ALSEP

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ELECTRONIC SYSTEMS TEST PROGRAM

APOLLO COMMUNICATIONS SYSTEM

ALSEP

COMMAND LINK

TEST REPORT

HASD NO. 642D-835246

LEC

LOCKHEED ELECTRONICS COMPANY

HOUSTON AEROSPACE SYSTEMS

A Division of Lockheed Aircraft Corporation

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Prepared by:

Lockheed Electronics Company

Houston Aerospace Systems Division

Houston, Texas

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For

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Manned Spacecraft Center

Houston, Texas

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PREFACE

To verify the command link from the unified S-band Manned Space Flight Network (MSFN) to the Apollo Lunar Surface Experiments Package (ALSEP), a series of tests was performed at the Manned Spacecraft Center at Houston, Texas. The ALSEP command link test program was primarily devoted to the investigation of anomalies associated with the Early Apollo Scientific Experiments Package (EASEP), which was placed on the lunar surface by the Apollo 11 astronauts, and the investigation of the effects of two simultaneous uplink (MSFN-ALSEP) signals on the ALSEP. This report contains the results, conclusions, and recommendations concerning the ALSEP tests.

The system performance and related conclusions presented in this document are based on the capabilities of the specific system (hardware) tested. Because of the summary nature of this document, much of the data obtained in the ALSEP tests are not presented here, but are contained in the data package (see Reference 1).

Valuable support and assistance were provided by the Spacecraft Systems Test Office and their supporting contractor personnel in the development of test documentation and in the operation and maintenance of the spacecraft systems during testing. The personnel of the Spacecraft Systems Test Office also provided the major portion of the spacecraft systems supporting effort and performed the function of Spacecraft Systems Test Coordinator.

This report has been prepared for the Tele/Communications Systems Division of NASA's Manned Spacecraft Center under Contract NAS 9-5191. It is distributed for information purposes only. The conclusions and recommendations contained herein should neither be regarded as representing a firm position of NASA's Manned Spacecraft Center, nor should they obligate or commit the Center in any way.

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LIST OF ABBREVIATIONS

ALSEP	-	Apollo Lunar Surface Experiments Package
AMPL	-	Amplifier
bps	-	Bits-per-Second
CM	-	Command module
CMD	-	Command
CV	-	Command Verification
CX	-	Command Execution
dB	-	Decibels
dBm	-	Decibels, power referenced to one milliwatt
demod.	-	Demodulator
det.	-	Detector
DRUL	-	Down Range Uplink; a part of the digital command system network which performs the function of "uplinking" digital commands
EASEP	-	Early Apollo Scientific Experiments Package
ESTL	-	Electronic Systems Test Laboratory
EVA	-	Extravehicular Astronaut
EVCS	-	Extravehicular Communications System
FF	-	Flip-flop
FM	-	Frequency modulation
freq.	-	Frequency
Hz	-	Hertz, cycles per second
IF	-	Intermediate frequency
Integ.	-	Integrator
kHz	-	Kilohertz, equal to 1,000 cycles per second
LBR	-	Low Bit Rate (530 bits per second)
LM	-	Lunar Module
MHz	-	Megahertz, equal to 1,000,000 cycles per second
ms	-	Millisecond
MSC	-	Manned Spacecraft Center
MSFN	-	Manned Space Flight Network
MSP	-	Message Sent Pulse

N/A	-	Not Applicable
NBR	-	Normal Bit Rate (1060 bits per second)
NRZ	-	Nonreturn-to-Zero
OSC	-	Oscillator
PCM	-	Pulse Code Modulation
PM	-	Phase Modulated
PSK	-	Phase Shift Keyed
rcvr	-	Receiver
ref	-	Reference
Reg	-	Register
RF	-	Radio frequency
RTG	-	Radioisotope Thermoelectric Generator
S-Band	-	The range of frequencies between 1.55 GHz and 5.2 GHz
ST	-	Schmitt Trigger
STD	-	Standard
Sync	-	Synchronization
TLM	-	Telemetry
TPET	-	Test Planning and Evaluation Test
UDB	-	Updata Buffer
USB	-	Unified S-band
USBSS	-	Unified S-band System Simulator
VCO	-	Voltage Controlled Oscillator
VHF	-	Very high frequency
XMTR	-	Transmitter
φ	-	Phase

SECTION 1

INTRODUCTION

This document presents the objectives, results, and conclusions of the ALSEP Command Link Test Program. The tests were performed in the Electronic Systems Test Laboratory (ESTL) at the Manned Spacecraft Center (MSC) between 18 August 1969 and 22 September 1969.

The objective of these tests was to determine, by experimental means, the performance of the ALSEP command channel under different MSFN-to-ALSEP uplink conditions (Figure 1-1). It was also of interest to determine if previously experienced problems could be repeated and explained.

During checkout of the ALSEP (or EASEP) at the manufacturer's facility, at Kennedy Space Center, and during the Apollo 11 mission, conditions were experienced which required special investigation. One of the conditions was the command verification (CV) 177 problem. When the ALSEP received a valid uplink command, it sent a downlink verification of the received command followed by an extraneous verification of a 177 command (approximately one time for eight valid uplink commands). Another unexpected condition was the receipt of a CV without an uplink carrier. The EASEP, left on the lunar surface by the Apollo 11 crew, reportedly sent false verifications of received commands at the rate of approximately three per hour during periods when no uplink signal was present. In addition, since ground testing performed with more than one uplink radio frequency (RF) carrier showed that false command verifications occurred, additional data concerning the effects of two simultaneous uplink RF carriers with several possible combinations of modulation were desirable. The objectives were attained by measuring performance characteristics such as received carrier powers, commands sent, commands verified, and commands executed.

Appendix A lists the references used during the test program and in the preparation of this report.

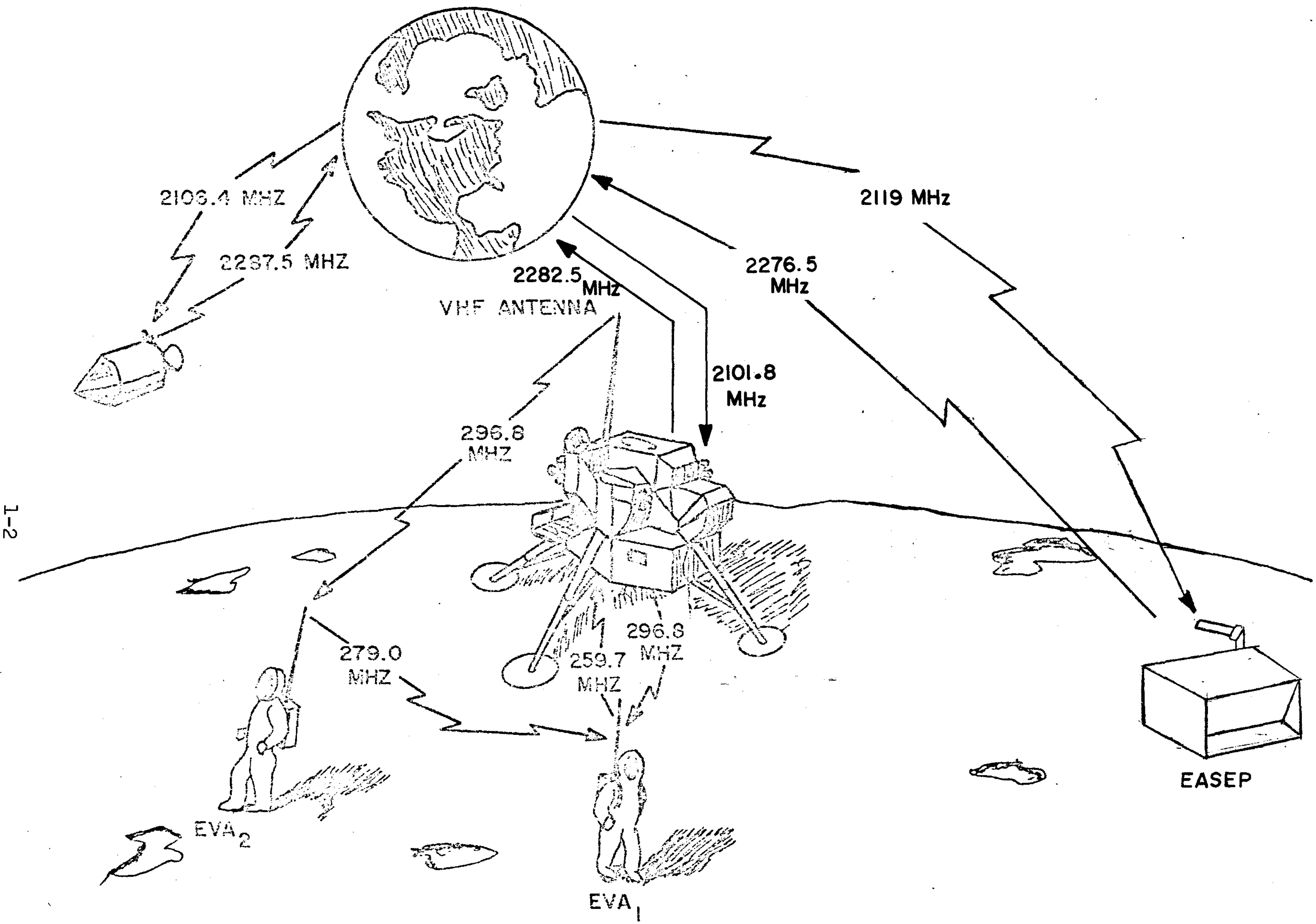


FIGURE 1-1. EVCS/LM/MSFN COMMUNICATIONS SYSTEM

SECTION 2

SYSTEM PERFORMANCE SUMMARY

2.1 General

The ALSEP command link tests were conducted to determine the performance of ALSEP under different MSFN/ALSEP uplink signal conditions.

2.2 Dual Uplink RF Carrier Test

The test data indicated that an ALSEP package receiving two simultaneous uplink RF carriers will execute random commands at intervals determined by a number of uplink parameters. Two variables, the relative phase shift between the PSK components and the difference in RF carrier power between the two uplink signals, affected the rate of execution of random commands significantly.

With two different valid commands transmitted to ALSEP with equal uplink RF power levels, the ALSEP was unable to execute either valid command. However, it verified 106 random commands during a 20-minute test and would probably have executed random commands during a longer test. When the difference between two RF power levels exceeded 3 dB, the stronger uplink was able to command the ALSEP consistently.

With the two uplink RF carriers modulated with all ones, the ALSEP verified and executed random commands.

The verification and execution of random commands occurred most frequently when the phase shift between the PSK references of the two uplink signals was approximately 90 degrees. The minimum time interval between the execution of random commands was approximately one minute.

The ALSEP was not significantly affected by 1 kHz or 2 kHz frequency offsets between the two uplink RF carriers.

