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ELECTRONIC SYSTEMS TEST LABORATORY

ORBITER/AFSCF S-BAND DIRECT LINK

SYSTEM VERIFICATION TEST REPORT

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COMMUNICATIONS EVALUATION SECTION

COMMUNICATIONS PERFORMANCE AND INTEGRATION BRANCH

TRACKING AND COMMUNICATIONS DEVELOPMENT DIVISION

ORBITER/AFSCF S-BAND DIRECT LINK

SYSTEM VERIFICATION TEST REPORT

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PREFACE

A series of communications systems tests to verify the Orbiter-AFSCF/RTS (Air Force Satellite Control Facility/Remote Tracking Station) RF compatibility and system performance were conducted at the Johnson Space Center ESTL (Electronic Systems Test Laboratory). In addition to the certification of space/ground systems compatibility and that performance is adequate to meet mission requirements, these tests provided a means to identify and resolve any potential problem areas and system limitations early so as not to impact mission schedules.

To implement these tests, prototype Orbiter communications subsystem hardware obtained from the prime contractor, and AFSCF equipment identical to the equipment located at the AFSCF/RTS, were installed in representative mission configuration in the ESTL providing a space/ground communications systems configuration equivalent to the Orbiter-AFSCF/RTS PM and FM links that will be used during the OFT program. All activities associated with this effort were supported by representatives of the AFSCF, Sunnyvale, California, and their integrations contractor, the Ford Aerospace and Communications Corporation. Results and recommendations have been summarized and presented at the tenth meeting of the CATSGT (Communications and Tracking System Ground Test) Panel. Recommendations and/or problem areas discussed herein are being worked through the CATSGT Panel with AFSCF participation.

The author wishes to acknowledge the support and participation of Meredith W. Hamilton, Linda K. Bromley and Ned J. Robinson in the preparation of this report.

CONTENTS

CONTENTS

CONTENTS

FIGURES

CONTENTS

CONTENTS

CONTENTS

CONTENTS

GLOSSARY

ACCU	AUDIO CENTRAL CONTROL UNIT
AFSCF	AIR FORCE SATELLITE CONTROL FACILITY
AG	AIR-TO-GROUND
AGC	AUTOMATIC GAIN CONTROL
ASGLS	ADVANCED SPACE GROUND LINK SYSTEM
ATU	AUDIO TERMINAL UNIT
AUX OSC	AUXILARY OSCILLATOR
BER	BIT ERROR RATE
BIØ L	BI-PHASE-L
BPS	BITS PER SECOND
BW	BANDWIDTH
dB	DECIBELS
dBHz	DECIBELS HERTZ
dBM	DECIBELS REFERENCE TO 1 MILLIWATT
DFI	DEVELOPMENT FLIGHT INSTRUMENTATION
DL	DOWNLINK
DOD	DEPARTMENT OF DEFENSE
DSIS	DEFENSE COMMUNICATIONS SYSTEM/SATELLITE CENTRAL
EMR	ELECTROMECHANICAL RESEARCH
ERDS	ESTL RANGE AND DOPPLER SIMULATOR
ESTL	ELECTRONIC SYSTEMS TEST LABORATORY
FM	FREQUENCY MODULATION
GRARE	GROUND RECEIVING AND RANGING EQUIPMENT
GSFC	GODDARD SPACE FLIGHT CENTER
GSTDN	GROUND SPACEFLIGHT TRACKING AND DATA NETWORK

GLOSSARY

Hz	HERTZ
ICD	INTERFACE CONTROL DOCUMENT
ID	IDENTIFICATION
IF	INTERMEDIATE FREQUENCY
IPS	INCHES PER SECOND
JSC	JOHNSON SPACE CENTER
KBPS	KILOBITS PER SECOND
KHz	KILOHERTZ
KW	KILOWATTS
LBW	LOOP BANDWIDTH
MFR	MULTIFUNCTION RECEIVER
MHz	MEGAHERTZ
MRR	MESSAGE REJECTION RATE
M/S	METERS PER SECOND
MSFTP	MANNED SPACE FLIGHT TELEMETRY PROCESSOR
NASA	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
NMI	NAUTICAL MILE
NRZ-L	NON-RETURN-TO-ZERO-L
NSP	NETWORK SIGNAL PROCESSOR
OFT	OPERATIONAL FLIGHT TEST
IO	OPERATIONAL INSTRUMENTATION
OPS	OPERATIONS
P/B	PLAYBACK
PCM	PULSE CODE MODULATION
PM	PHASE MODULATION

GLOSSARY

P_{rec}/N_o	POWER RECEIVED-TO-NOISE SPECTRAL DENSITY
PSK	PHASE SHIFT KEY
RCU	RF CONTROL UNIT
RF	RADIO FREQUENCY
RQMT	REQUIREMENT
RRE	RANGE RATE EXTRACTOR
RTS	REMOTE TRACKING STATION
SCE	SPACECRAFT COMMAND ENCODER
SCEIB	SCE INTERFACE BUFFER
SCV	SHUTTLE COMMAND/VOICE MULTIPLEXER/DEMULTIPLEXER
SCF	SATELLITE CONTROL FACILITY
SEN	SHIELDED ENCLOSURE NUMBER
SGLS	SPACE/GROUND LINK SYSTEM
SNR	SIGNAL-TO-NOISE RATIO
SPE	STATIC PHASE ERROR
SSO	SPACE SHUTTLE ORBITER
STC	SATELLITE TEST CENTER
STDN	SPACEFLIGHT TRACKING AND DATA NETWORK
STS	SPACE TRANSPORATION SYSTEM
TBD	TO BE DETERMINED
TDM	TIME DIVISION MULTIPLEX
TRAS	TEST REQUIREMENT AND STATUS (REPORT)
UL	UPLINK
VCO	VOLTAGE CONTROLLED OSCILLATOR
XMTR	TRANSMITTER

1. SUMMARY

1.1 General

Space-to-ground S-band communications system compatibility and performance tests were performed for the various radio frequency links. These tests conducted at the JSC/ESTL (Johnson Space Center/Electronic Systems Test Laboratory) consisted of the various uplink and downlink signal combinations (data rates) for the phase modulation system and both realtime and playback data rates for the frequency modulated downlink systems. In addition, tests involving encryption/decryption, Doppler and acquisition were performed. The results of these tests show that the S-band transponder for the Space Shuttle Orbiter is compatible with the S-band equipment of the AFSCF/RTS (Air Force Satellite Control Facility/Remote Tracking Station). It is also concluded that the performance of the Orbiter-AFSCF/RTS direct link exceeds the required performance and that this communications link will meet the system requirements of the STS (Space Transportation System).

1.2 S-Band PM Uplink Test

A summary of the uplink circuit margins is shown in Table 1-1. It can be seen from the table that the uplink performance was better (greater than 3 dB) than the required performance and that the minimum circuit margin was 47.1 dB.

1.3 S-Band PM Downlink Tests

A summary of the downlink circuit margins is shown in Table 1-2. It can be seen from the table that the measured performance of the downlink was slightly better (less than 1 dB) than the required performance and that the minimum circuit margin was 12.7 dB.

ESTL
JSC/HOUSTON

TABLE 1-1 UPLINK CIRCUIT MARGIN SUMMARY

UPLINK SIGNAL COMBINATION	P_{rec}/N_o REQUIRED FOR 1×10^{-5} BER		P_{rec}/N_o FOR 1×10^{-4} BER	EXPECTED** P_{rec}/N_o (dBHz)	EXPECTED MARGIN (dB)	MEASURED MARGIN FOR 1×10^{-4} BER (dB)	MEASURED MARGIN FOR 1×10^{-5} BER (dB)
	ICD*	MEASURED	MEASURED				
24L	56.2	53.1	51.8	103.6	47.4	52.8	50.5
24H	59.7	56.5	55.2	103.6	43.9	48.4	47.1

* ICD2-OD003 DOD MISSION REQUIREMENTS

** AFSCF/RTS TRANSMIT POWER: +30 dBW, AFSCF/RTS TRANSMIT ANTENNA GAIN 45 dB, SLANT RANGE 1122 NMI (5° ELEVATION FOR 270 NMI ORBIT), ORBITER RECEIVE ANTENNA GAIN +3 dB.

ESTL
JSC/HOUSTON

TABLE 1-2 PM DOWNLINK CIRCUIT MARGIN SUMMARY

SIGNAL COMBINATION		P_{rec}/N_o REQUIRED FOR 1×10^{-5} BER		P_{rec}/N_o FOR 1×10^{-4} BER	EXPECTED ** P_{rec}/N_o (dBHz)	MEASURED MARGIN FOR 1×10^{-4} BER (dB)	MEASURED MARGIN FOR 1×10^{-5} BER (dB)
UL	DL	ICD *	MEASURED	MEASURED			
24L	02	69.8	69.4	67.8	86.3	18.5	16.9
24H	03	72.8	73.6	72.0	86.3	14.3	12.7

* ICD2-0D003 DOD MISSION REQUIREMENTS

** OFT MISSIONS - ORBITER TRANSMIT POWER - 3 dBW; ORBITER ANTENNA GAIN - 3 dB; SLANT RANGE - 1122 NMI (5° ELEVATION FOR 270 NMI ORBIT); AFSCF/RTS ANTENNA GAIN - 47.5 dB.

1.4. S-band FM Downlink Tests

A summary of the FM downlink circuit margins is shown in Table 1-3. It can be seen from the table that the minimum circuit margin was 11.5 dB (for 128 kbps DFI telemetry data) for the Microdyne receiver and 8.4 dB (for 8:1 playback of 128 kbps OI telemetry data) for the ASGLS receiver.

1.5 RF Acquisition Tests

It was determined during the Orbiter/GSTDN PM direct link tests that the uplink carrier must be unmodulated for initial acquisition of the uplink and that reacquisition with a modulated uplink carrier after a loss of the uplink lock will most probably result in a false lock.

False locks of the modulated downlink carrier were not completely eliminated by the main carrier acquisition unit (anti-sideband lock) installed in the GRARE receiver. Approximately 14 percent of the acquisition attempts resulted in false locks.

1.6 Doppler Tests

The two-way Doppler tracking accuracy tests were conducted for uplink/downlink modes 24H/03' with either high or low frequencies and with Doppler frequencies of ±129.874 kHz. The results of these various tests show that the three-sigma two-way Doppler random error was better than the ICD (reference 1) requirement of 0.0054 meters per second for a two-second Doppler integration time.

1.7 Effects of Cryptographic Process on System Performance

The use of cryptographic devices degrades uplink performance by 1.5 dB, the PM downlink performance by 2.0 dB and the FM downlink performance by 1.8 dB.

