	56.5	56.4	56.4

*1) The noise temperature (T) for the FM modes equals 210°K; so, KoT= -205.4 dBW.

**2) The noise temperature (Ts) for the PM modes is dependent on the magnitude of the received carrier power ($Ts= A+BP_T\alpha$): A= 210°K, B= $.305 \times 10^{16}$ °K/watt, α= modulation loss of the carrier.

+3) See Table IV for definition of PM modes.

TABLE III

TOTAL RECEIVED SIGNAL POWER
TO
THERMAL NOISE POWER DENSITY RATIOS
REQUIRED FOR THE APOLLO LM
DOWNLINK

Channel-Services	Total Required Signal Power P_T in dBW	(P_T/KoT) Req.
Frequency Modulation Modes*		
LM-Voice with BIOMED-with TV	-123.0 dBW	82.4 dB
LM-Voice with BIOMED-no TV	-123.0	82.4
LM EVCS Voice, PLSS & EVA BIOMED (dual EVA) -with TV	-126.0	79.4
LM EVCS Voice, PLSS & EVA BIOMED (dual EVA) -no TV	-127.0	78.4
LM EVCS Voice, PLSS & EVA BIOMED (single EVA) -with TV	-130.3	75.1
LM EVCS Voice, PLSS & EVA BIOMED (single EVA) - no TV	-131.3	74.1
51.2 KBPS TLM-with TV	-130.0	75.4
51.2 KBPS TLM-no TV	-131.6	73.8
1.6 KBPS TLM-with TV	-138.6	66.8
1.6 KBPS TLM-no TV	-140.2	65.2
TV	-132.5	72.9

*This data was taken from Reference 2.

TABLE III (Continued)

Channel-Services	Total Required Signal Power P_T in dBW	(P_T/KoT) Req.
Phase Modulation Modes*		
51.2 KBPS TLM w/1) - full mode**	-138.8 dBW	66.4 dB
2) - voice/HL BIOMED	-139.7	65.5
Voice/HL BIOMED w/1) - full mode**	-140.6	64.7
2) - 51.2 KBPS TLM	-141.5	63.8
3) - 1.6 KBPS TLM	-146.2	59.2
1.6 KBPS TLM w/1) - voice/HL BIOMED	-149.2	56.2
2) - B. U. Voice	-153.8	51.6
3) - 1.6 KBPS TLM only	-157.2	48.2
Ranging w/full mode	-150.8	54.5
B. U. voice w/1) - 1.6 KBPS TLM	-155.3	50.1
2) - B. U. Voice only	-159.4	46.0
Key only	-180.8	24.6

*This data was calculated using the equations contained in Reference 1 and the system parameters contained in Table IV.

**A full PM mode is comprised of 51.2 KBPS telemetry, normal voice and ranging data.

TABLE IV

USB SYSTEM PARAMETERS USED IN
COMMUNICATIONS MARGINS
CALCULATIONS FOR THE LM

Parameter	Ground Station Nominal	Ground Station Worst	LM Nominal	LM Worst	Units
Receive Carrier	2282.5	2282.5	2101.802	2101.802	MHz.
NSD Constant A	210.	210.	3600.	3600.	Degrees Kelvin
NSD Constant B	3.05	3.05	.126	.126	X10.EXP15 Degrees/Watt
IF Bandwidth	4.8	5.3	4.8	5.1	MHz.
Video Bandwidth	-	-	1.8	1.8	MHz.
Ranging Channel Constant (R_0)	-	-	.630	.630	None**
Carrier Loop Bandwidth	50.	50.	1100.	1500.	Hz.
Pointing Loss	0.	0.	-	-	
-LM Steerable	-	-	.5	.5	dB.
-LM Erectable	-	-	2.0	2.0	
Polarization Loss	0.	0.	0.	0.	dB.
Transmit Power	10.	9.5	.0186	.0186	K watts

TABLE IV (Continued)

Parameter	Ground Station Nominal	Ground Station Worst	LM Nominal	LM Worst	Units
Antenna Gains (Transmit)					
-MSFN (85')	50.5	50.5	-	-	dB.
-DSN (210')	58.5	58.5		-	
-LM (Steerable)	-	-	20.3	20.3	dB.
-LM (Erectable)	-	-	34.0	34.0	
Antenna Gains (Receive)					
-MSFN (85')	52.5	52.5	-	-	dB.
-DSN (210')	60.5	60.5	-	-	
-LM (Steerable)	-	-	16.5	16.5	
-LM (Erectable)	-	-	31.7	31.7	
Transmit Circuit Loss					
-MSFN (85') & DSN (210')	0.	0.	-	-	dB.
-LM (Steerable)	-	-	-5.0	-5.0	
-LM (Erectable)	-	-	-8.9	-8.9	
Receive Circuit Loss					
-MSFN (85') & DSN (210')	0.	0.	-	-	dB.
-LM (Steerable)	-	-	-6.0	-6.0	
-LM (Erectable)	-	-	-10.3	-10.3	

TABLE IV (Continued)

Parameter	Ground Station Nominal	Ground Station Worst	LM Nominal	LM Worst	Units
Required Signal/Noise Ratios					
(PM)					
- Carrier	12.0	12.0	12.0	12.0	dB.
- Up Voice (For 90% word intelligibility)	-	-	10.0	10.0	dB.
- Up Data (For a maximum message rejection rate of one per 1000)	-	-	10.0	10.0	dB.
- Down Voice (For 90% word intelligibility)	8.0	8.0	-	-	dB.
- TLM (51.2 KBPS) (For a BER=10^{-6})	8.5	8.5	-	-	dB.**
- TLM (1.6 KBPS) (For a BER=10^{-6} with normal voice)	5.9	5.9	-	-	dB.
(For a BER=10^{-6} with Back Up Voice)	8.0	8.0	-	-	dB.*
- Ranging (For a maximum acquisition time of 60 sec.)	32.0	32.0	-	-	dB.