The ALSEP verified 91 random commands and executed none during tests involving two unmodulated uplink RF carriers. A longer test would probably have produced executions of random commands. Table 2-1 summarizes the time intervals between successive verifications or executions of random commands under different uplink conditions.

2.3 Single Uplink RF Carrier Test

When the ALSEP received one uplink RF carrier modulated with a valid command, it verified and executed all commands. When the ALSEP was in normal bit rate, 1060 bps, a verification of a 177 command followed the verification of the valid command sent in 23 cases out of 180. The ratio of 177 command verifications (CV177) to valid command verifications (CV) was 23/180 or approximately 1/8 as predicted by earlier investigation and ALSEP command decoder circuit analysis. When the ALSEP was in low bit rate, 530 bps, the ratio of CV177's to valid CV's was 11/180 or approximately 1/16.

Since a 177 command is not an allowable command, it was not executed by the ALSEP and caused no harm. Cursory circuit analysis indicated that the CV177 condition discussed above will always produce a verified but unexecuted 177 command.

2.4 No Uplink RF Carrier Test

With no uplink RF signal, the ALSEP verified 23 commands in a 10.5-hour period, approximately one random verification every 27 minutes. Due to the limited duration of the test, no executions of random commands were observed. However, calculations indicate that one execution of a random command is probable every 84 hours.

TABLE 2-1 RANDOM VERIFICATION AND EXECUTION OF COMMANDS

TEST CONDITION	TIME INTERVAL BETWEEN RANDOM *	
	COMMAND VERIFICATIONS	COMMAND EXECUTIONS
Dual uplink RF carriers		
with valid commands	2 seconds	1 minute
with idling ones	2 seconds	7 minutes
with no modulation	10 seconds	29 minutes **
Single uplink RF carrier	0	0
No uplink RF carrier	27 minutes	84 hours **

* Worst Case Conditions

** Calculated

SECTION 3
SYSTEMS DESCRIPTION

3.1 General

This section describes the equipment and test configurations used in the test program.

3.2 Equipment Tested

The basic system test configuration for the MSFN-ALSEP uplink tests is shown in Figure 3-1. The ALSEP equipment was located in a shielded enclosure to provide RF isolation. ALSEP test model number 1 was tested and was electrically representative of the ALSEP flight hardware. The MSFN unified S-band equipment used is listed in Table 3-1. Detailed information on the test equipment shown in Figure 3-1 can be found in Reference 2.

Figure 3-2 shows the radioisotope thermoelectric generator (RTG) simulator, and Figure 3-3 shows the ALSEP as tested.

A simplified block diagram of the ALSEP data subsystem is presented in Figure 3-4.

The 2119 MHz uplink carrier is received by the central station antenna, coupled through the diplexer, and applied to the command receiver. The output signal from the command receiver is a phase shift keyed (PSK) composite signal of the 2 kHz data subcarrier and a 1 kHz synchronization subcarrier which is applied to the command decoder. The data demodulator demodulates the PSK signal to provide digital timing and command data. The command decoder decodes the command data and applies the discrete commands to control ALSEP operations. The data processor accepts binary and analog data from the experiment and support subsystems. It generates timing and synchronization signals, converts analog data to digital form, formats digital data, and provides data in the form of a split-phase