TABLE 1-3 FM DOWNLINK CIRCUIT MARGINS

ESTL
JSC/HOUSTON

DATA	AFSCF/RTS RECEIVER	CONDITIONS	MEASURED P_{rec}/N_o BER - 1×10^{-5} (dBHz)	EXPECTED P_{rec}/N_o BER - 1×10^{-5} (dBHz)	MEASURED CIRCUIT MARGIN (dB)
PLAYBACK TDM DATA (OPS RECORDER)	MICRODYNE	1:1	70.0	88.2	18.2
	"	5:1	74.7	88.2	13.5
	ASGLS	1:1	74.8	88.2	13.4
	"	5:1	79.8	88.2	8.4
PLAYBACK OI TELEMETRY (OPS RECORDER)	ASGLS	1:1 15 IPS	73.6	88.2	14.6
		8:1 15 IPS	79.8	88.2	8.4
		1:1 24 IPS	73.1	88.2	15.1
		5:1 24 IPS	78.6	88.2	9.6
	MICRODYNE	1:1 15 IPS	68.7	88.2	19.5
		8:1 15 IPS	75.2	88.2	13.0
		1:1 24 IPS	68.3	88.2	19.9
		5:1 24 IPS	74.3	88.2	13.9

TABLE 1-3 FM DOWNLINK CIRCUIT MARGINS (CONT'D)

ESTL
JSC/HOUSTON

DATA	AFSCF/RTS RECEIVER	CONDITIONS	MEASURED P_{rec}/N_o BER - 1 x 10^{-5} (dBHz)	EXPECTED P_{rec}/N_o BER - 1 x 10^{-5} (dBHz)	MEASURED CIRCUIT MARGIN (dB)
REALTIME DOD PAYLOAD DIGITAL DATA	ASGLS	4 KBPS:NRZ-L	67.5	88.2	20.7
		BI-Ø-L	67.0	88.2	21.2
		256 KBPS:NRZ-L	75.0	88.2	13.2
		BI-Ø-L	75.4	88.2	12.8
	MICRODYNE	250 BPS:NRZ-L	52.6	88.2	35.6
		BI-Ø-L	52.9	88.2	35.3
		4 KBPS:NRZ-L	58.3	88.2	29.9
		BI-Ø-L	58.7	88.2	29.5
		256 KBPS:NRZ-L	70.4	88.2	17.8
		BI-Ø-L	70.6	88.2	17.6
DFI PCM TELEMETRY	MICRODYNE	128 KBPS: REAL TIME PLAYBACK	72.0 72.0	83.5 83.5	11.5 11.5
		16 KBPS: REALTIME PLAYBACK	71.8 71.8	83.5 83.5	11.7 11.7

2. INTRODUCTION

2.1 General

The system verification tests for the S-band phase and frequency modulation (PM and FM) direct link communications between the SSO (Space Shuttle Orbiter) and the AFSCF/RTS (Air Force Satellite Control Facility/ Remote Tracking Station) were conducted in accordance with detailed test procedures (reference 2) in the ESTL (Electronic Systems Test Laboratory) during the months of May, June, and July 1979.

The results of these tests are presented in Section 3. Section 4 contains a list of applicable references.

The cryptographic communications capability provided by the Orbiter will not be used during OFT (Orbital Flight Test). However, during operational Air Force missions, time-division multiplexed data will be encrypted prior to transmission and decrypted in the Orbiter or STC (Satellite Test Center). Thus, the effects of the encryption/decryption process on bit error were also measured during the test program. The results of these tests are presented in Appendix A.

Some equipment which is required for the normal AFSCF/RTS operational configuration was not available for the compatibility tests in the ESTL. Differences between the operational configuration and the ESTL test configuration for the PM uplink, PM downlink, and the FM downlink are shown in figures 2-1, 2-2, and 2-3, respectively. Where possible, GSTDN equipment was used to simulate the functions of the AFSCF/STC.

2.2 S-band PM and FM Direct Communications Link

An overview of the S-band PM and FM direct communications links between the Orbiter and the AFSCF/RTS is shown in figure 2-4.