TABLE IV (Continued)

Parameter	Ground Station Nominal	Ground Station Worst	LM Nominal	LM Worst	Units
Predection Bandwidths					
- Up Voice	-	-	22.0	22.0	KHz.**
- Up Data	-	-	23.0	27.0	KHz.**
- Down Voice	42.0	48.0	-	-	KHz.
- TLM (51.2 KBPS)	180.	180.	-	-	KHz.
- TLM (1.6 KBPS)	7250.	7250.	-	-	Hz.
- Ranging	1.	1.	-	-	Hz.

Except for the items indicated by (* and **), the system parameters listed above were taken from Reference 3.

*This parameter was taken from a plot of test data contained in "Apollo Block II Command Module Unified S-Band Manned Space Flight Network Systems Test Program's Data and Performance Summary, " EB68-3224 (U), November 8, 1968, MSC Houston, Texas.

**These parameters were taken from Reference 2.

TABLE IV (Continued)

UPLINK MODES - CSM: 2106.4 MHZ LM/SLV - 2101.8 MHZ

MODE	SIGNAL COMBINATION	MODULATION TECHNIQUE	SUBCARRIER FREQUENCY (MHZ)	PEAK CARRIER DEVIATION
1	Ranging	PM on Carrier	---	1.34 ± 0.13 Rad
2	Voice	FM/PM	30	1.85 ± 0.18 Rad
3	Command	PSK/FM/PM	70	1.85 ± 0.18 Rad
4	Ranging	PM on Carrier	---	0.38 ± 0.04 Rad
	Voice	FM/PM	30	1.2 ± .12 Rad
5	Ranging	PM on Carrier	---	0.38 ± 0.04 Rad
	Command	PSK/FM/PM	70	1.2 ± .12 Rad
6	Ranging	PM on Carrier	---	0.44 ± 0.04 Rad
	Voice	FM/PM	30	1.0 ± 0.1 Rad
	Command	PSK/FM/PM	70	1.0 ± 0.1 Rad
7	Voice	FM/PM	30	1.1 ± 0.1 Rad
	Command	PSK/FM/PM	70	1.1 ± 0.1 Rad
8	Ranging	PM on Carrier	---	0.38 ± 0.04 Rad
	Backup Voice	FM/PM	70	1.2 ± 0.12 Rad

TABLE IV (Continued)

LM PM DOWNLINK MODES (2282.5 MHZ)

MODE	SIGNAL COMBINATION	MODULATION TECHNIQUE	SUBCARRIER FREQUENCY (MHZ)	PEAK CARRIER DEVIATION
00	No Carrier	---	---	---
01	HBR TLM	PCM/PM/PM	1.024	1.3 + 21%, -15% Rad
	Voice w/BIOMED	FM/PM	1.25	0.9 + 22%, -14% Rad
02	Ranging]	PM on Carrier	---	Varies with Received uplink
	HBR TLM	PCM/PM/PM	1.024	1.3 + 21%, -15% Rad
	Voice w/BIOMED	FM/PM	1.25	0.9 + 22%, -14% Rad
03	LBR TLM	PCM/PM/PM	1.024	1.3 + 21%, -15% Rad
03	Backup Voice	PM on Carrier	---	0.8 + 25%, -15% Rad
	LBR TLM	PCM/PM/PM	1.024	1.3 + 21%, -15% Rad
05	Backup Voice	PM on Carrier	---	0.8 + 25%, -25% Rad
06	Key	AM/PM	512 KHZ	1.4 + 20%, -16% Rad
07	LBR TLM	PCM/PM/PM	1.024	0.7 + 21%, -15% Rad
	Voice	FM/PM	1.25	1.3 + 22%, -14% Rad
08	Backup Voice	PM on Carrier	---	0.73 + 65%, -39% Rad
	LBR TLM	PCM/PM/PM	1.024	1.3 + 21%, -15% Rad

The modulation indexes for both the uplink and the downlink modes are taken from "AS-506 MCC/MSFN Mission Configuration/System Description, June, 1969, Manned Spacecraft Center, Houston, Texas."

BELLCOMM, INC.

SUBJECT: Communications Performance of Possible Apollo (LM) USB Downlink Configurations Case 320

FROM: N. W. Schroeder

DISTRIBUTION LIST

NASA Headquarters
B. P. Brown/MOR
G. P. Chandler/MAO
J. K. Holcomb/MAO
T. A. Keegan/MA-2
A. W. Kinny/MOP
C. M. Lee/MA
J. T. McClanahan/MOR
T. H. McMullen/MA
J. D. Stevenson/MO
W. E. Stoney/MA

Bellcomm, Inc.
W. J. Benden
A. P. Boysen, Jr.
R. K. Chen
F. El-Baz
L. A. Ferrara
D. R. Hagner
J. J. Hibbert
N. W. Hinners
B. T. Howard
D. B. James
J. E. Johnson
H. Kraus
J. A. Llewellyn
J. P. Maloy
J. Z. Menard
B. F. O'Brien
J. T. Raleigh
P. E. Reynolds
I. I. Rosenblum
I. M. Ross

Bellcomm, Inc. (Continued)
L. Schuchman
R. L. Selden
P. F. Sennewald
R. V. Sperry
A. W. Starkey
J. W. Timko
B. P. Tunstall
R. L. Wagner
A. G. Weygand
W. D. Wynn
Central Files
Department 1024 File
Library