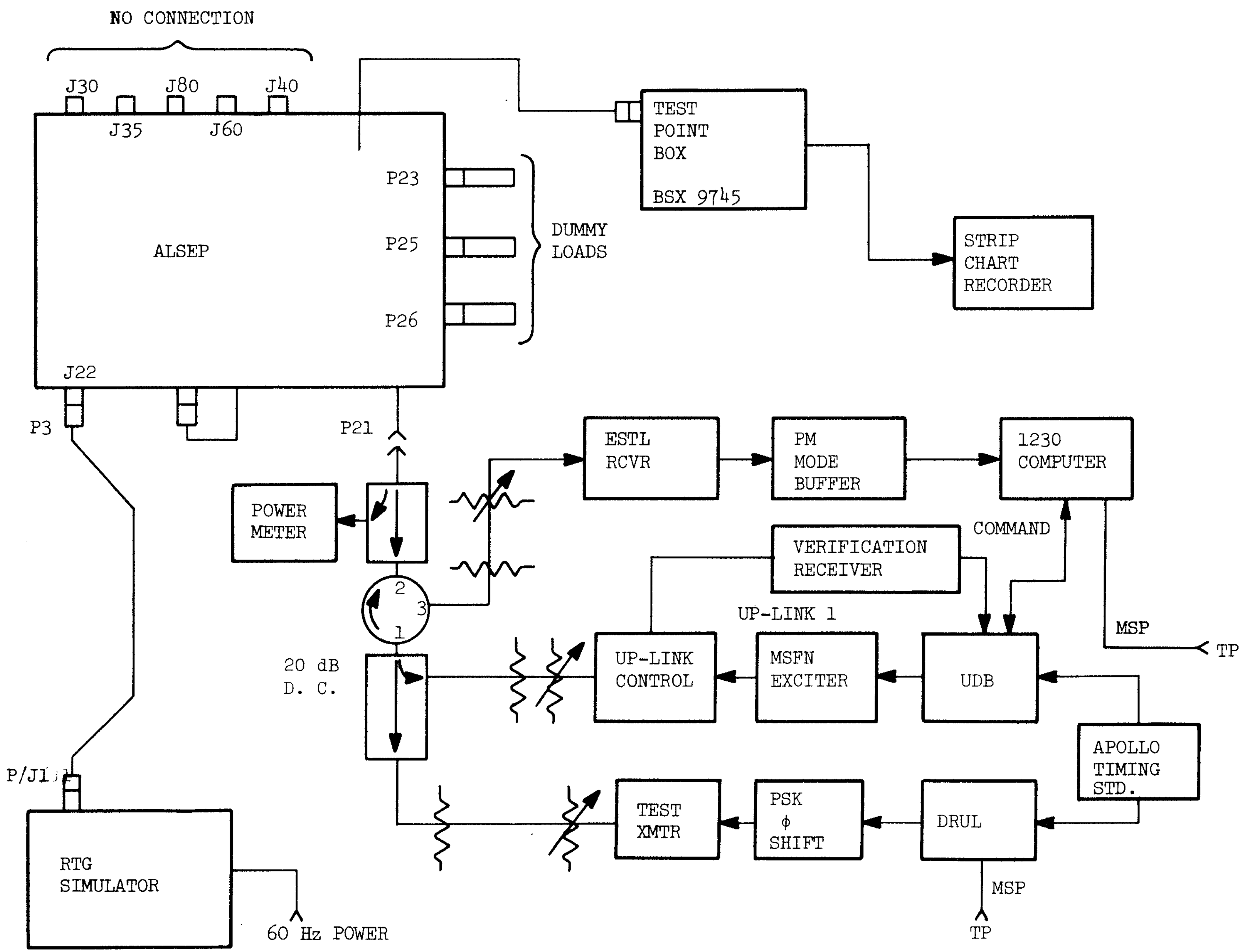


Figure 3-1 Block Diagram of the Basic System Test Configuration

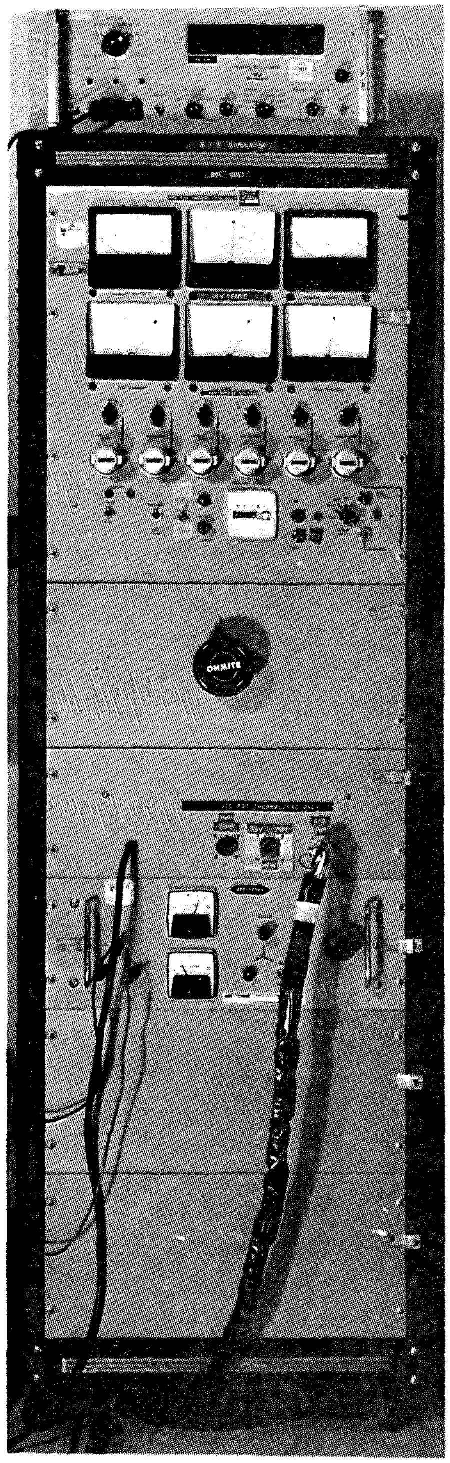


Figure 3-2 RTG Simulator

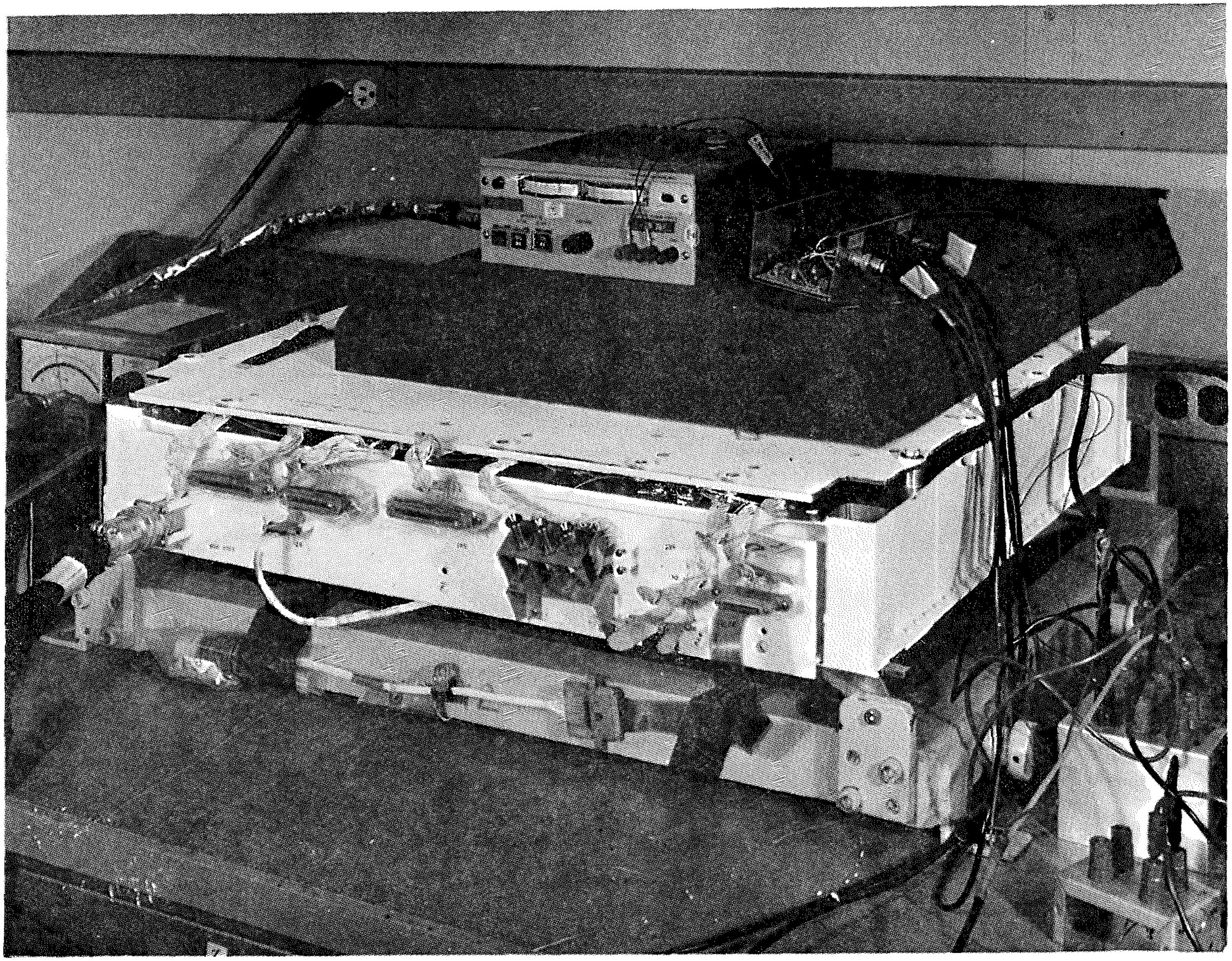


Figure 3-3 ALSEP Equipment

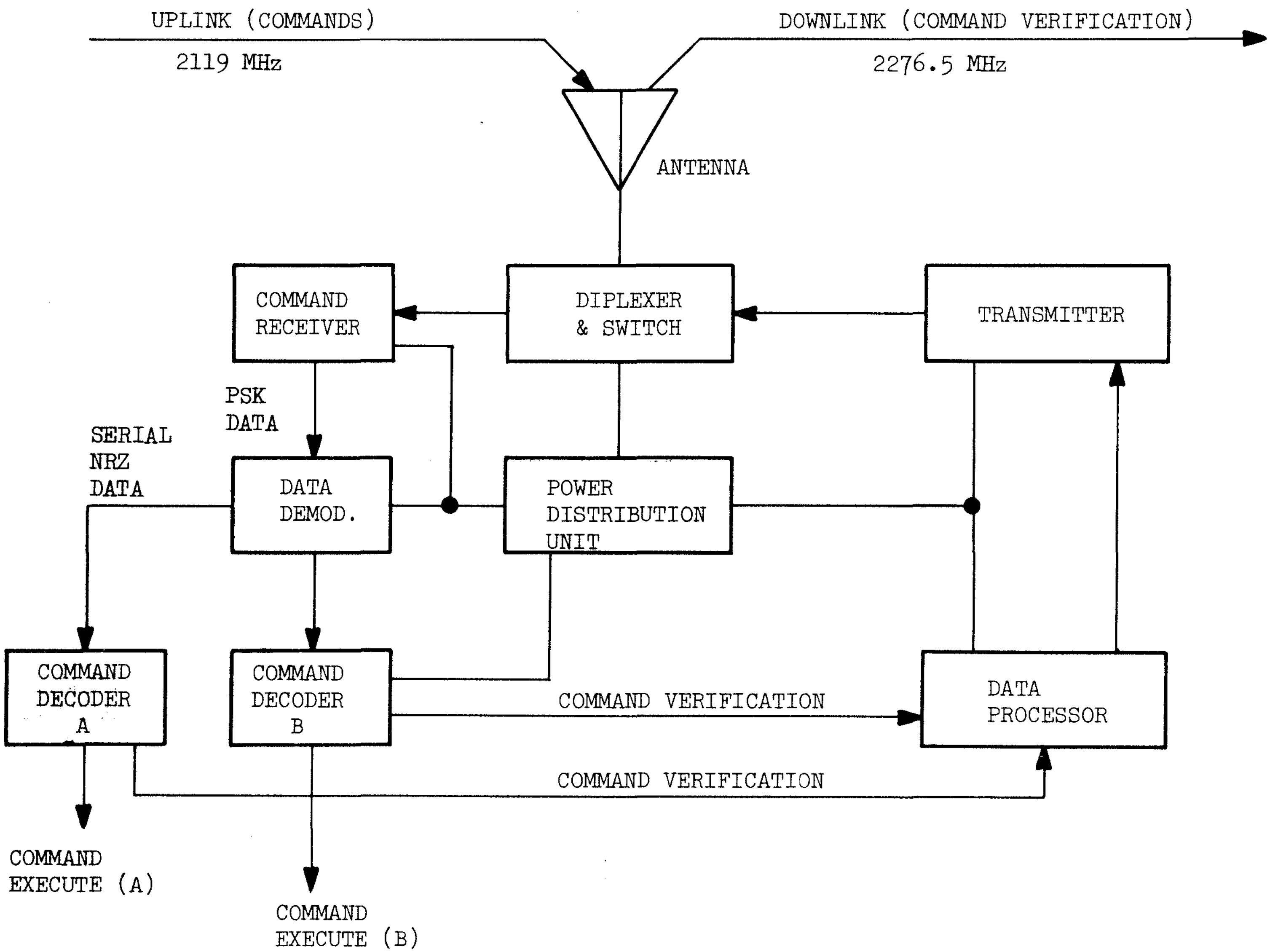


Figure 3-4 Data Subsystem, Simplified Block Diagram

TABLE 3-1

MAJOR MSFN EQUIPMENT UTILIZED

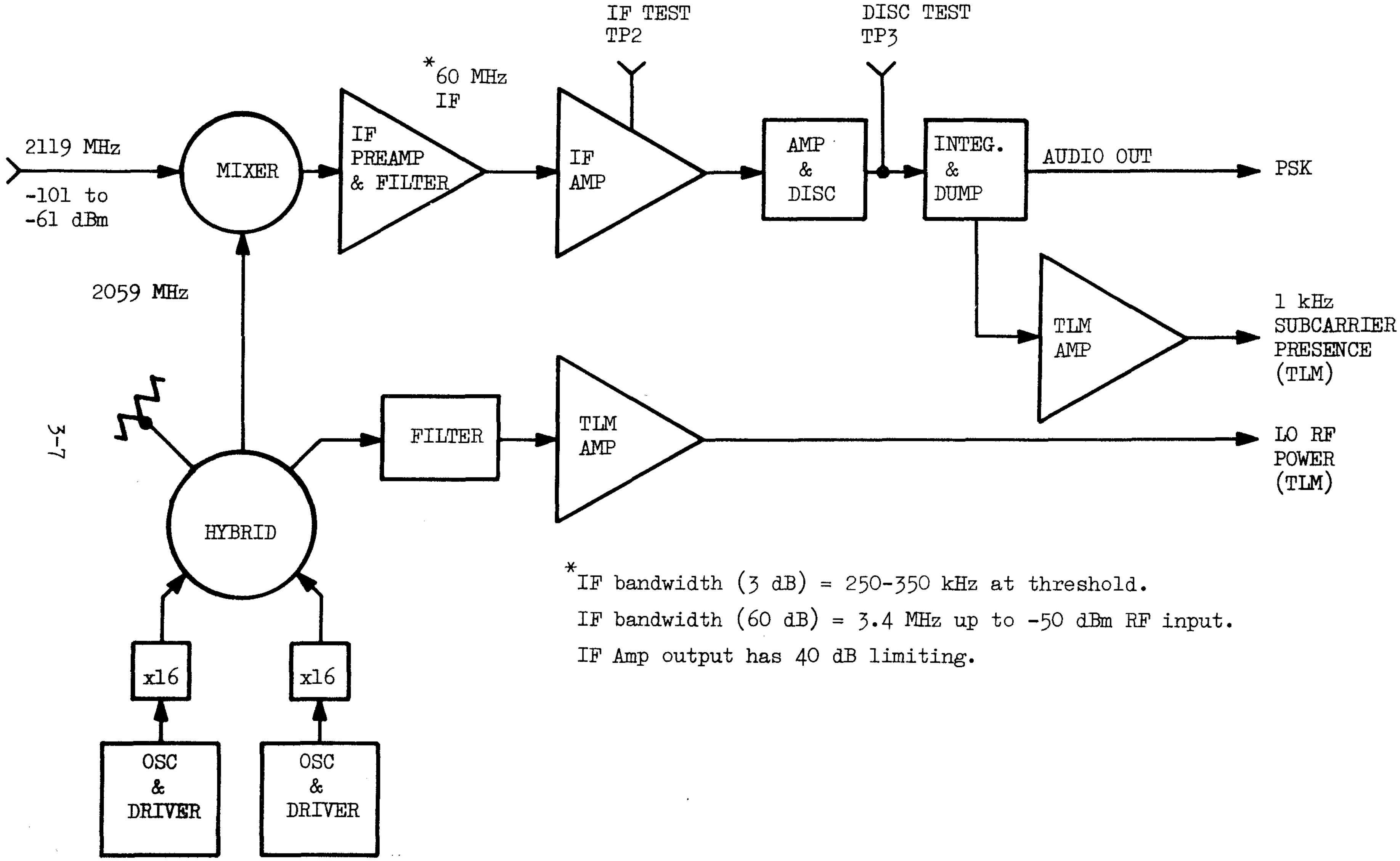
Ground Station Subsystem Nomenclature	Serial Number
USB Receiver/Exciter	14
Apollo Updata Buffer	15
1230 Computer	17
ALSEP Command Verification	
Receiver System	
USBSS CM/ALSEP Test XMTR	
DRUL	56284

modulated signal to the transmitter. The transmitter generates the downlink transmission carrier and phase modulates the carrier with the signal from the data processor. The transmitter signal is selected by the diplexer switch and routed to the antenna for downlink transmission to the MSFN.