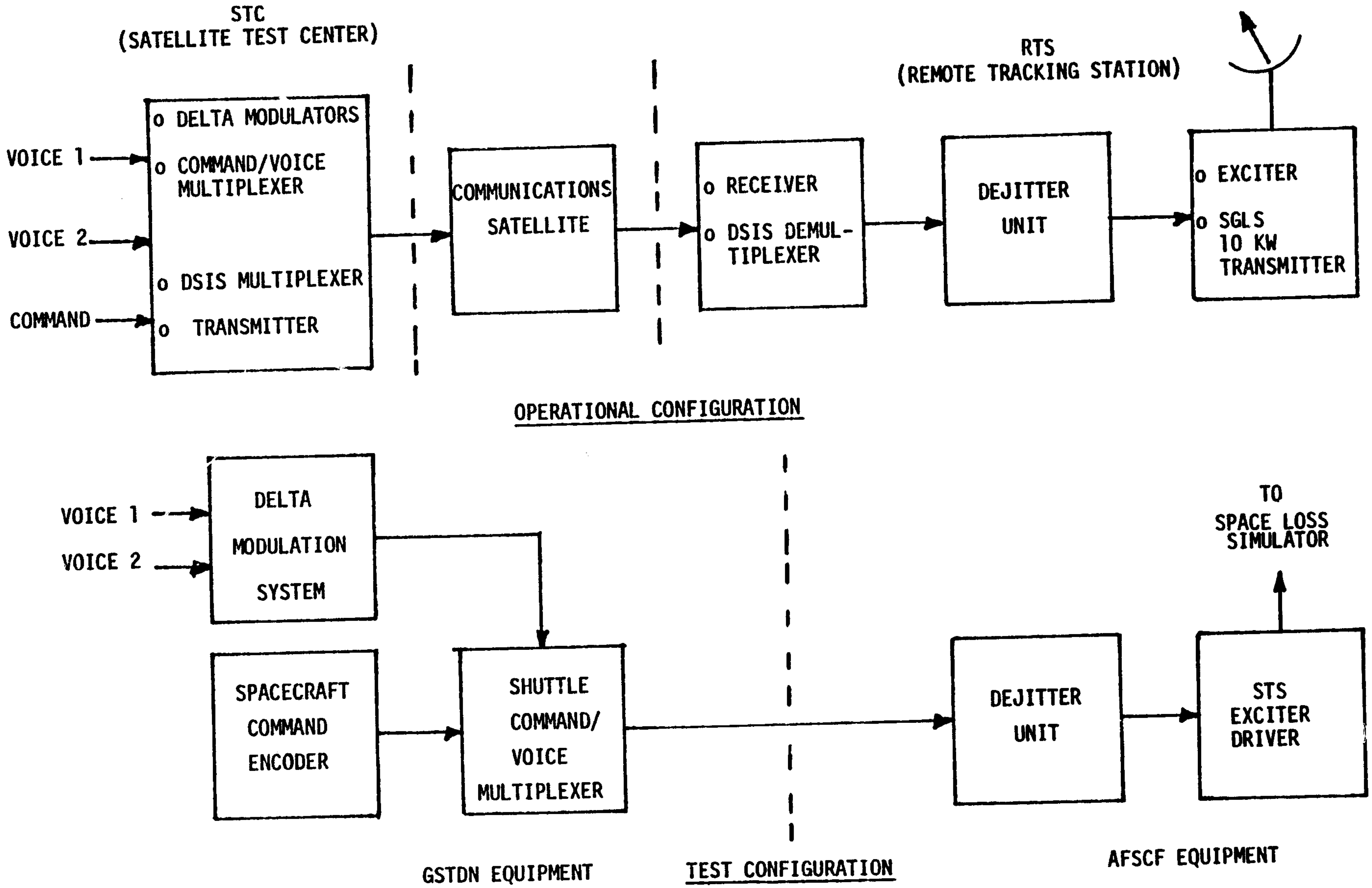

FIGURE 2-1 COMPARISON OF OPERATIONAL AND TEST CONFIGURATION - PM UPLINK

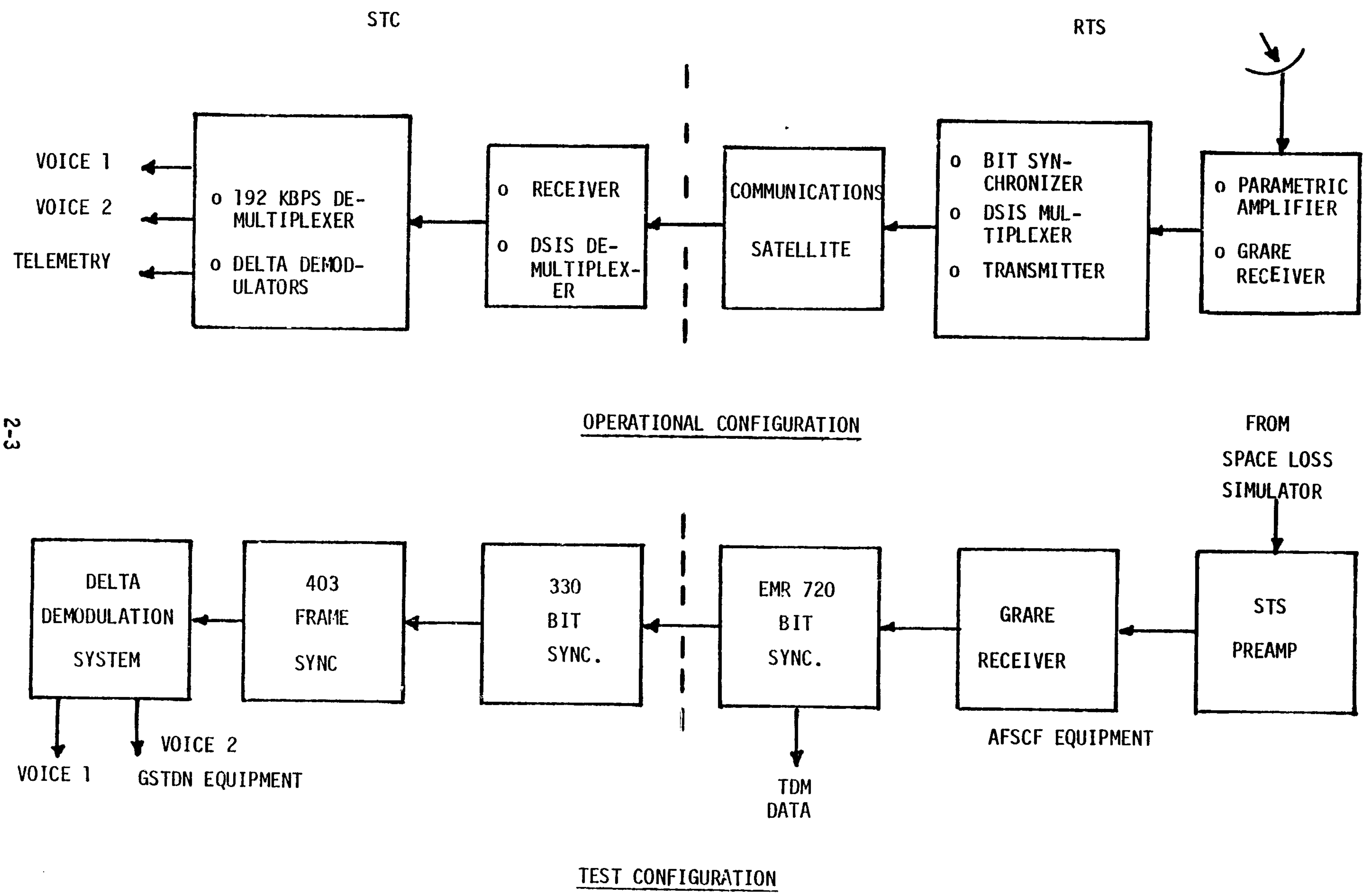

FIGURE 2-2. COMPARISON OF OPERATIONAL AND TEST CONFIGURATIONS - PM DOWNLINK

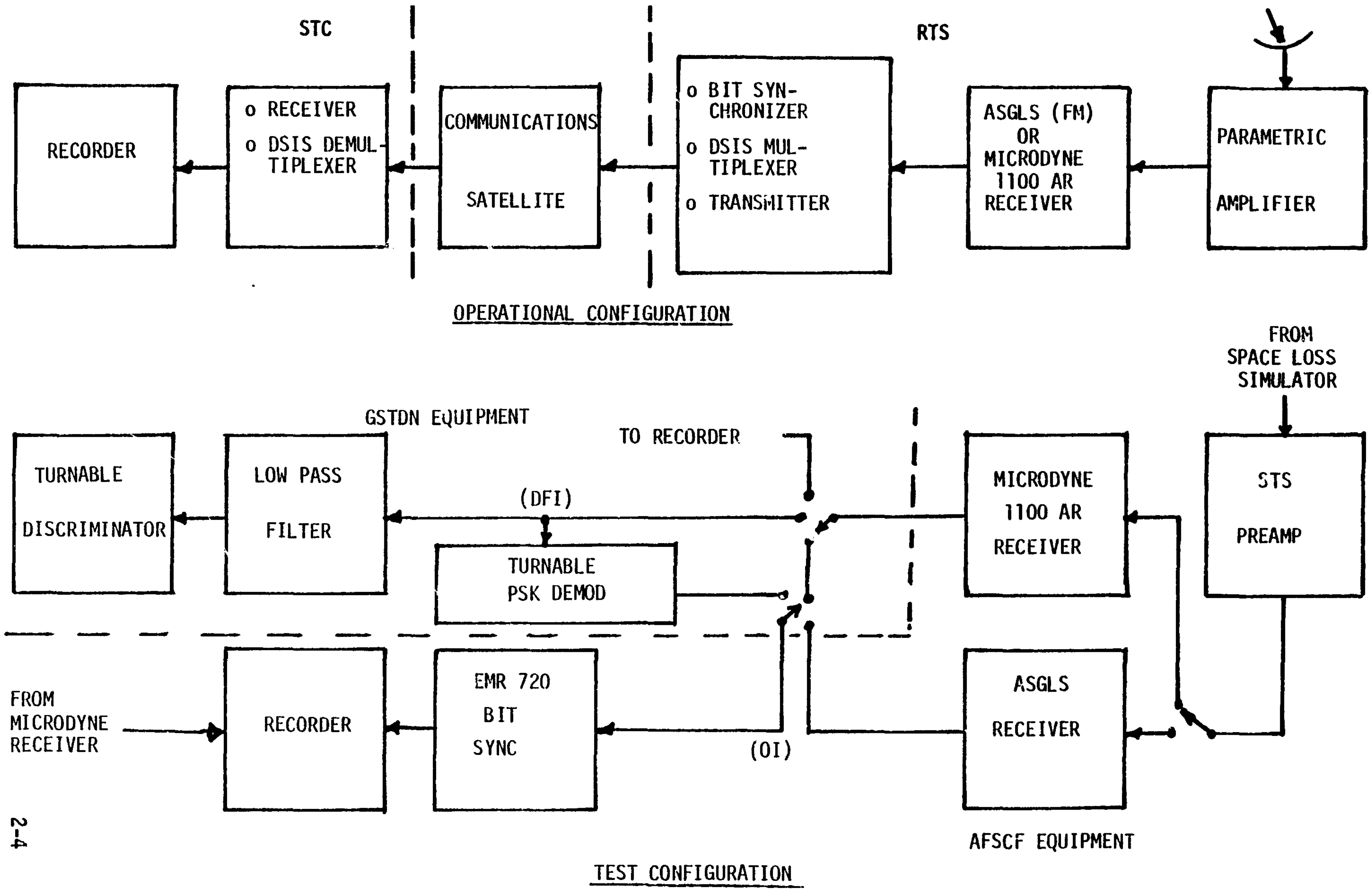

FIGURE 2-3. COMPARISON OF OPERATIONAL AND TEST CONFIGURATIONS - FM LINK

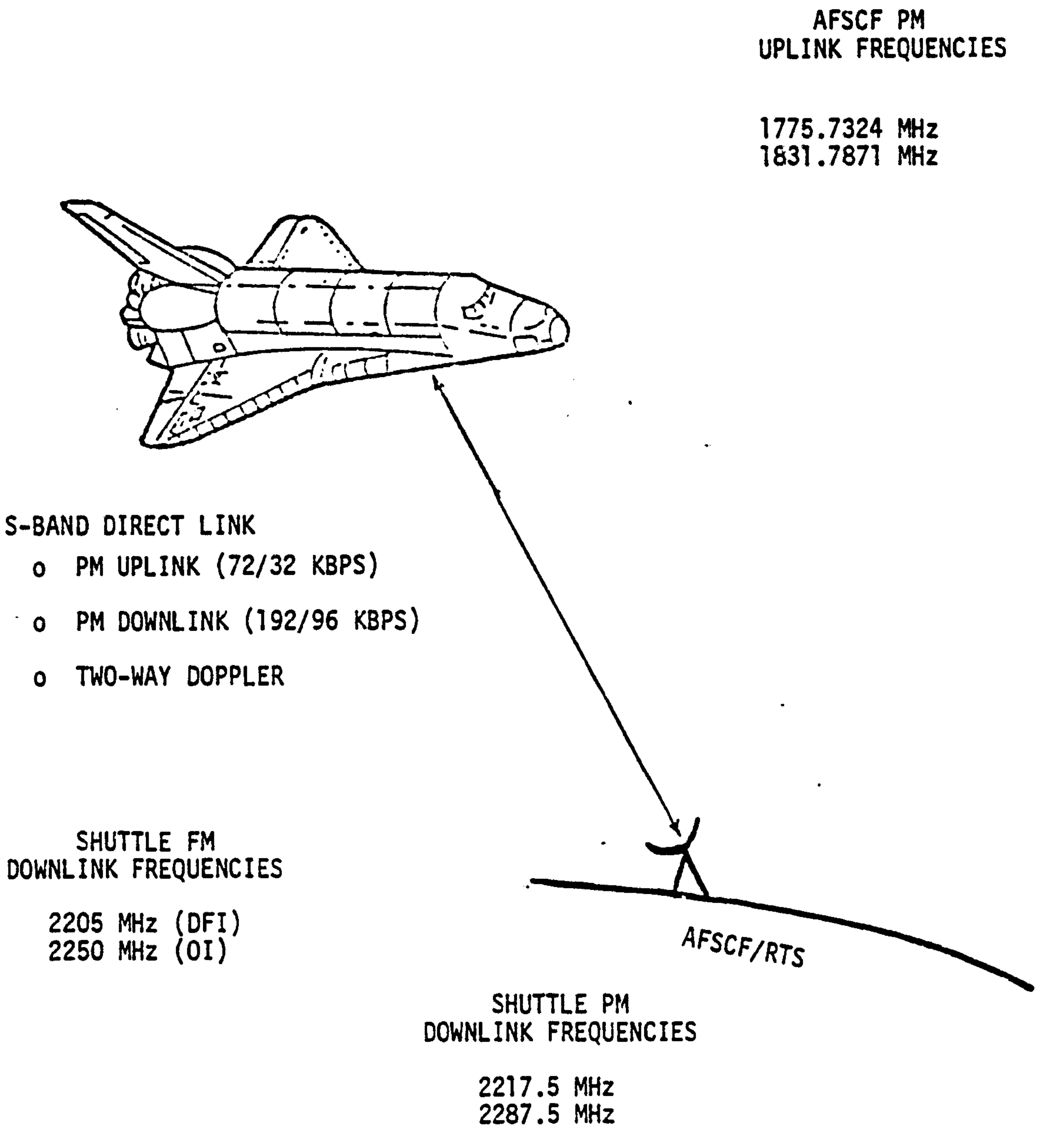

FIGURE 2-4 S-BAND PM AND FM DIRECT LINK OVERVIEW

2.2.1 AFSCF/RTS-to-Orbiter S-band Direct Uplink

The functional interface configuration for the AFSCF/RTS-to-Orbiter S-band direct uplink is shown in figure 2-5. The two signal combinations which are available for use on this link are identified in Table 2-1. In signal combination 24H (high rate data mode) each voice channel is encoded by converting the analog audio signal into a 32 kbps digital sequence using an adaptive variable-slope delta modulator. The 2.4 kbps command information is encoded into a 6.4 kbps data sequence by a command encoder. The two digital delta-modulated voice channels, each at 32 kbps, are TDM (time-division miltiplexed) with 6.4 kbps command information and 1.6 kbps of synchronization and identification signals. The resulting 72 kbps TDM data signal will then be used to PSK (phase-shift key) the uplink carrier. On the Orbiter, a coherent PSK demodulator restores the 72 kbps TDM baseband signal, which is then processed by the NSP (network signal processor). The demultiplexer identifies the synchronization pattern and separates the voice channels, command channel, and station ID data. The voice signals are converted to analog by the voice delta demodulators and the command channel is routed to the command decoder, all within the NSP.

In signal combination 24L (low rate data mode) only one delta modulated voice channel (at the rate of 24 kbps) is provided and the resulting TDM channel rate will therefore be 32 kbps (24 kbps voice, 6.4 kbps command and 1.6 kbps synchronization). Operation of signal combination 24L is then the same as that of signal combination 24H.

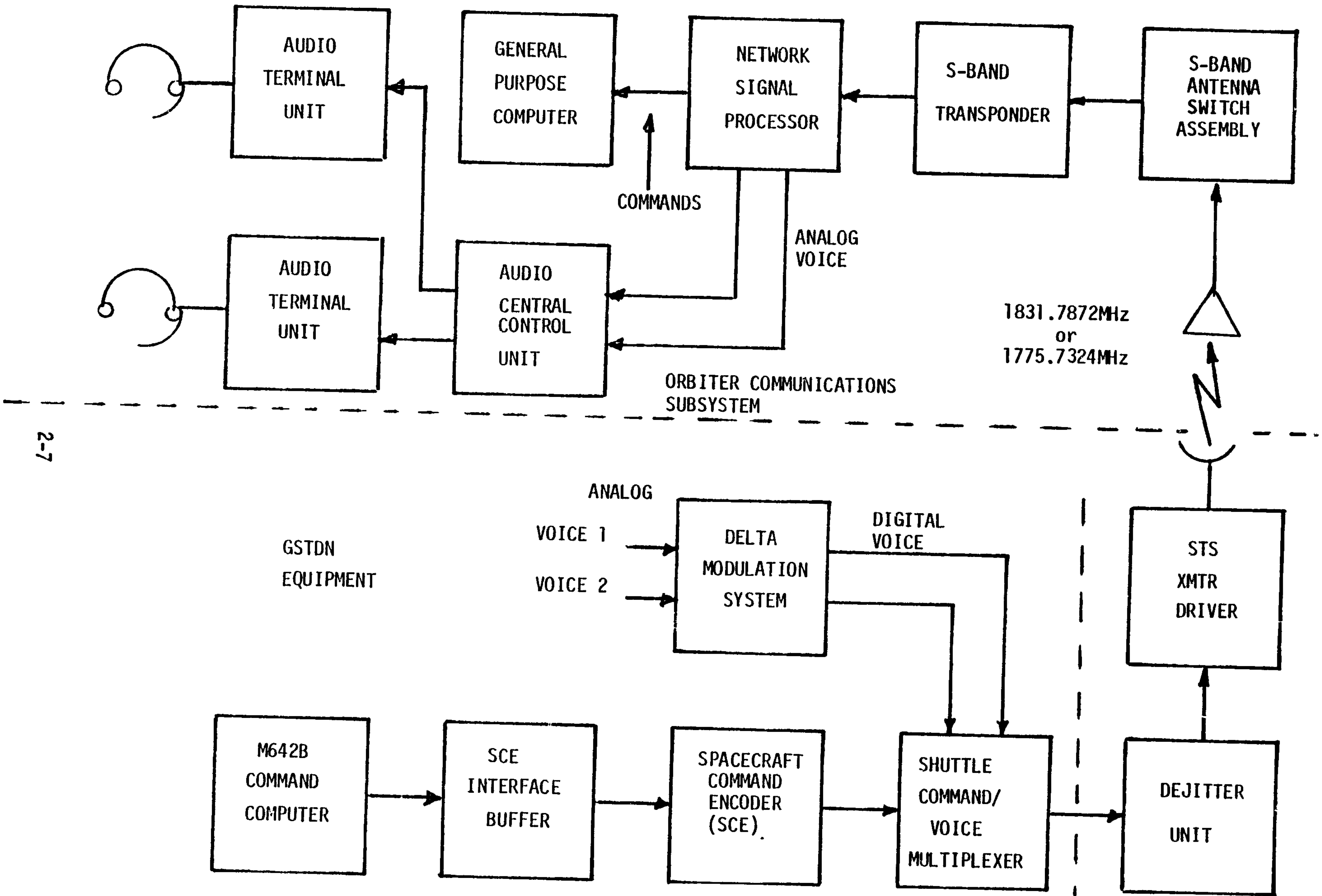

FIGURE 2-5 AFSCF/RTS-TO-ORBITER S-BAND PM DIRECT UPLINK FUNCTIONAL TEST CONFIGURATION

TABLE 2-1

UPLINK SIGNAL COMBINATIONS AND PERFORMANCE REQUIREMENTS

SIGNAL COMBINATION	INFORMATION TRANSMITTED	MODULATION TECHNIQUES	MODULATION INDEX (RADIANS)	ORBITER* REQUIRED P_{rec}/N_o (dBHz)	EXPECTED P_{rec}/N_o (dBHz)
24H	72 KBPS TDM INCLUDING TWO VOICE SIGNALS AND COMMANDS	PSK	$\pm \pi/2$	59.7	103.6
24L	32 KBPS TDM INCLUDING ONE VOICE SIGNAL AND COMMANDS	PSK	$\pm \pi/2$	56.2	103.6

* ICD 2 - 0D003

2.2.2 Orbiter-to-AFSCF/RTS S-band PM Direct Downlink

The functional interface configuration for the Orbiter-to-AFSCF/RTS S-band PM direct downlink is shown in figure 2-6. The four signal combinations which were tested are identified in Table 2-2. In signal combination 03 (high rate data mode) each voice channel is encoded by converting the analog audio signal into a 32 kbps sequence using an adaptive variable-slope delta modulator. The two 32 kbps digital delta-modulated voice channels are TDM with the 128 kbps telemetry channel to form a 192 kbps TDM bit sequence. This TDM bit sequence and noise turned around in the transponder ranging channel are then used to phase modulate the downlink carrier. The coherent frequency turnaround ratio in the SGLS (Space Ground Link System) mode is 256/205. In the noncoherent mode, the auxiliary oscillator and appropriate multiplexers are used to generate a downlink carrier frequency of 2287.5 or 2217.5 MHz.

At the AFSCF/RTS, a carrier tracking receiver and wideband phase demodulator restores the 192 kbps TDM baseband signal.

In signal combination 02 (low rate data mode) only one delta modulated voice channel at the rate of 32 kbps and a low rate telemetry channel at the rate of 64 kbps are combined to result in a TDM channel rate of 96 kbps.

2.2.3 Orbiter-to-AFSCF/RTS S-band FM Direct Downlink

The functional interface configuration for the Orbiter-to-AFSCF/RTS OI S-band FM direct downlink is shown in figure 2-7. This link uses a wideband frequency modulation transmitter (carrier frequency 2250.0 MHz) to transmit attached payload telemetry a bit rates from 250 bps to 256 kbps. When payload telemetry transmission is not required, the FM link can be utilized to transmit playback of recorded data.

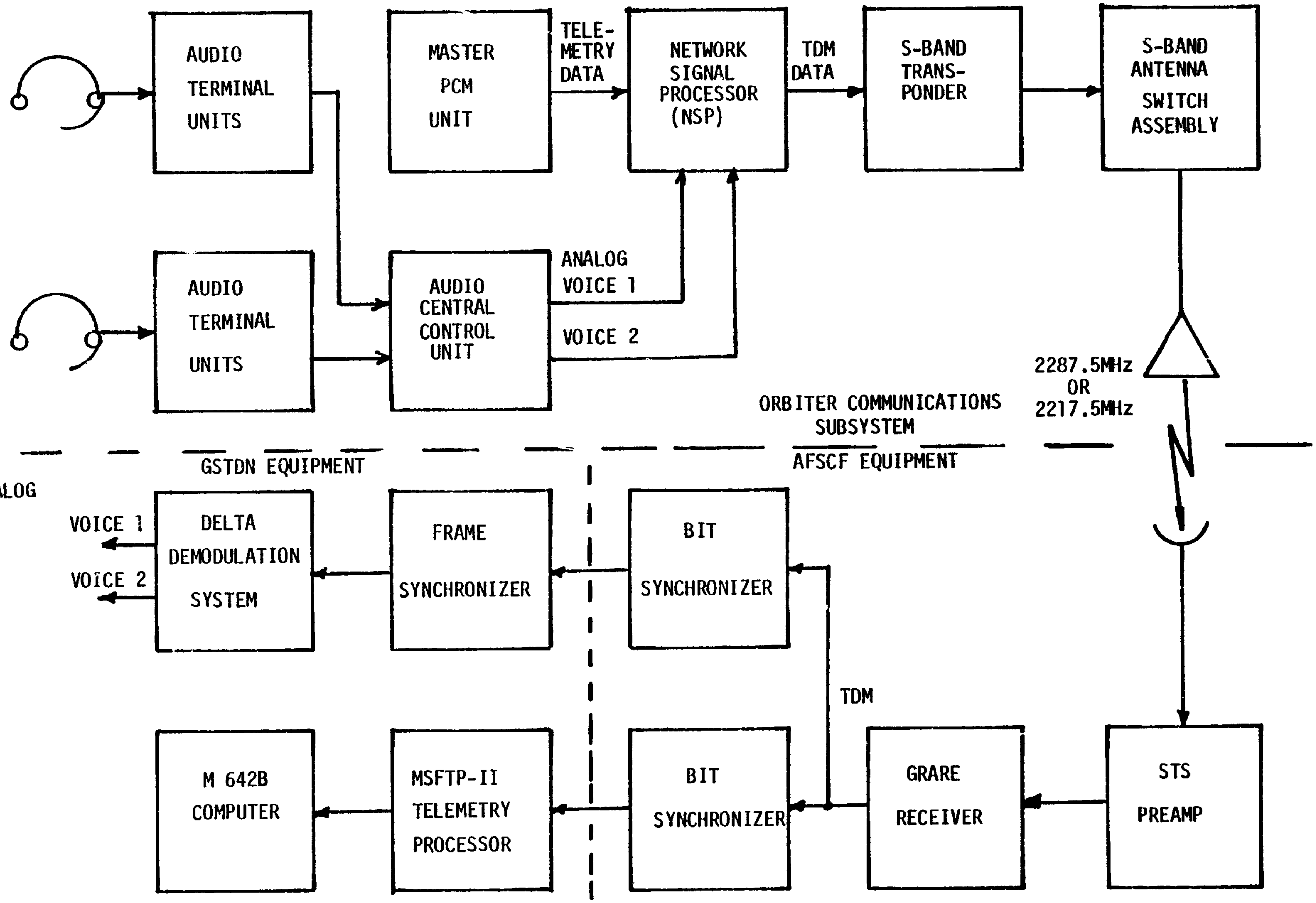

FIGURE 2-6. ORBITER-TO-AFSCF/RTS S-BAND PM DIRECT DOWNLINK FUNCTIONAL TEST CONFIGURATION

TABLE 2-2 PM DOWNLINK SIGNAL COMBINATIONS AND PERFORMANCE REQUIREMENTS

COMBINATION	INFORMATION TRANSMITTED	MODULATION TECHNIQUE	MODULATION INDEX (RADIANS)	AFSCF/RTS REQUIRED P_{rec}/N_o (dBHz)
02'	96 KBPS TDM (1 VOICE SIGNAL AT 32 KBPS AND 1 TELEMETRY AT 64 KBPS) (RANGING CHANNEL DISABLED)	PM	0.55	67.0
03'	192 KBPS TDM (2 VOICE SIGNALS AT 32 KBPS EACH AND 1 TELEMETRY AT 128 KBPS) (RANGING CHANNEL DISABLED)	PM	0.55	70.0
02	96 KBPS TDM (1 VOICE SIGNAL AT 32 KBPS AND 1 TELEMETRY AT 64 KBPS PLUS TURNAROUND RANGING CHANNEL NOISE	PM	0.55	69.8*
03	192 KBPS TDM (2 VOICE SIGNALS AT 32 KBPS EACH AND 1 TELEMETRY AT 128 KBPS PLUS TURNAROUND RANGING CHANNEL NOISE)	PM	0.55	72.8*

* The required P_{rec}/N_o shown is 2.8 dB greater than presently documented in ICD 2-0D003 (dated 8-28-77). ICD will be updated to reflect the additional requirement.