Figure 3-5 is a more detailed block diagram of the command receiver. The input signal is mixed with a crystal controlled 2059 MHz local oscillator signal to produce a 60 MHz intermediate frequency (IF) signal. The oscillator/driver amplifier output frequency of 128.7 MHz is increased to 2059 MHz by a frequency multiplier. The two 2059 MHz signals from the frequency multipliers are applied to a strip-line hybrid which is the combiner for redundant local oscillators.

The 60 MHz IF signal from the mixer is amplified in the IF preamplifier and filter module and in the IF amplifier module. The discriminator is a double tuned diode discriminator which provides frequency modulation (FM) detection. The integrator circuit in the output amplifier and integrator module provides phase detection of the FM detected signal. The output signal from the command receiver is a PSK signal which is applied to the data demodulator.

The data demodulator (Figure 3-6) accepts the composite PSK signal from the command receiver. The demodulator is divided into three sections--the synchronization detection section, the data detection section, and the threshold detection section.



*IF bandwidth (3 dB) = 250-350 kHz at threshold.
IF bandwidth (60 dB) = 3.4 MHz up to -50 dBm RF input.
IF Amp output has 40 dB limiting.

Figure 3-5 ALSEP Command Receiver

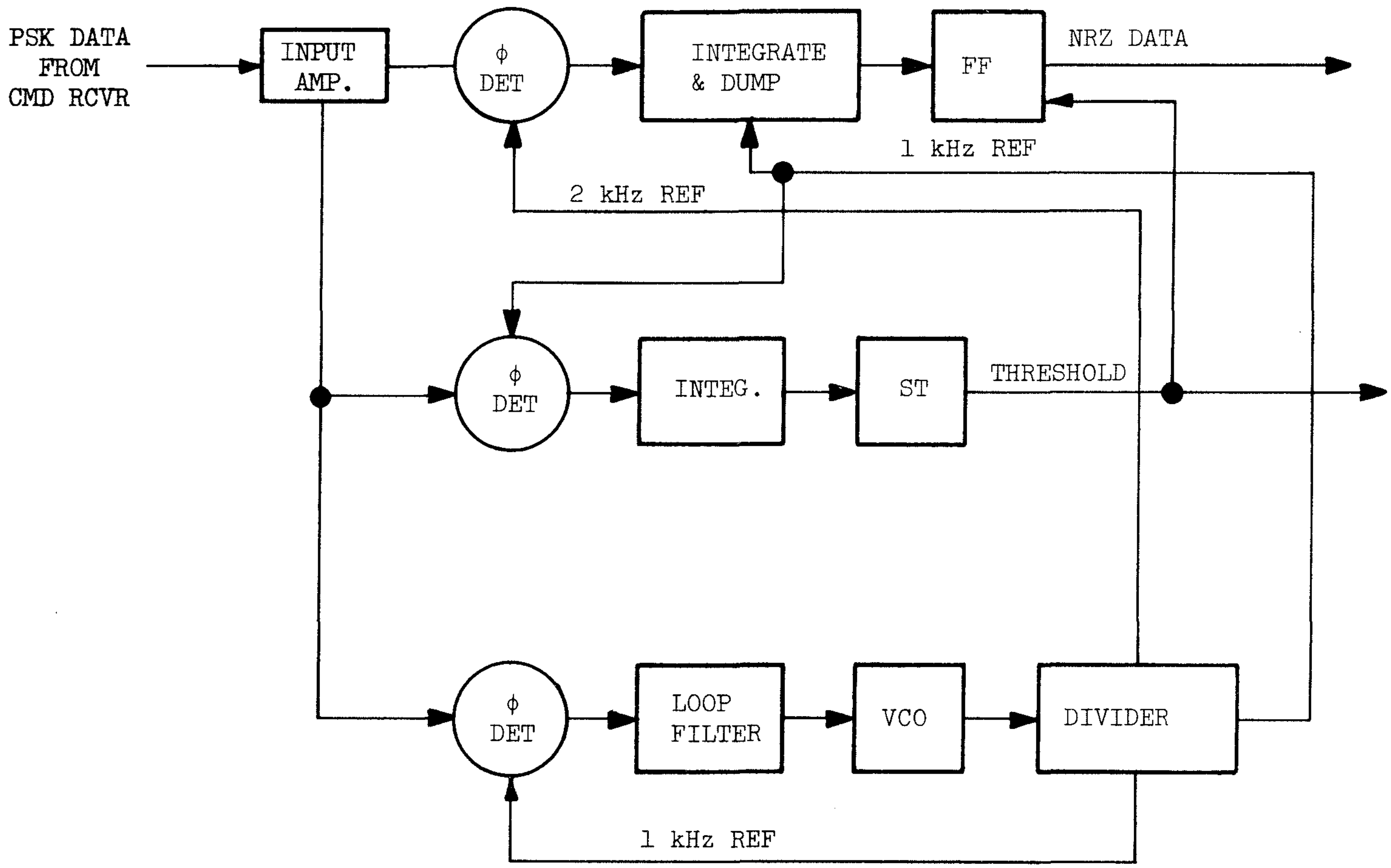


Figure 3-6 Data Demodulator Block Diagram

A voltage controlled oscillator (VCO) phase-lock loop in the synchronization detection section establishes bit synchronization by comparing the 1 kHz input with a 1 kHz reference signal. The filtered synchronization phase detector output is used to control the operation of the VCO. Synchronized 1 kHz, 2 kHz, and 4 kHz signals are applied to the digital section for sub-bit timing purposes.

Data detection and extraction are accomplished in the data detection section by comparing the 2 kHz component of the PSK signal with a synchronized 2 kHz reference signal. The data phase detector output is fed to an integrator and dumped at a 1 kHz repetition rate. Mark or space decisions are stored in the data flip-flop. The output of the flip-flop is serial nonreturn-to-zero (NRZ) data.

The threshold function indicates 1 kHz subcarrier phase lock and enables the output of valid data. It uses a phase detector, an integrator, and a Schmitt trigger circuit.

Figure 3-7 is a functional diagram of the command decoder with the digital section shown in detail. The digital section of the decoder consists of a decoder controller, a code programmer with an address detector gate, an address memory flip-flop, parity check circuitry, an eight stage shift register, 100 command decoding gates, and a delayed command sequencer.

To improve the reliability of the digital logic, redundant subsections provide an alternate path to decode a command message. These redundant subsections are referred to as A and B. Each of the subsections function identically, but the address gates respond to different address information.

In the normal mode, the serial data enter shift registers A and B and continually shift through these registers. The decoder remains in the search mode until a valid address has been detected by either the A or B address gate. For example, if address decoder A detects a valid address code in shift register A (8 bit data register), it immediately sets address

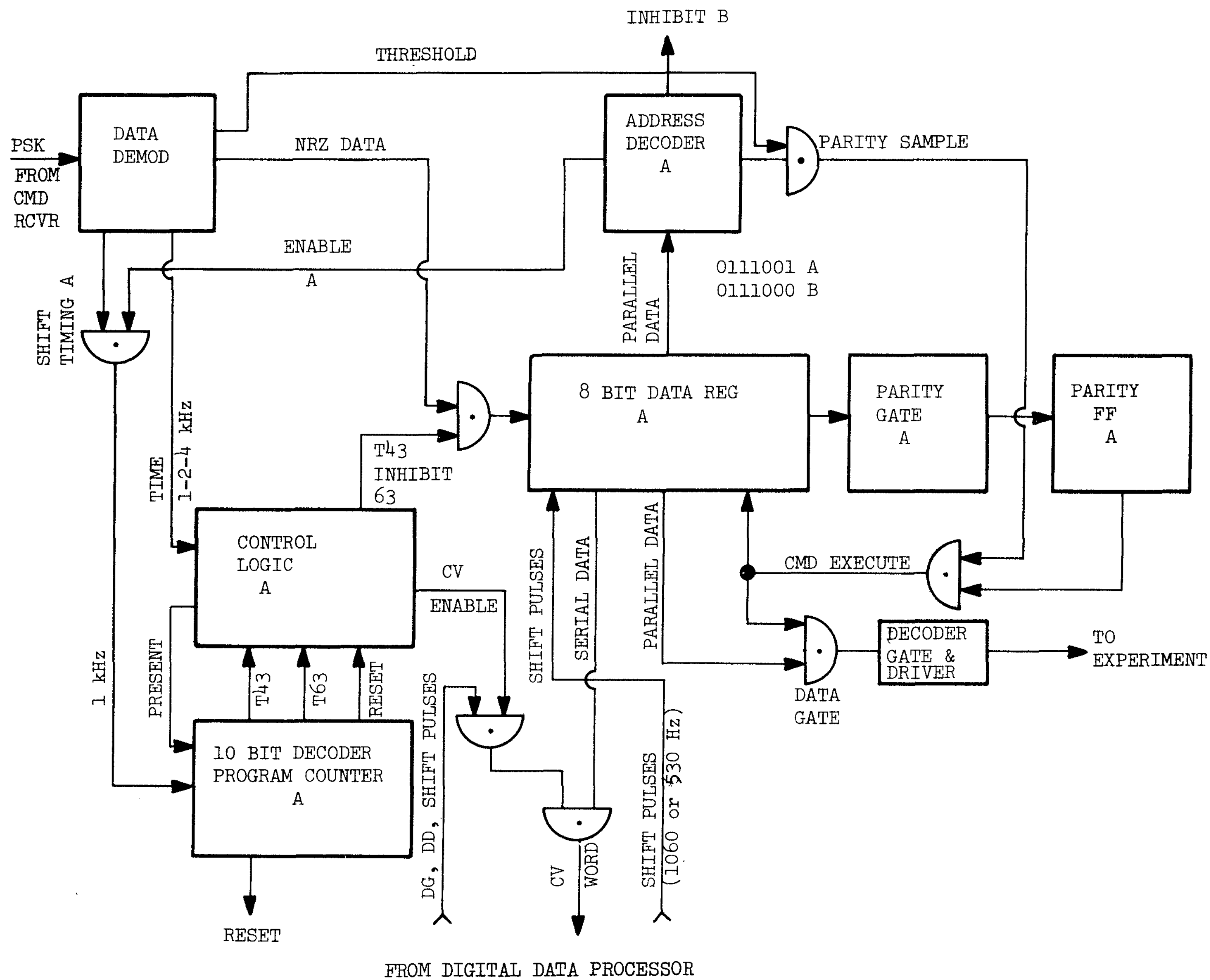


Figure 3-7 Command Decoder, Functional Diagram

memory flip-flop A, which simultaneously starts the 10-bit decoder program counter A, and inhibits address gate B. The program counter A begins counting at T29 after seven timing periods, and programmer A activates parity comparator A which performs a bit-by-bit comparison of the seven command and seven command complement bits (see Figure 3-8). At the end of this comparison, a parity check takes place. If correct, the appropriate command decode gate is activated for 20 milliseconds and a command execute pulse sets the first stage of shift register A to a one. This signifies that a proper command has been received. If parity does not check, the command is inhibited and the first stage of shift register A is set to a zero. Table 3-2 lists the commands for ALSEP test model #1.