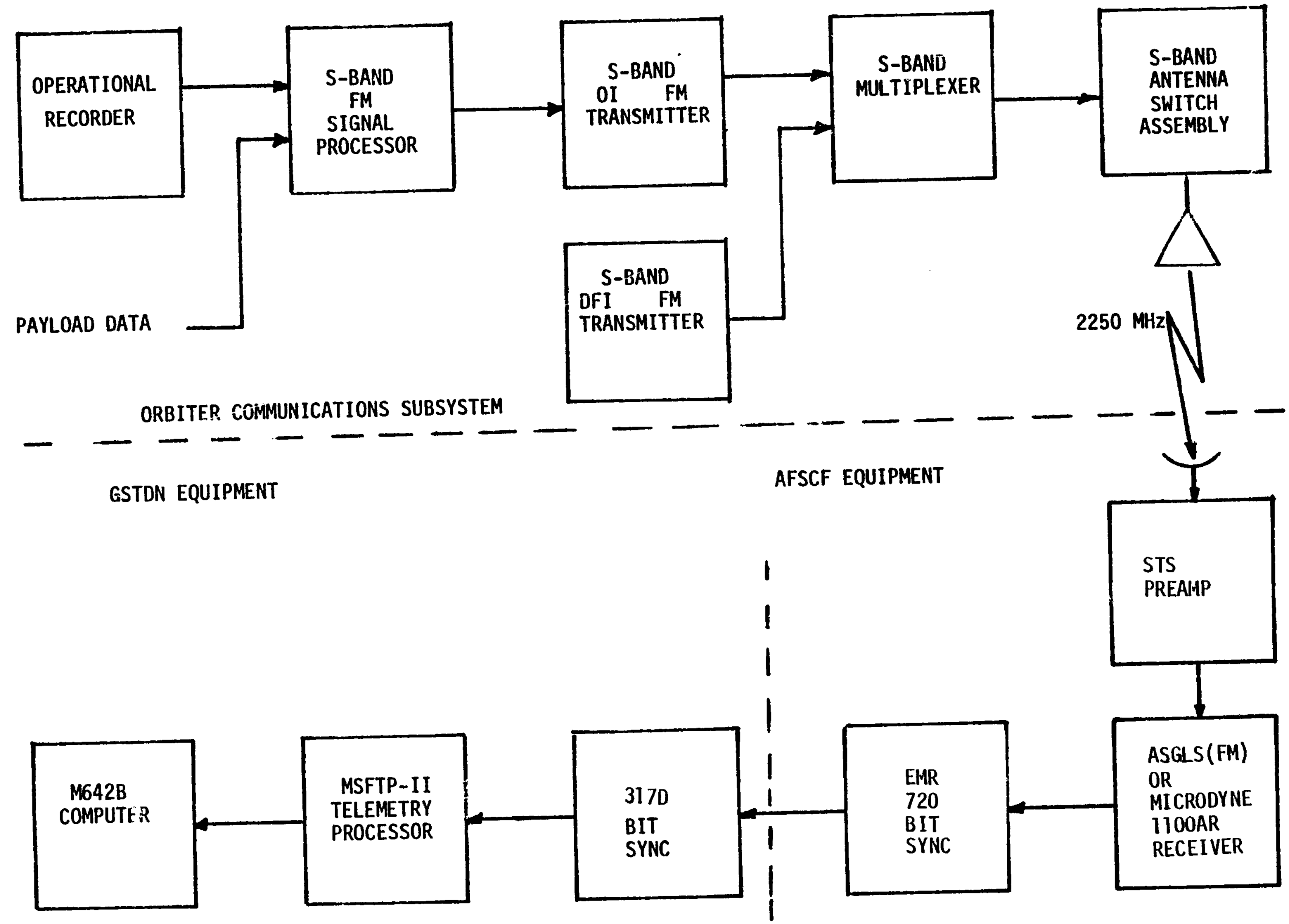

FIGURE 2-7 ORBITER-TO-AFSCF/RTS OI S-BAND FM DIRECT DOWNLINK FUNCTIONAL TEST CONFIGURATION

The functional interface configuration for the Orbiter-to-AFSCF/RTS DFI S-band FM direct downlink is shown in figure 2-8. This link uses a FM transmitter (carrier frequency 2205.0 MHz) to transmit DFI (development flight instrumentation) data. The 128 kbps PCM data phase shift keys the 1.024 MHz subcarrier prior to frequency division multiplexing with the 15 FM subcarrier channels. The multiplexed composite signal is then used to FM (frequency modulate) the 2205.0 MHz carrier.

2.3 Test Objectives

The objectives of the AFSCF/RTS S-band direct link tests are:

- O Verify compatibility of the S-band Orbiter/AFSCF/RTS direct link equipment for the Shuttle OFT program.
- O Evaluate performance of the S-band AFSCF/RTS PM direct uplink and downlink channels.
- O Evaluate performance of the S-band OI (operational instrumentation) and DFI (developmental flight instrumentation) FM downlinks.
- O Determine circuit margins for the individual voice and telemetry channels.
- O Evaluate performance of the radio frequency acquisition system.
- O Evaluate performance of the two-way Doppler system.
- O Determine if measured link performance will meet the minimum Air Force mission requirements.
- O Evaluate effects of encryption/decryption on data channel performance.

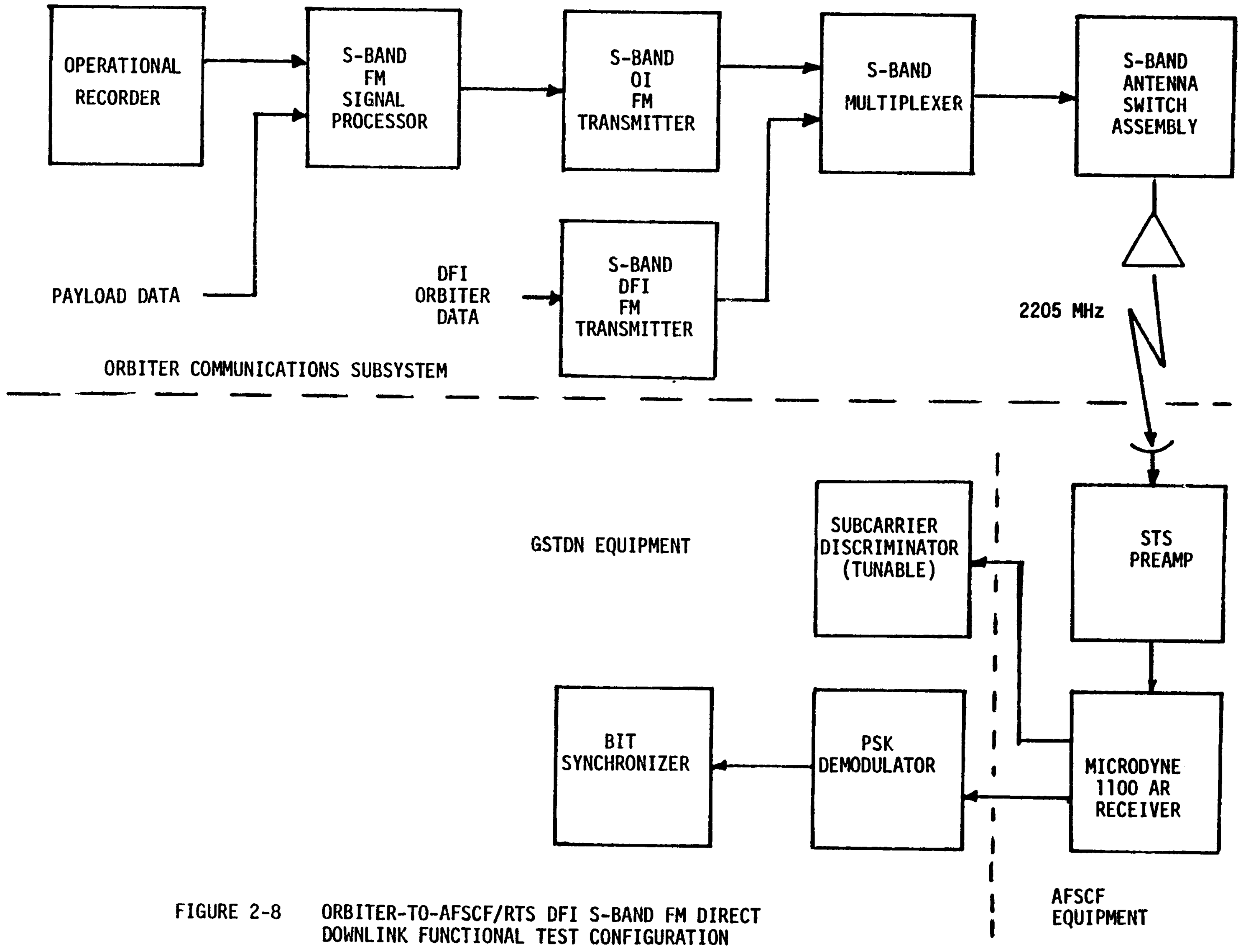

FIGURE 2-8 ORBITER-TO-AFSCF/RTS DFI S-BAND FM DIRECT DOWNLINK FUNCTIONAL TEST CONFIGURATION

2.4 Test Requirements

The test requirements which are defined in the System Development Test Requirements and Status Report for AFSCF Direct Link (reference 3) and the System Verification Test Plan for Orbiter/AFSCF S-band Direct Link (reference 4) are summarized in Tables 2-3 and 2-4. These requirements have been established to assure that adequate test data will be provided for the proper analysis and evaluation of the Orbiter/AFSCF/RTS direct link performance.

2.5 Systems Performance Evaluation Criteria

Key link performance parameters as specified in ICD 2 - 0D003 were used as a basis for analysis of the test data. In the following material, the test results are comapred to these performance parameters and both successes and failures noted.

TABLE 2-3. TEST REQUIREMENTS

(PM LINKS)

PM CHANNEL TO BE TESTED	TYPE OF TEST
UPLINK TDM	BIT ERROR RATE PERCENT DATA LOSS
UPLINK COMMAND	MESSAGE REJECTION RATE VERIFICATION OF ERROR FREE COMMANDS
UPLINK VOICE	SUBJECTIVE VOICE QUALITY WORD INTELLIGIBILITY
DOWNLINK TDM	BIT ERROR RATE
DOWNLINK VOICE	SUBJECTIVE VOICE QUALITY WORD INTELLIGIBILITY
UPLINK CARRIER	RF ACQUISITION
DOWNLINK	RF ACQUISITION
UPLINK/DOWNLINK	TWO-WAY RF ACQUISITION TWO-WAY RF ACQUISITION WITH DOPPLER CARRIER TRACKING THRESHOLD TWO-WAY RF REACQUISITION TWO-WAY DOPPLER ACCURACY

TABLE 2-4 TEST REQUIREMENTS

(FM LINKS)

FM CHANNEL TO BE TESTED	TYPE OF TEST
PLAYBACK OI TDM DATA	BIT ERROR RATE PERCENT DATA LOSS SUBJECTIVE VOICE QUALITY
PLAYBACK OI TELEMETRY DATA	BIT ERROR RATE PERCENT DATA LOSS
REALTIME DOD PAYLOAD DIGITAL DATA	BIT ERROR RATE PERCENT DATA LOSS
DFI ANALOG TELEMETRY SUBCARRIERS	PREDETECTION SNR POSTDETECTION SNR
DFI PCM TELEMETRY DATA	BIT ERROR RATE

3. SYSTEM PERFORMANCE EVALUATION

3.1 General

Key link performance parameters as specified in ICD 2-0D003 were used as a basis for analysis of the test data. In the following material the test results are compared to these performance parameters and both successes and failures noted.

The performance evaluation contained in this section is presented in a manner which parallels the six major phase of testing as follows:

- O PM Uplink Channel
- O PM Downlink Channel
- O FM Operational Instrumentation Downlink Channel
- O Development Flight Instrumentation Downlink Channel
- O RF Acquisition Probability
- O Doppler Accuracy

The tests results presented in this section have been summarized from the test data package (reference 5). In general, selected test results have been plotted and presented in a format more suitable for evaluation.

3.2 S-band PM Uplink Tests

These tests were conducted to determine the performance of the uplink TDM channel, the uplink command channel, and the uplink voice channels.

3.2.1 Uplink TDM Channel Performance

The performance of the uplink TDM channel was determined by a series of bit error rate and percent data loss tests for the uplink modes shown in Table 2-1. A block diagram of the configuration used during these tests is shown in figure 3-1.

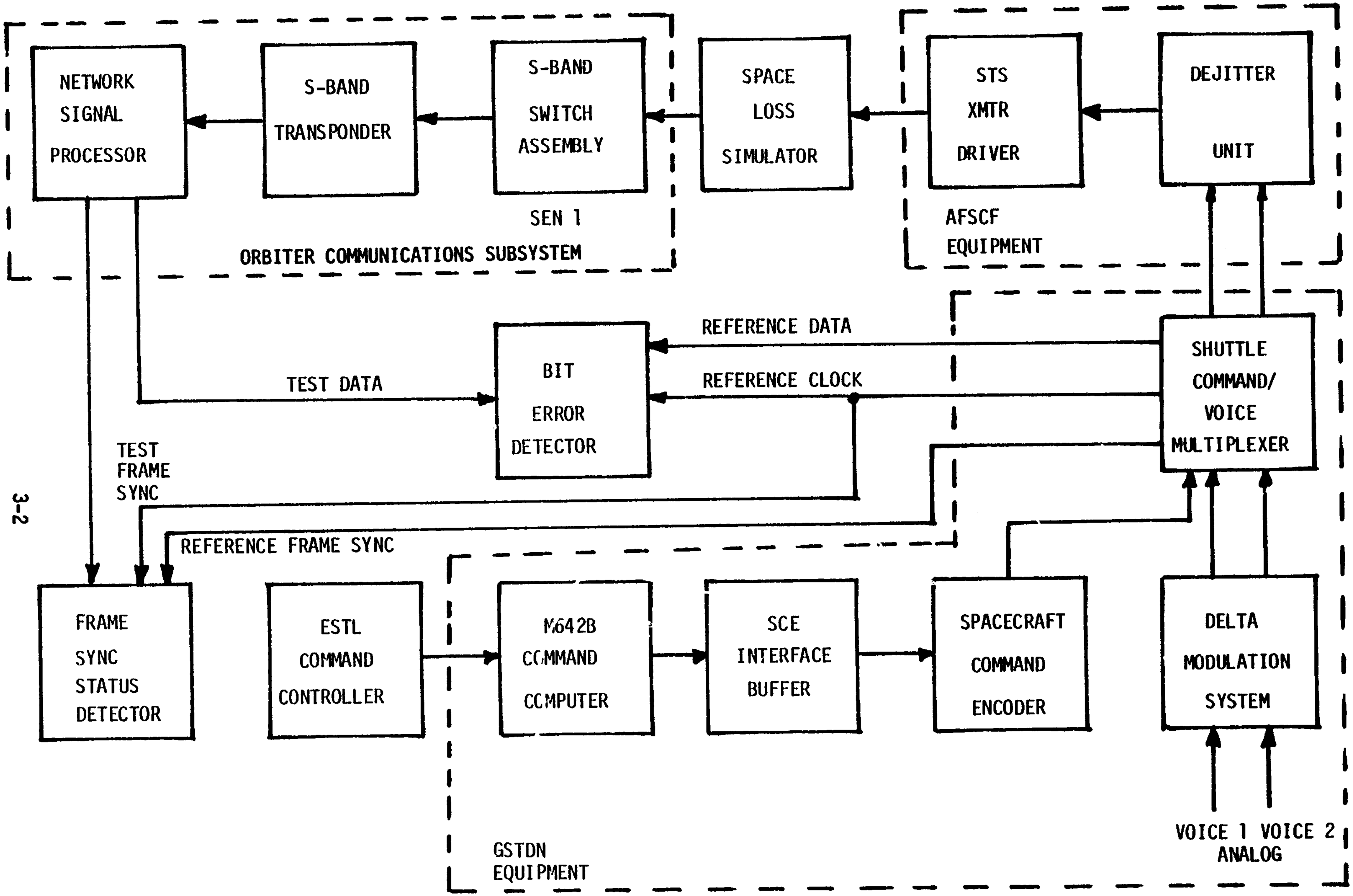

FIGURE 3-1 UPLINK BIT ERROR RATE AND PERCENT DATA LOSS TEST CONFIGURATION

The uplink TDM channel bit error rate tests with active voice and commands were conducted for uplink combinations 24L and 24H. As can be seen in figure 3-2, the performance achieved with uplink signal combination 24H was 3.2 dB better than the ICD requirement of a 1×10^{-5} BER at P_{rec}/N_o of 59.7 dBHz (conversions from total received power to P_{rec}/N_o are based on maximum specified transponder noise figure of 8 dB).

For signal combination 24L, the performance was 3.1 dB better than the ICD requirement. Figure 3-2 also shows that the difference in performance achieved with uplink signal combinations 24H and 24L at a BER of 1×10^{-5} was 3.4 dB. Theoretical difference for the uplink modes is 3.5 dB.

Uplink TDM channel bit error rate tests were also performed with the voice channels in an inactive mode (no audio modulation present). There was no significant difference in the BER performance of the uplink TDM channel when in the active or inactive voice modes.

The effects of Doppler on the uplink TDM channel were determined by placing $\pm$60 kHz of Doppler on the uplink rf carrier (1775.7324 MHz or 1831.7871 MHz). A proportional amount of Doppler was also imposed on the modulation clocks. The results of the various Doppler tests showed that there were no detectable effects on the performance of the uplink TDM channel.

The uplink TDM channel percent data loss performance as a function of P_{rec}/N_o is shown in figure 3-3. For the high rate data mode (24H) a BER of 1×10^{-2} occurs at the P_{rec}/N_o of 51.1 dBHz and the 10 percent data loss occurs at a P_{rec}/N_o of 46.7 dBHz. For the low rate data mode (24L) a BER of 1×10^{-2} occurs at the P_{rec}/N_o of 47.6 dBHz and the 10 percent data loss occurs at a P_{rec}/N_o of 43.3 dBHz. In either case the 10 percent data loss does not occur until the BER is greater than 1×10^{-2}. A summary of the circuit margins for the uplink TDM channel is presented in Table 3-1.