Normally at this time, shift register A contains the seven bit command and the parity information. This information, named the command verification (CV) message, stays in the register until the data processor requests transfer (data demand) of this data. As soon as the transfer takes place, a master reset signal returns the command decoder to the search mode. Likewise, the command verification message is inhibited if the data demand is not activated during the following two-second timing interval.

In contrast to the normal mode of operation, the active seismic mode inhibits the command verification message from reaching the data processor. The command decoder receives an active seismic ON command to operate in this mode and an active seismic OFF command to operate in the normal mode. The foregoing description applies equally to subsection B whenever address gate B detects its own address.

TABLE 3-2

ALSEP COMMANDS (OCTAL)

003	ACTIVE SEISMIC ON	101	FEEDBACK FILTER
005	ACTIVE SEISMIC OFF	102	COARSE SENSOR
006	NORMAL DATA RATE	103	LEVELING MODE
007	SLOW DATA RATE	104	OCTAL COMMAND 104
011	RESET X AND Y PROCESSOR	105	OCTAL COMMAND 105
012	XMTR A SELECT	106	OCTAL COMMAND 106
013	XMTR ON	107	OCTAL COMMAND 107
014	XMTR OFF	110	OCTAL COMMAND 110 (STROBE)
015	XMTR B SELECT	111	THERMAL CONTROL BYPASS ON
017	PDM LOAD 1 ON	112	THERMAL CONTROL BYPASS OFF
021	PDM LOAD 1 OFF	113	DUST COVER REMOVAL
022	PDM LOAD 2 ON	114	AUTOMATIC VOLTAGE SEQUENCE ON
023	PDM LOAD 2 OFF	115	STEP VOLTAGE LEVEL
024	BACKUP HEATER ON	117	AUTOMATIC VOLTAGE SEQUENCE OFF
025	BACKUP HEATER OFF	120	CHANNELTRON VOLTAGE INCREASE ON
027	DUST DETECTOR ON	121	CHANNELTRON VOLTAGE INCREASE OFF
031	DUST DETECTOR OFF	122	DUST COVER REMOVAL
032	TIMER OUTPUT ACCEPT	123	RANGE SELECT
033	TIMER OUTPUT INHIBIT	124	STEADY FIELD OFFSET
034	DATA PROCESSOR X ON	125	STEADY FIELD HOLD
035	DATA PROCESSOR Y ON	127	FLIP CALIBRATE INHIBIT
036	EXP 1 POWER ON	131	FLIP CALIBRATE INITIATE
037	EXP 1 POWER STANDBY	132	FILTER FAILURE BYPASS
041	EXP 1 STANDBY OFF	134	THERMAL CONTROL SELECT
042	EXP 2 POWER ON	135	NORMAL (GRADIENT)MODE SELECT
043	EXP 2 POWER STANDBY	136	RING-SOURCE CONDUCTIVITY MODE
044	EXP 2 STANDBY OFF	140	HEAT-PULSE CONDUCTIVITY MODE SELECT
045	EXP 3 POWER ON	141	FULL SEQUENCE
046	EXP 3 POWER STANDBY	142	PROBE 1 SELECT
050	EXP 3 STANDBY OFF	143	PROBE 2 SELECT
052	EXP 4 POWER ON	144	MEASUREMENT SELECT OCTAL 144
053	EXP 4 POWER STANDBY	145	MEASUREMENT SELECT OCTAL 145
054	EXP 4 STANDBY OFF	146	MEASUREMENT SELECT OCTAL 146
055	EXP 5 POWER ON	152	HEATER ADVANCE
056	EXP 5 POWER STANDBY	156	GEOPHONE CALIBRATE
057	EXP 5 STANDBY OFF	160	SET SEISMIC DATA MODE
060	SET 1	162	SEQUENTIAL FIRE
062	SET 2	163	FIRE GRENADE 1
063	CHANGE GAIN LPX-LPY	164	FIRE GRENADE 2
064	GAIN CHANGE LPZ	165	FIRE GRENADE 3
065	CAL S. P.	166	FIRE GRENADE 4
066	CAL L. P.	170	ARM GRENADES
067	GAIN CHANGE SPZ	171	SET ENGRG DATA MODE
070	LEVELING POWER X MOTOR	172	GEOPHONE SEQUENCE
071	LEVELING POWER Y MOTOR		
072	LEVELING POWER Z MOTOR		
073	UNCAGE		
074	LEVELING DIRECTION		
075	LEVELING SPEED		

Figure 3-8 illustrates the program timing associated with the operation of the command decoder. Commands are transmitted as a 61-bit message with the following format:

a.	Preamble	20 bit minimum (all zeros or all ones for synchronization)
b.	Decoder address	7 bits (selects decoder subsection)
c.	Command complement	7 bits (for parity check)
d.	Command	7 bits
e.	Timing	20 bits (all zeros or all ones - command execution interval)

The demodulator section achieves phase and bit synchronization during the first 18 timing bits of the preamble and maintains synchronization during the entire command timing interval.

The 64, 32, 16, 8, 4, 2, and 1 binary weighted code is used to decode the seven-bit decoder address group, the seven-bit command complement group, and the seven-bit command group.

Seven address bits are used to uniquely command three ALSEP assemblies. Each command decoder responds to two address codes--one for section A and another for section B. The address codes for ALSEP test model #1 are 0111001 for decoder A and 0111000 for decoder B.

The seven-bit command complement group is transmitted after the address and is followed with the seven-bit command group. The command decoder performs a bit-by-bit parity check over the command complement and command bits. A decoder command is executed if parity is correct.

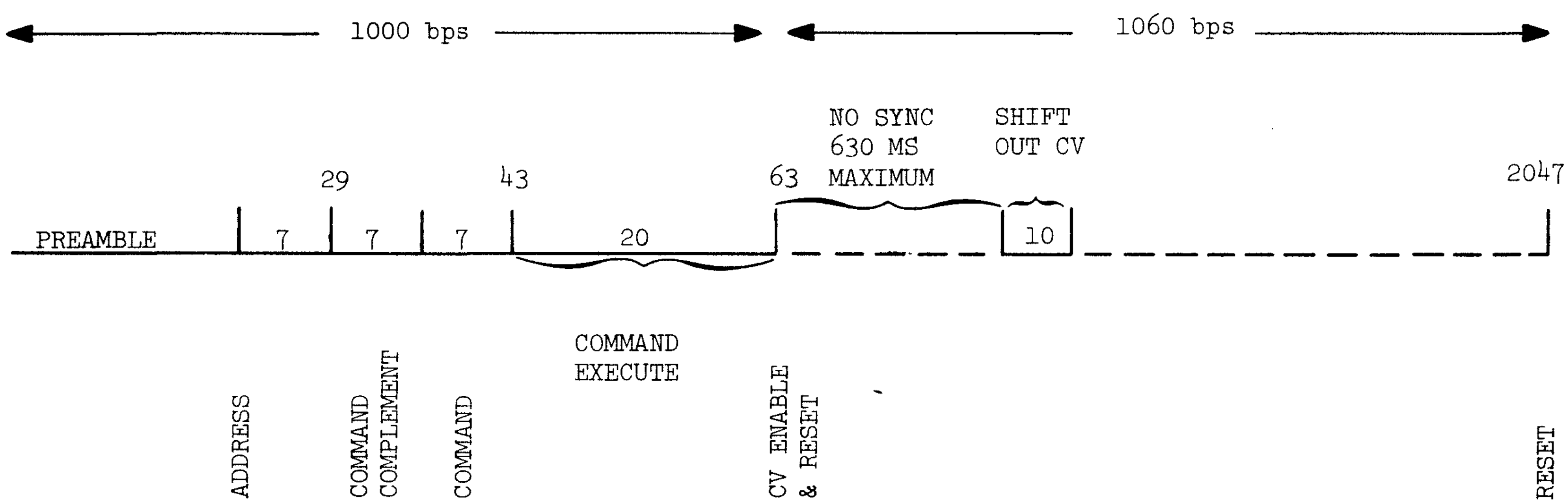


Figure 3-8 Program Timing

Twenty timing bits are transmitted to allow for a 20-millisecond command execution timing interval.

The command decoder stores an eight-bit command verification message which consists of seven command bits and a parity bit. The command verification message is sampled by, and shifted to, the data processor once every frame if a command has been received.

The command word rate is limited to approximately one message per second during a data processor normal mode of operation and to approximately one message per two seconds during the data processor slow mode of operation.

No special requirements exist for intercommand operation. Loss of synchronization between commands does not affect the operation of the command decoder.

SECTION 4
ALSEP COMMAND LINK TESTS

4.1 General

The material in this section describes the measurement techniques which were used during the ALSEP command link test program, describes the measured performance of the ALSEP under controlled test conditions, and presents calculations of the probabilities of certain events based on limited laboratory test data.

4.2 Dual Uplink RF Carriers With Valid Commands Tests

The purpose of these tests was to determine the effect of two simultaneous uplink RF carriers modulated with different valid commands on the ALSEP.

4.2.1 Test Procedure

A block diagram of the test configuration is shown in Figure 4-1. The two uplink RF carriers were provided by the MSFN exciter and the test transmitter, so the two RF sources were not synchronized. The 1230 computer, using the ALSEP command program, sent commands to the updata buffer (UDB), which converted the commands to phase shift keyed (PSK) format. The PSK signal modulated the 2119 MHz uplink RF carrier at 3 radians. The down range uplink (DRUL) supplied commands to the test transmitter, which provided the interfering uplink signal. Switches within the DRUL equipment allowed the logic to be set to provide a preselected command at any desired rate. The two uplink commands were not sent simultaneously, but the PSK 1 kHz references were synchronized.

The two modulated RF carriers, 2119 MHz, were coupled through precision waveguide-beyond-cutoff variable attenuators and were coupled into the ALSEP RF input. The downlink modulated RF carrier was coupled to the ESTL receiver through a circulator which provided additional isolation between the two transmitters and the receiver.