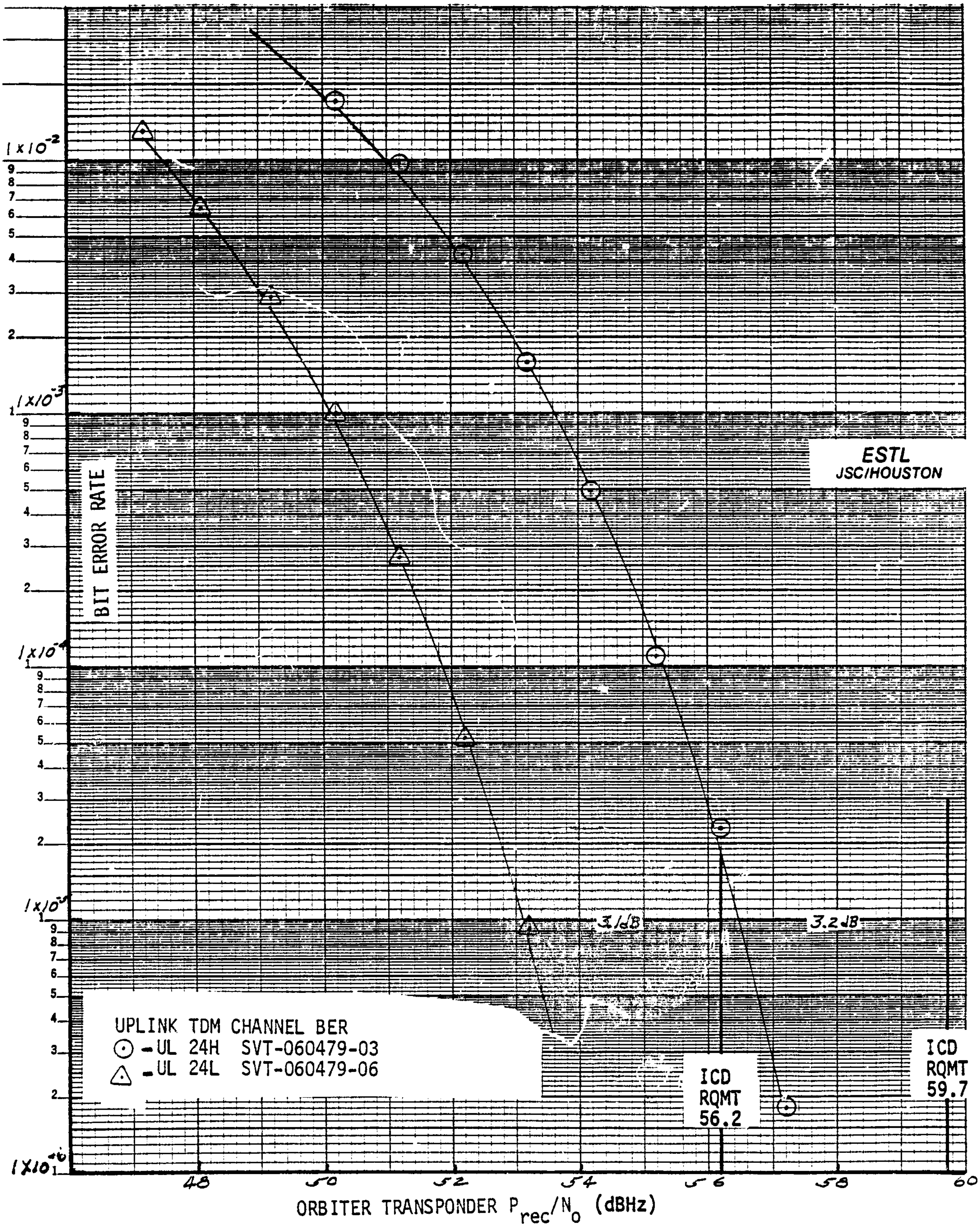

FIGURE 3-2 UPLINK TDM CHANNEL BIT ERROR RATE AS A FUNCTION OF ORBITER TRANSPONDER P_{rec}/N_o

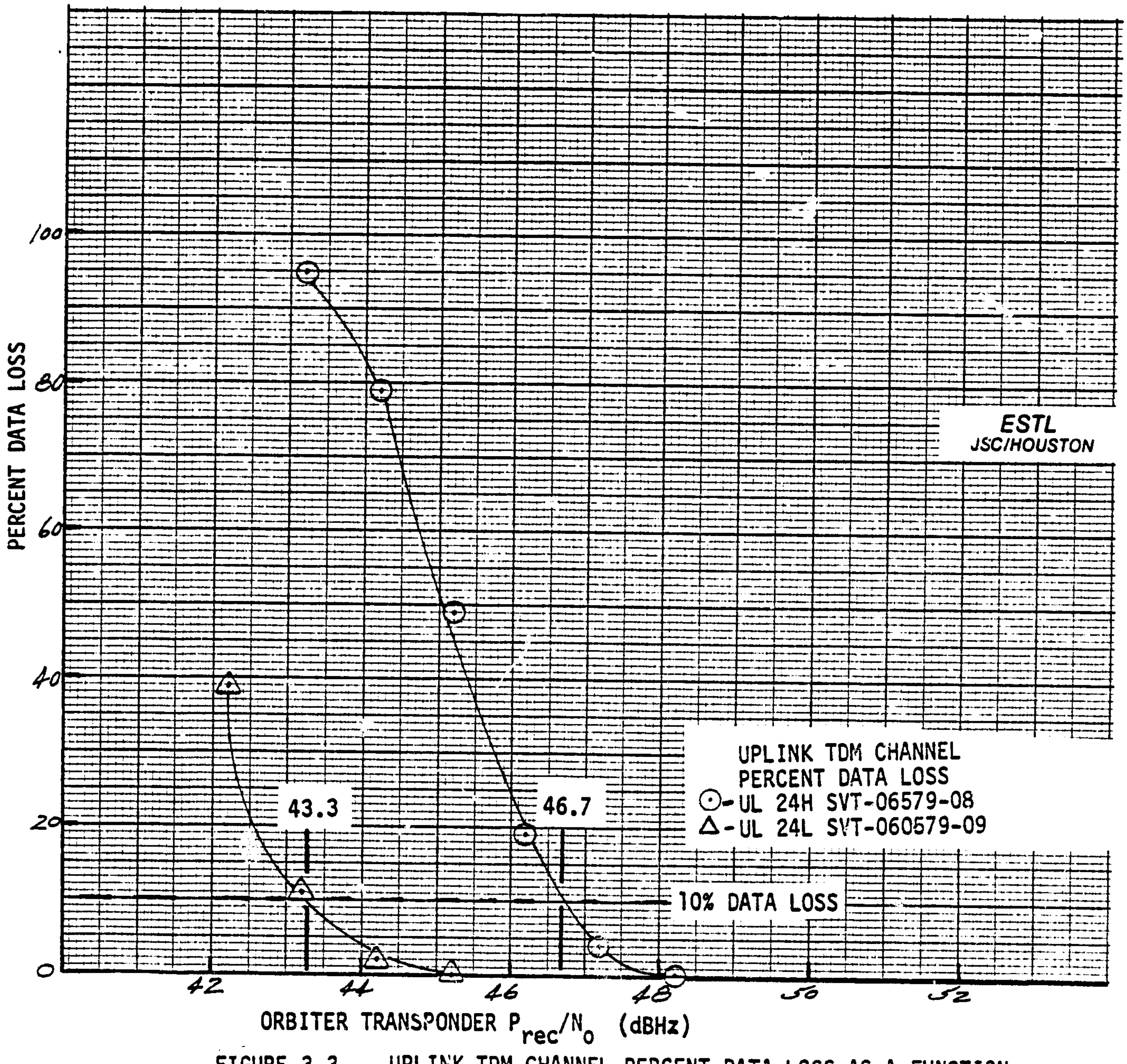

FIGURE 3-3 UPLINK TDM CHANNEL PERCENT DATA LOSS AS A FUNCTION OF ORBITER TRANSPONDER P_{rec}/N_o

TABLE 3-1 UPLINK CIRCUIT MARGIN SUMMARY

UPLINK SIGNAL COMBINATION	P_{rec}/N_o REQUIRED FOR 1 x 10^{-5} BER		P_{rec}/N_o FOR 1 x 10^{-4} BER	EXPECTED** P_{rec}/N_o (dBHz)	EXPECTED MARGIN (dB)	MEASURED MARGIN FOR 1x10^{-4} BER (dB)	MEASURED MARGIN FOR 1x10^{-5} BER (dB)
	ICD*	MEASURED	MEASURED				
24L	56.2	53.1	51.8	103.6	47.4	52.8	50.5
24H	59.7	56.5	55.2	103.6	43.9	48.4	47.1

* ICD2-0D003 DOD MISSION REQUIREMENTS

** AFSCF/RTS TRANSMIT POWER: +30 dBW, AFSCF/RTS Transmit Antenna Gain 45 dB, Slant Range 1122 nmi (5° Elevation for 270 nmi Orbit), Orbiter Receive Antenna Gain +3 dB

3.2.2 Uplink Command Channel Performance

The performance of the uplink command channel was evaluated by measuring the message rejection rate for uplink signal combinations 24H and 24L. In addition, it was verified that error free commands could be processed by the NSP (Network Signal Processor) and transferred to general purpose computers at bit error rates of 1×10^{-4}.

The message rejection rate tests for the uplink command channel were conducted with active voice and commands in a laboratory simulation of the uplink signal. Results of the MRR tests were used to predict or calculate the command channel BER.

Serial BER for the command channel was calculated from the message rejection rate test data using the following expression.

$$MRR = 3\,[1-(1-BER)^{32}] + [1-(1-BER)^{31}]$$

The calculated command channel BER is compared to the measured TDM BER in figure 3-4. As shown there is a good agreement between the calculated and measured bit error rate which provide a given MRR. As can be seen in the figure, a BER of 1×10^{-5} at the command decoder results in MRR's of 2.1×10^{-3} for 24H and 1.5×10^{-3} for 24L. Thus the link does not meet the ICD requirement of a MRR of 1×10^{-3} at a BER of 1×10^{-5}.

A demonstration of the ability of the uplink command system to generate, transmit via the AFSCF/RTS, receive by the Orbiter, decode and transfer error-free commands to simulated general purpose computers was accomplished.

For uplink signal combination 24H, a total of 9763 error-free commands out of 10,000 commands transmitted were processed at a BER of 1.87×10^{-4}. For uplink signal combination 24L, 9787 error-free commands were processed at a BER of 1.69×10^{-4}.