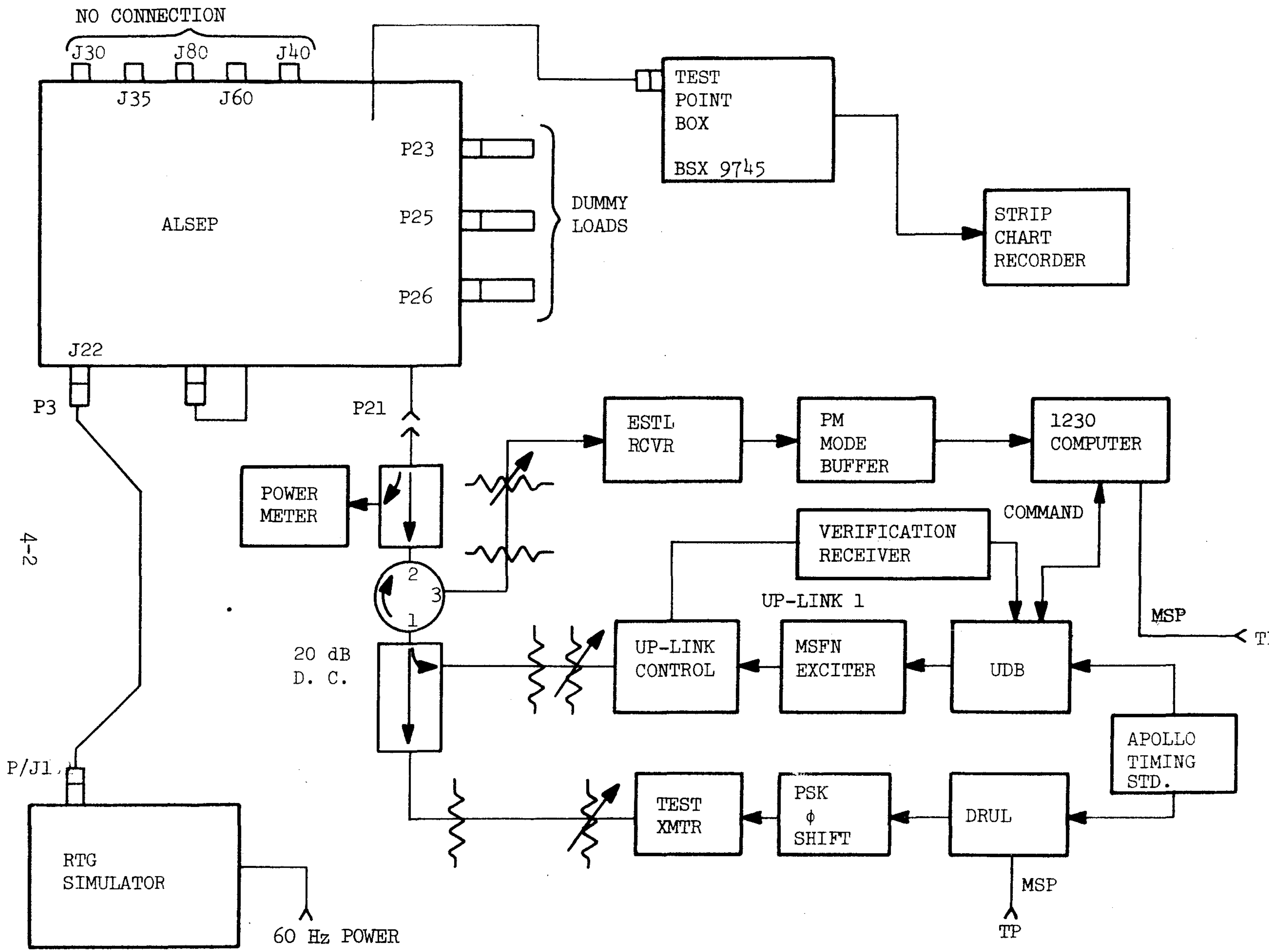


Figure 4-1 ALSEP Dual Uplink Test Configuration

The command verification (CV) enable pulse, the command execute (CX) enable pulse (issued by the digital decoder), and the message sent pulses (MSP) from the DRUL and computer were monitored continuously on the strip chart recorder.

The message sent pulses from the DRUL and the UDB via the 1230 computer were recorded on a strip chart (Figure 4-2). Simultaneously, the command verification enable A and B pulses and the command execute A and B pulses were recorded. Therefore, time correlation between uplink commands sent, downlink verifications of commands received by the ALSEP, and commands executed by ALSEP could be made. Since the strip chart recordings provided no method of identifying a particular CV or CX, the 1230 computer in conjunction with the ESTL receiver and PM mode buffer provided additional data. The computer printout (Table 4-1) word 46 identified all CV's and CX's which can be time correlated to the strip chart recordings. The CV enable pulses are numbered on the strip chart recording and identified on the computer printout. It can be seen that the circled command execute pulse corresponded to CV enable pulse "8" and was randomly executed because it did not correspond to a message sent pulse. The random execute was identified as a command 134 from the computer printout.

4.2.2 Results

The results of all ALSEP command link tests performed in this program are itemized in Table 4-2. The first column in the table identifies the test number which is composed of the month, day, year, and number of the test run during that day. The duration of the test in minutes is given in next column. The power output, PSK phase, and RF carrier frequency from the updata buffer/MSFN exciter were held constant while the same parameters were varied in the DRUL/test transmitter. ΔP, $\Delta\phi$, and Δf_c in the table show the differences in RF carrier power, PSK phase, and RF carrier frequency between the two uplink signals. During the

TABLE 4-1 SAMPLE COMPUTER PRINT-OUT

	DAY	HR	MIN	SEC	FRAME	WORD 33	WORD 46	XMIT COUNT	PCM COUNT	TSTA COUNT
	01	21	38	12	8	120	63		352	21
	01	21	38	12	9	233			353	21
	01	21	38	15	13	1	164		354	21
	01	21	38	17	17		66		355	22
	01	21	38	18	18		167		356	22
	01	21	38	20	21	216			357	22
	01	21	38	27	33	207	47		358	22
	01	21	38	28	34	216	1		359	22
	01	21	38	29	37	261	143		360	22
	01	21	38	30	38		70		361	22
	01	21	38	33	43	202	34		362	22
1	01	21	38	42	58	202	132		363	22
2	01	21	38	43	59	246	65		364	22
3	01	21	38	44	61	210	57		365	22
4	01	21	38	46	65	333	72		366	22
5	01	21	38	49	69		124		367	23
6	01	21	38	50	71	205	67		368	23
7	01	21	38	54	78	227	16		369	23
8	01	21	38	58	84	144	134		370	23
9	01	21	38	58	85		54		371	23
	01	21	39	03	2	15	174		372	23
	01	21	39	05	6	301	106		373	23
	01	21	39	06	7	134	43		374	23
	01	21	39	06	8	120	3		375	23
	01	21	39	07	9	166			376	23
	01	21	39	12	17		172		377	23

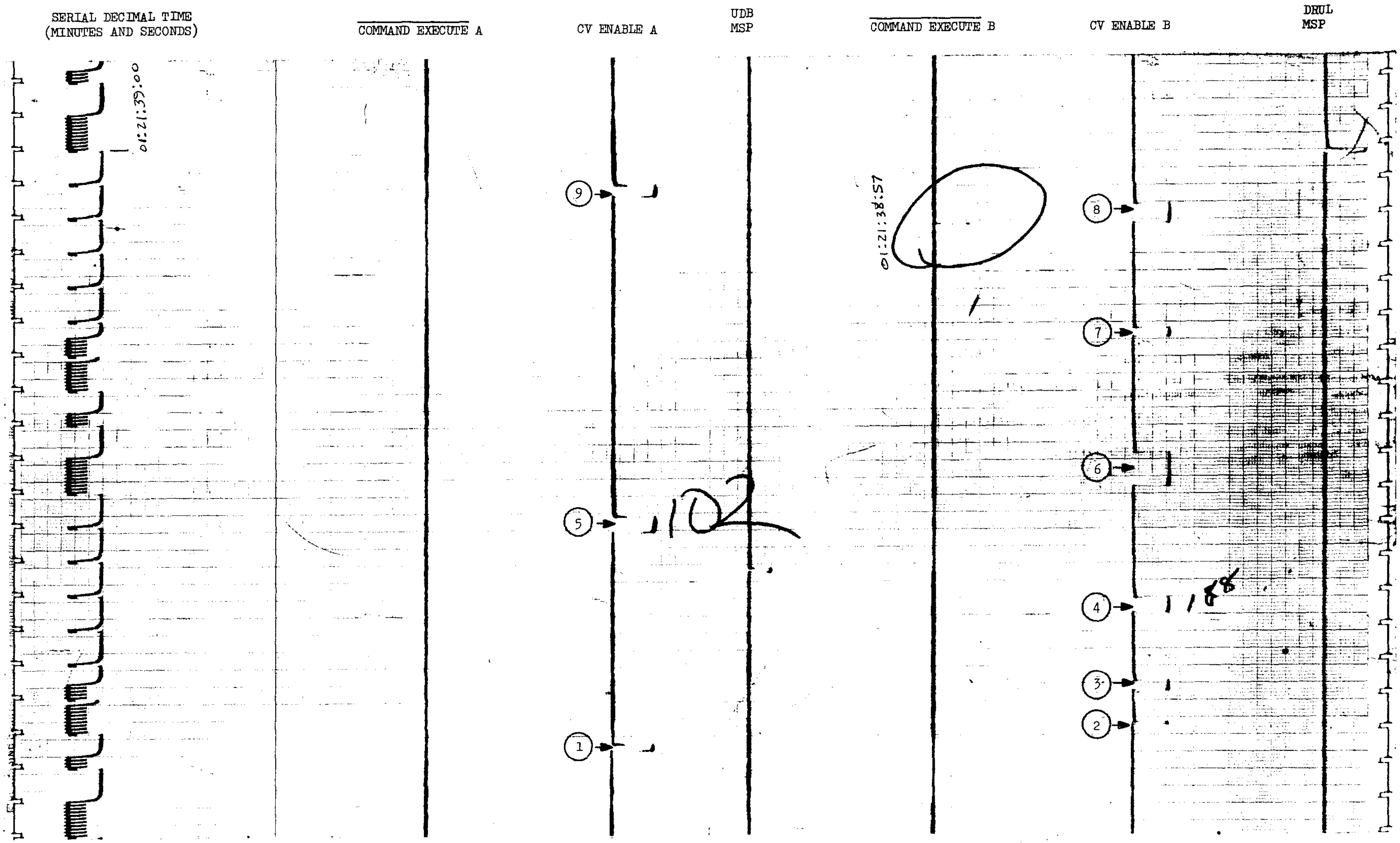


Figure 4-2 Sample Strip Chart Recording

test run on August 25, 1969, (TPET No. 082569-1) 116 commands, 034, were sent from the UDB via the MSFN exciter and 91 commands, 006, were sent from the DRUL via the test transmitter to the ALSEP. Both uplink commands were addressed to ALSEP command decoder A. The ALSEP processed and executed no commands; however, the ALSEP command decoder A verified 70 commands and decoder B verified 36 commands. None of the command verifications corresponded to the commands sent.

By analyzing all data in Table 4-2, it was evident that when the ALSEP received two simultaneous equal amplitude uplink RF carriers which were modulated with two different valid commands, the ALSEP was unable to execute or verify either uplink command, but gave 106 random command verifications. With 1.5 dB to 3 dB difference in RF carrier power levels, approximately 75 percent of the commands from the stronger uplink RF carrier were executed and no commands were executed from the weaker RF carrier; approximately 1 random command was executed every 2.3 minutes under these conditions.

With the PSK waveforms 90 degrees out of phase and with the RF carrier power levels equal, the ALSEP was unable to execute either valid uplink command; however, it verified 536 and executed one random command during the 15-minute test. With the PSK phase shift set to 70 degrees, the conditions remained the same except that 835 random commands were verified and 4 random commands were executed by ALSEP in 30 minutes.

When ALSEP received two simultaneous uplink RF carriers with equal power and with 1 kHz or 2 kHz carrier frequency offsets, one carrier with a valid command and the other unmodulated, it was unable to execute the uplink command.

4.3 Dual Uplink Carriers With All Ones Modulation Tests

The purpose of these tests was to determine the effect of two simultaneous uplink RF carriers modulated with all ones (idling) on the ALSEP.

TABLE 4-2

ALSEP COMMAND LINK TEST DATA SUMMARY FOR ESTL

TEST NO.	TIME (MIN.)	DRUL COMPARED TO UDB ΔP (dB)	Δφ (deg.)	Δfc (kHz)	COMMAND SENT	ADDRESS	NUMBER OF COMMANDS SENT	STRIP CHART CV ENABLE	COMMAND EXECUTE ENABLE
082569-1	15	0	0	0	UDB 034 DRUL 006	A A	116 91	70 A 36 B	0 0
082569-2	5	0	0	0	UDB 034 DRUL 006	A B	37 30	54 A 126 B	1A(177) 2B(177)
082569-3	15	0	0	0	UDB 034 DRUL 006	A B	116 89	56 A 34 B	1A(177) 0
082669-1	15	-1.5	0	0	UDB 034 DRUL 006	A B	113 90	222 A 192 B	85A(61 ea 034, 20 ea 177, 2 ea 137, 1 ea 167, 1 ea 035) 0
082669-2	80	0	0	0	UDB & DRUL -	All 1's w/o TP		312A,564B	0
082669-3	60	0	0	0	UDB & DRUL	All 1's with TP		323A,455B	0
082769-1	120	0	0	0	UDB - DRUL -	All 1's with TP All 1's w/o TP		344A,1042B	3A, 7B (9 ea 177, 1 ea 077)
082769-2	15	-1.5	0	0	UDB - DRUL -	All 1's with TP All 1's w/o TP		5A, 3B	0
082769-3	15	-1.5	0	0	UDB & DRUL -	All 1's w/o TP		12A, 3B	0
082769-4	15	-1.5	0	0	UDB & DRUL -	All 1's with TP		2A, 0B	0
082769-5	30	0	$+45^\circ$	0	UDB & DRUL -	All 1's with TP		505A,932B	1 (177)
082769-6	30	0	$+45^\circ$	0	UDB & DRUL -	All 1's w/o TP		403A,1107B	1 (160)
082769-7	30	0	$+45^\circ$	0	UDB - DRUL -	All 1's with TP All 1's w/o TP		510A,1733B	0
082769-8	30	0	$+90^\circ$	0	UDB & DRUL -	All 1's with TP		644A,1129B	3A, 11B (154, 2 ea 137,115,106,075,073,071,066,065,056,032, 031,021) Command 056(Exp. 5 power standby) was observed in equipment.
082869-1	30	0	$+90^\circ$	0	UDB & DRUL -	All 1's w/o TP		527A,872B	6A, 4B (066,067,107,123, 2 ea 127,145,152,157,165) Command 007 ("To LBR") was observed in equipment.
082869-2	30	0	$+90^\circ$	0	UDB - DRUL -	All 1's with TP All 1's w/o TP		753A,989B	3A, 10B (2ea 000,033,042,056,067,075,111,112,125,133,134,173)
082869-3	30	0	-90°	0	UDB & DRUL -	All 1's with TP		459A,857B	8A, 6B (006, 2 ea 013,031,067,115,121,126,134,152,173, 2 ea 176,177)
082869-4	30	0	-90°	0	UDB - DRUL -	All 1's with TP All 1's w/o TP		361A,661B	3A, 6B (025,061,073,133,136,137,167, 2 ea 177) Command 012 (XMTR A select) was observed in equipment.
082869-5	30	0	-90°	0	UDB & DRUL -	All 1's w/o TP		641A,886B	3A, 12B (002,006,033,041,061,063,064,073,074,133,145,151,160,027)
082869-6	30	0	-45°	0	UDB & DRUL -	All 1's with TP		965A,1011B	1A, 3B (017,071,173,177)
082969-1	30	0	-45°	0	UDB & DRUL -	All 1's w/o TP		704A,987B	4B (176, 3 ea 177)
082969-4	30	0	-45°	0	UDB - DRUL -	All 1's with TP All 1's w/o TP		766A,797B	1B (170)

TABLE 4-2

ALSEP COMMAND LINK TEST DATA SUMMARY FOR ESTL (CONTINUED)

TPET NO.	TIME (MIN.)	DRUL COMPARED TO UDB ΔP (dB)	Δφ (deg.)	Δfc (kHz)	COMMAND SENT	ADDRESS	NUMBER OF COMMANDS SENT	STRIP CHART CV ENABLE	COMMAND EXECUTE ENABLE
082969-5	15	-1.5	+90°	0	UDB & DRUL -	All 1's with TP		0	0
082969-6	30	0	+90°	+1	UDB & DRUL -	All 1's with TP		238A,517B	8B (000,002,036,055,106,121,141,161) Command 014 (XMTR Off) was observed in equipment.
082969-7	30	0	+90°	+2	UDB & DRUL -	All 1's with TP		195A,302B	3B (000,112,134)
083069-1	15	0	--	+1	UDB & DRUL -	No modulation		10A,81B	0
083069-2	15	0	--	+2	UDB & DRUL -	No modulation		0	0
083069-3	30	0	0	+1	UDB & DRUL -	All 1's with TP		564A,697B	1A (000)
083069-4	30	0	0	+2	UDB & DRUL	All 1's with TP		493A,363B	0
083069-5	15	0	0	+1	UDB 034 DRUL --	A CARRIER	30 ONLY	1A,7B	0
083069-6	15	0	0	+2	UDB 034 DRUL --	A CARRIER	30 ONLY	6B	0
083069-7	30	One (UDB) Up-link -104.2 dBm				All 1's w/o TP		499A,562B	0
083069-8	30	One (DRUL) Up-link -90.1 dBm			006	B	180	180B	180B (23 ea extraneous CV 177's in NBR)
083069-9	30	One (DRUL) Up-link -90.1 dBm			007	B	180	180B	180B (11 ea extraneous CV 177's in LBR)
090269-1	240	No Up-link carrier						9B	0 Executes. Random CV: (050,061,065,066,111,132,135,137,157)
090269-10	15	-1.5	0	0	UDB 034 DRUL 006	A A	114 90	113A,1B	99A (78 ea 034, 20 ea 000, 1 ea 177)
090369-1	15	-3	0	0	UDB 034 DRUL 006	A A	113 90	113 A 0 B	113A (79 ea 034, 33 ea 000, 1 ea w/o CV enable) 0B
090369-2	15	0	0	0	UDB 034 DRUL 006	A A	113 90	146 A 19 B	0A 0B
090369-3	15	0	+90°	0	UDB 034 DRUL 006	A A	109 90	181 A 355 B	1A (045) 0B
090369-4	15	0	+70°	0	UDB 034 DRUL 006	A A	121 90	264 A 571 B	1A (076,105,112,170) 3B
090369-5	15	0	+70°	0	UDB & DRUL -	All 1's with TP		408 A 442 B	0A 1B (073)
090369-6	15	-1.5	+90°	0	UDB 034 DRUL 006	A A	114 90	114 A 0 B	113A (71 ea 034, 39 ea 000, 3 ea 177) 0B
090369-7	30				ALSEP TRP = 102.5 dBm 1 kHz sine wave @ 1.7 rad. Peak Single UL RF level Min for 100% lock			1481A 1125 B	11A 1 ea (022;030;031;042;052;063;066;071;105;106;116; 121; 122;124;125;130;144;147;154;156;161;164;170) 12B
090269-10	15	-1.5	0	0	UDB 034 DRUL 006	A B	114 90	115 A 1 B	96A (80 ea 034, 14 ea 000, 2 ea 177) 0B
090369-11	15	-1.5	0	0	UDB 034 DRUL 006	A A	114 90	114 A 0 B	103A (73 ea 034, 28 ea 000, 2 ea 177) 0B

TABLE 4-2

ALSEP COMMAND LINK TEST DATA SUMMARY FOR ESTL (CONCLUDED)

TPET. NO.	TIME (MIN.)	DRUL COMPARED TO UDB ΔP (dB)	 Δφ (deg.)	 Δfc (kHz)	COMMAND SENT	ADDRESS	NUMBER OF COMMANDS SENT	STRIP CHART CV ENABLE	 COMMAND EXECUTE ENABLE
091569-1	290		No Up-link Carrier					8B	0
091669-1	120		No Up-link Carrier					5B,1A	0
091669-2	---		No Up-link Carrier					TP-7 & TP-8 20 ms/sample, 25 photos	
091669-3	---		No Up-link Carrier					TP-3 (Audio Out) 70 ms total, 2 photos	
091669-4	---		No Up-link Carrier					TP-9 (1 kHz Sq. Wave) 10 ms/sample, 4 photos	
091669-5	---		RF Carrier with 1 kHz S.C. at threshold					TP-9 10 ms/sample, 2 photos	
091669-6			RF Carrier with 1 kHz S.C. at threshold					TP-7 & TP-8 20 ms/sample, 4 photos	
091669-7			RF Carrier with 1 kHz S.C. at threshold					TP-3 10 ms/sample, 2 photos	
092269-1	10	-2	0	0	UDB 034 DRUL 006	A A	77 60	77A 1B	77A (75 ea 034, 1 ea 030, 1 ea 136) OB
092269-2	15	-3	0	0	UDB 034 DRUL 000	A A	115 90	115A OB	115A (115 ea 034) OB

4.3.1 Test Procedure

The test configuration used was similar to that shown in Figure 4-1, except that all ones modulation was used rather than valid commands. The tests were performed with and without a test pattern, alternate ones and zeros for 75 milliseconds at 30-second intervals. The UDB was used as the primary uplink signal and the DRUL as the interference signal. The strip chart recorder and computer printout were utilized as in the dual uplink with valid commands test. Several tests were run with a DRUL PSK phase shift, the two uplink frequencies separated by 1 kHz or 2 kHz, and with the two uplink carrier powers at different levels.

4.3.2 Results

When the ALSEP received two simultaneous uplink RF carriers which were modulated with all ones, with or without a test pattern, the ALSEP verified and executed random commands.

With the PSK waveforms in phase, 3065 random commands were verified on the downlink, and 11 were executed in 305 minutes. The results were not significantly changed by separating the RF carrier frequencies by 1 kHz or 2 kHz to simulate doppler offsets which could possibly appear as PSK interference. With the PSK waveforms 45 degrees out of phase, 9920 random commands were verified, and 11 were executed in 180 minutes. With the PSK waveforms 90 degrees out of phase, 8779 random commands were verified, and 75 were executed in 180 minutes. During a 15-minute test with 1.5 dB RF carrier power difference, no command verifications or executes were experienced. With the PSK waveforms 70 degrees out of phase, 850 commands were verified and one executed in 15 minutes. With the PSK waveforms 90 degrees out of phase and with 1 kHz or 2 kHz separation in RF carrier frequencies, 1196 random commands were verified, and 11 commands were executed in one hour.

These data indicated that the ALSEP executed the greatest number of random commands per unit of time when the PSK phase shift between the UDB and DRUL was 90 degrees.

4.4 Dual Uplink Carriers Without Modulation Tests

The purpose of these tests was to determine the effect of two simultaneous unmodulated uplink RF carriers on the ALSEP.

4.4.1 Test Procedure

The test configuration was similar to that shown in Figure 4-1, except that there was no modulation on either uplink. The two uplink carrier powers were set to equal levels, and the downlink was monitored using the strip chart recorder and computer printout.

4.4.2 Results

When the ALSEP received two simultaneous uplink RF carriers which were separated by 1 kHz, the ALSEP verified 91 random commands, but executed none during a 15-minute test. When the ALSEP received two simultaneous uplink RF carriers which were separated by 2 kHz, the ALSEP verified or executed no commands during a 15-minute test.

4.5 Single Uplink RF Carrier With Modulation Tests

The purposes of these tests were to determine the performance of the ALSEP at uplink carrier power levels near threshold and to investigate the random verification of 177 commands.

4.5.1 Test Procedure

The test configuration was similar to that presented in Figure 4-1, except that only a single uplink RF carrier was utilized. Using the UDB/MSFN exciter, all ones modulation without a test pattern was transmitted to the ALSEP. In other tests, the DRUL/test transmitter was used to transmit valid commands to the ALSEP.

4.5.2 Results

When the ALSEP received one uplink RF carrier which was modulated with a valid command, the ALSEP verified and executed all of the 360 commands sent. At times, following the downlink verifications of the uplink commands which were executed by the ALSEP, false 177 commands were verified. The 177 command cannot be executed since the ALSEP does not recognize 177 as a command (see Table 3-2).

In normal bit rate, 1060 bps, the verification of a 177 command followed the verification of a valid executed command 23 times out of 180 valid commands sent (approximately one time out of 8 valid commands). In low bit rate, 530 bps, the verification of a 177 command followed the verification of a valid executed command 11 times out of 180 valid commands sent (approximately one time out of 16 valid commands).

4.6 ALSEP Downlink Without Uplink Carrier Test

The purpose of this test was to investigate the verification and/or execution of commands by the ALSEP when no commands were received.

4.6.1 Test Procedure

The test configuration was similar to that shown in Figure 4-1, except that there was no uplink carrier. The downlink frequency was monitored continuously for the duration of the test.

4.6.2 Results

With no uplink RF carrier to the ALSEP, the ALSEP verified 23 commands on the downlink, but executed none during 10.5 hours. Of the 23 CV's observed, one was from the ALSEP command decoder A. An attempt was made to determine the relationship between the random occurrences of command verifications (CV) from either decoder.

With no uplink RF carrier to the ALSEP, photographs of the NRZ data from the data demodulator were taken and examined. It was determined that the ratio of zeros to ones was approximately 20:1. Since the address of ALSEP command decoder A is 0111001 and the address of ALSEP command decoder B is 0111000, more command verifications should occur for ALSEP command decoder B which has fewer ones. Based on the ratio of ones to zeros in the NRZ data into the command decoders, there should be approximately 20 verifications of commands on command decoder B (CV_B) for each verification of a command on command decoder A (CV_A). The laboratory data discussed above showed 1 CV_A and 22 CV_B in 10.5 hours. The data agreed closely, but the accuracy was limited by the number of data samples.

Since it was not feasible to conduct long, time consuming tests and investigations such as would be required to determine accurately the time interval between random CV's and CX's, the following calculations based on known parameters and measured performance were made.

The probability of a command execute (P_{cx}) was calculated using the following logic:

The command execution required a 7-bit command and the 7-bit command complement. The probability of randomly receiving a particular 14-bit binary sequence was $1/2^{14}$. However, there were 2^7 different possible sequences in which the first 7 bits (command complement) and the second 7 bits (command) were valid. Therefore

$$P_{cx} \text{ (assuming good CV)} = \frac{1}{2^{14}} \left(2^7\right) = \frac{1}{2^7} = \frac{1}{128}$$

In other words, for every 128 CV's there should have been 1 CX.

Using data with 90° phase shift between the PSK references of the two uplink signals, it was found that 10,031 random CV's occurred while 84 CX's were recorded.

$$\frac{10{,}031}{84} \cong 119 \text{ CV's per CX}$$

This measured figure of 119 CV's per CX compared favorably with the calculated figure of 128, $1/2^7$.

The average time interval between random command verifications on ALSEP command decoder B with no uplink signal (22 CV_B's in 10.5 hours of testing) was

$$\frac{10.5}{22} = 0.48 \text{ hour}$$

The average time interval between random CX's should have been

$$128 \times 0.48 = 61 \text{ hours}$$

Since only 93 commands were executable out of 128 possible (see Table 3-2), the average time between CX's became

$$61 \; \frac{128}{93} = 84 \text{ hours}$$

APPENDIX A

REFERENCES

1. "MSFN/ALSEP Command Link Test Data Package," Report No. 642D-835532, Lockheed Electronics Company, 25 September 1969.

2. "Electronics Systems Test Program, ESCF Equipment Characteristics," Report No. EB65-3101 (U), Vol. II, Revision C, NASA/MSC, 31 May 1968.

MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

TO : See attached list

DATE: DEC 5 1969

EE7-11/69-104

FROM : EE/Chief, Tele/Communications Systems Division

SUBJECT: Additional results of ALSEP command anomaly investigation

Reference is made to our memorandum EE7-10/69-85, dated October 29, 1969, subject, "Results of ALSEP command anomaly investigation," with enclosures and Lockheed Electronics Test Report HASD No. 642D-835246.

The purpose of this memorandum is to provide additional information on command verifications and executions for the ALSEP when no uplink carrier is present.

With no uplink RF carrier to the ALSEP, the ALSEP verified 23 commands on the downlink, but executed none during 10.5 hours. Of the 23 CV's observed, one was from ALSEP command decoder A. An attempt was made to determine the relationship between the random occurrence of command verifications from either decoder with no uplink RF carrier to the ALSEP.

Photographs of the NRZ data from the data demodulator were examined. It was determined that the ratio of zeros to ones was approximately 20:1. This means the probability of a one, P(1), is $\frac{1}{20}$ and the probability of a zero, P(0), is $\frac{19}{20}$ or $P(1) = \frac{1}{20}$, $P(0) = \frac{19}{20}$

The ALSEP Command Decoder A address is 0111001 and address B is 0111000. From this then the probability of address A, P(A) would be calculated

$$P(A) = P(0)^3\ P(1)^4 = \left(\frac{19}{20}\right)^3 \left(\frac{1}{20}\right)^4$$

and the probability of address B, P (B) would be

$$P(B) = P(0)^4\ P(1)^3 = \left(\frac{19}{20}\right)^4 \left(\frac{1}{20}\right)^3$$

The relative occurrence of address B to A would be

$$P(B)/P(A) = \frac{\left(\frac{19}{20}\right)^4 \left(\frac{1}{20}\right)^3}{\left(\frac{19}{20}\right)^3 \left(\frac{1}{20}\right)^4} = \frac{19}{20}\ \frac{20}{1} = 19$$

This means that address B should occur approximately 19 times for each time address A occurs. The laboratory results discussed above showed 1 CV_A and 22 CV_B in 10.5 hours which agrees favorably with the predicted results.

Since it was not feasible to conduct long time consuming tests without an uplink carrier to determine the time required for a command execute the following calculations based on known parameters and measured performance were made.

The command execution requires a 7 bit command and a 7 bit command compliment. The probability of receiving a particular sequence may be calculated as follows:

From the previous page

$$P(0) = \frac{19}{20}$$

$$P(0) = \frac{1}{20}$$

Let A = Number of 1's in a sequence

B = Number of 0's in sequence

n = Length of sequence or command

Then the probability of an n bit sequence, P(n bits), is

$$P(n\ bits) = P(0)^{n-A}\ P(1)^{n-B}$$

and the probability of receiving the compliment, $P(\overline{nbits})$, is

$$P(\overline{nbits}) = P(0)^{n-B}\ P(1)^{n-A}$$

The probability of having both of these independent events occur randomly is the product of the two individual probabilities or

$$\text{Particular CX (assuming good CV)} = P(n\ bits)P(\overline{n\ bits})$$

$$\text{Particular CX (assuming good CV)} = P(0)^{n-A}P(1)^{n-B}P(0)^{n-B}P(1)^{n-A}$$

$$A+B = n$$

$$\text{Particular CX (assuming good CV)} = P(0)^{n}P(1)^{n}$$

For n=7 the probability may be given by

$$\text{Particular CX (assuming good CX)} = \left(\frac{19}{20}\right)^{7}\left(\frac{1}{20}\right)^{7}$$

There are 2^7 sequences which could exist in 7 bi-level bits and have a complement in the next 7 bits so the probability of any command existing, P_{CX} (assuming good CV), is

$$P_{CX} \text{ (assuming good CV)} = \left(\frac{19}{20}\right)^7 \left(\frac{1}{20}\right)^7 (2)^7$$

or

$$P_{CX} \text{ (assuming good CV)} = 7.55\text{X}10^{-8}\ \text{CX}/_{\text{CV}}$$

or

$$1.325\text{X}10^{7}\ \text{CV's}/_{\text{CX}}$$

The average time interval between random command verifications on ALSEP command decoder B with no uplink signal (22 VC's in 10.5 hr) was

$$\frac{10.5}{22} = .48\ \text{HR/CV}$$

The average time between command executes should be

$$(.48\ \text{HR/CV})\ (1.325\text{X}10^{7}\ \frac{\text{CV}}{\text{CX}}) = 6.37\ \text{X}\ 10^{6}\quad \text{HR/CX}$$

Only 93 commands of the possible 128 are executable or

$$(6.37\text{x}10^{6}\quad \text{HR}/_{\text{CX}})\ \left(\frac{128}{93}\right) = 8.77\text{x}10^{6}\quad \text{HR}/_{\text{CX}}$$

or 1000 years/$_{\text{CX}}$

From this it does not appear random executes with no uplink will be a problem.

ORIGINAL SIGNED BY

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