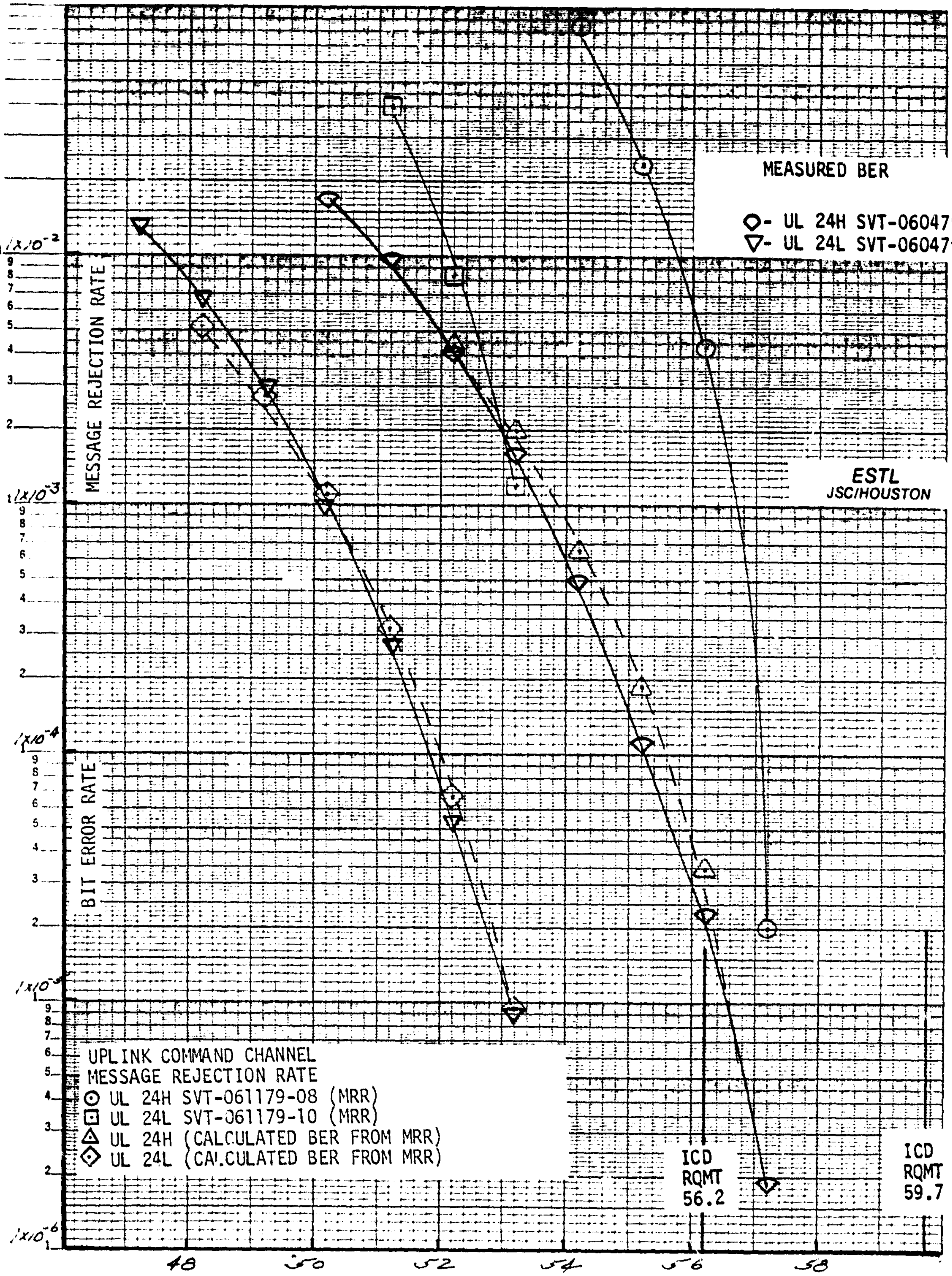

FIGURE 3-4 UPLINK COMMAND CHANNEL MESSAGE REJECTION RATE AS A FUNCTION OF ORBITER TRANSPONDER P_{rec}/N_o

3.2.3 Uplink Voice Channel Performance

The performance of the uplink voice channel was determined by conducting subjective voice quality and word intelligibility tests as a function of the transponder P_{rec}/N_o.

3.2.3.1 Subjective Voice Quality Evaluation

Figure 3-5 presents a functional block diagram of the test configuration used for the uplink subjective voice quality and word intelligibility tests. The uplink voice quality evaluation was performed for uplink signal combinations 24H and 24L. The criteria used to rate the voice quality is shown in Table 3-2. For uplink 24H, fair quality voice was obtained at a P_{rec}/N_o of 49.2 dBHz. This P_{rec}/N_o corresponds to a BER of 2.8×10^{-2}. For uplink 24L, fair quality voice was obtained at a P_{rec}/N_o of 45.7 dBHz. This P_{rec}/N_o corresponds to a BER of 3×10^{-2}. A summary for the results of these tests is present in Table 3-3.

3.2.3.2 Word Intelligibility Tests

The word intelligibility tests were performed using audio source tapes of phonetically balanced word lists. The source tapes were played through the GSTDN/AFSCF/RTS system and to the Orbiter where audio tapes were recorded at the ATU (audio terminal unit) output. Recordings were made at the P_{rec}/N_o levels required for good, fair and poor voice quality ratings, the expected P_{rec}/N_o for OFT and the ICD required P_{rec}/N_o.

The percent word intelligibility measurements were performed at the U. S. Army Electronic Proving Ground at Fort Huachuca, Arizona. The results of the word intelligibility tests are summarized in Table 3-4. Based on the specified word intelligibility of 90%, the test data indicates that circuit margins of 54.4 and 50.9 dB were achieved for signal combinations 24L and 24H,

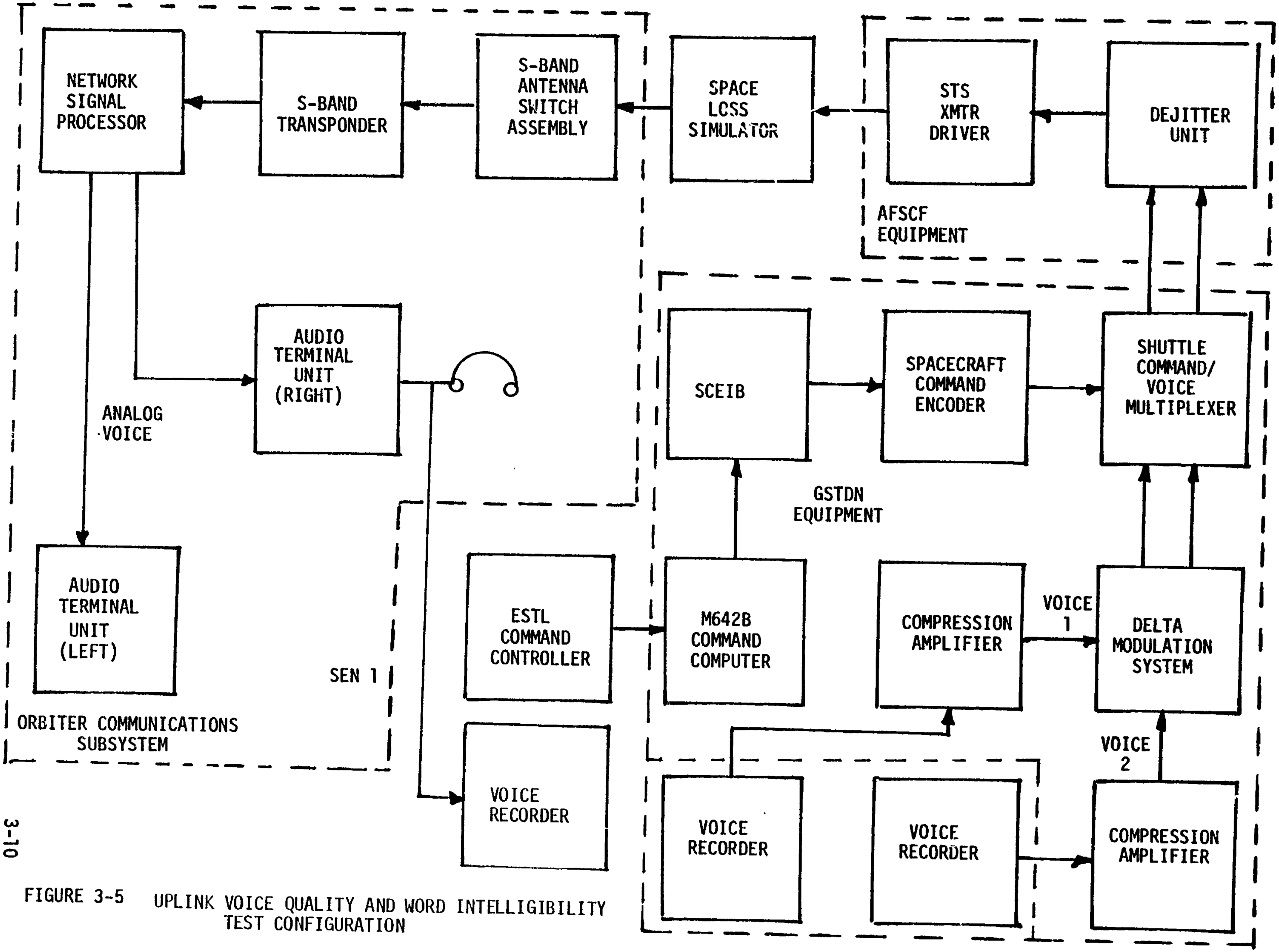

FIGURE 3-5 UPLINK VOICE QUALITY AND WORD INTELLIGIBILITY TEST CONFIGURATION

TABLE 3-2 VOICE QUALITY EVALUATION RATINGS

RATING	VOICE QUALITY
GOOD	Best possible voice with no noise present
FAIR	Voice with noise present but not objectionable
POOR	Voice with noise present at an objectionable level
USABLE	Voice which is usable but background noise would be uncomfortable over a long period of time
UNUSABLE	Voice which is masked by the system noise and is unintelligible

TABLE 3-3 SUBJECTIVE VOICE QUALITY EVALUATION

ESTL
JSC/HOUSTON

UPLINK SIGNAL CONFIGURATION	VOICE QUALITY RATING	P_{sc}/N_0 (dBHz)	BER	PERCENT DATA LOSS (%)
24H	Good	54.2	5×10^{-4}	0
	Fair	49.2	2.8×10^{-2}	0
	Poor	47.2	-	4.1
	Usable	46.2	-	10.6
	Unusable	45.2	-	42.9
24L	Good	50.2	1×10^{-3}	0
	Fair	45.7	3×10^{-2}	0
	Poor	43.7	-	4.3
	Usable	42.7	-	21.2
	Unusable	41.7	-	-

TABLE 3-4 UPLINK WORD INTELLIGIBILITY RESULTS

ESTL
JSC/HOUSTON

SIGNAL COMBINATION	VOICE QUALITY RATING	TRP (dBm)	P_{rec}/N_o (dBHz)	AVERAGE WORD INTELLIGIBILITY (PERCENT)
24H	Expected	- 65.9	100.1	94.0
24H	ICD Requirement	-106.3	59.7	93.7
24H	Good	-111.8	54.2	94.7
24H	Fair	-116.8	49.2	91.9
24H	Poor	-118.8	47.2	88.5
24L	Expected	- 65.9	100.1	94.6
24L	ICD Requirement	-106.3	59.7	94.1
24L	Good	-115.8	50.2	94.8
24L	Fair	-120.3	45.7	93.3
24L	Poor	-122.3	43.7	81.9

respectively. The test data also shows that BER's less than or equal to $1x10^{-2}$ provided word intelligibilities greater than 90% in accordance with ICD requirements.

3.3 S-band PM Direct Downlink Tests

The S-band PM direct downlink tests were conducted to determine the performance of the downlink TDM channel and the downlink voice channels.

A block diagram of the uplink configuration during the downlink tests is shown in figure 3-6. The uplink voice delta modulation system (DMS) was configured for an output pattern of alternating one's and zero's on air-ground 1 (AG-1) and air-ground 2 (AG-2) circuits. The Shuttle command voice multiplexer (SCV) was operated in the safe mode; in this mode, the command word is filled with zero's.

The configuration of the GRARE (PM) receiver for the downlink TDM channels is shown in Table 3-5. The frequency settings for the downlink were 2287.5 MHz for the downlink high frequency and 2217.5 MHz for the downlink low frequency. The switch positions used on the EMR 720 bit synchronizers are also documented in Table 3-5.

3.3.1 Downlink TDM Channel Performance

The performance of the AFSCF S-band downlink channel was determined by a series of bit error rate tests for the different combinations of uplink and downlink signals. A block diagram of the downlink configuration used during the PM downlink BER and percent data loss tests is shown in figure 3-7.

The uplink signal combinations that were used for the downlink TDM channel and the P_{rec}/N_o used during downlink testing are shown in Table 2-1. The uplink rf path was adjusted for the expected values of P_{rec}/N_o at the Orbiter.

The downlink signal combinations and performance requirements are shown in Table 2-2. It should be noted that in downlink signal combinations 02 and 03, the ranging channel is enabled. However, since the presence of a

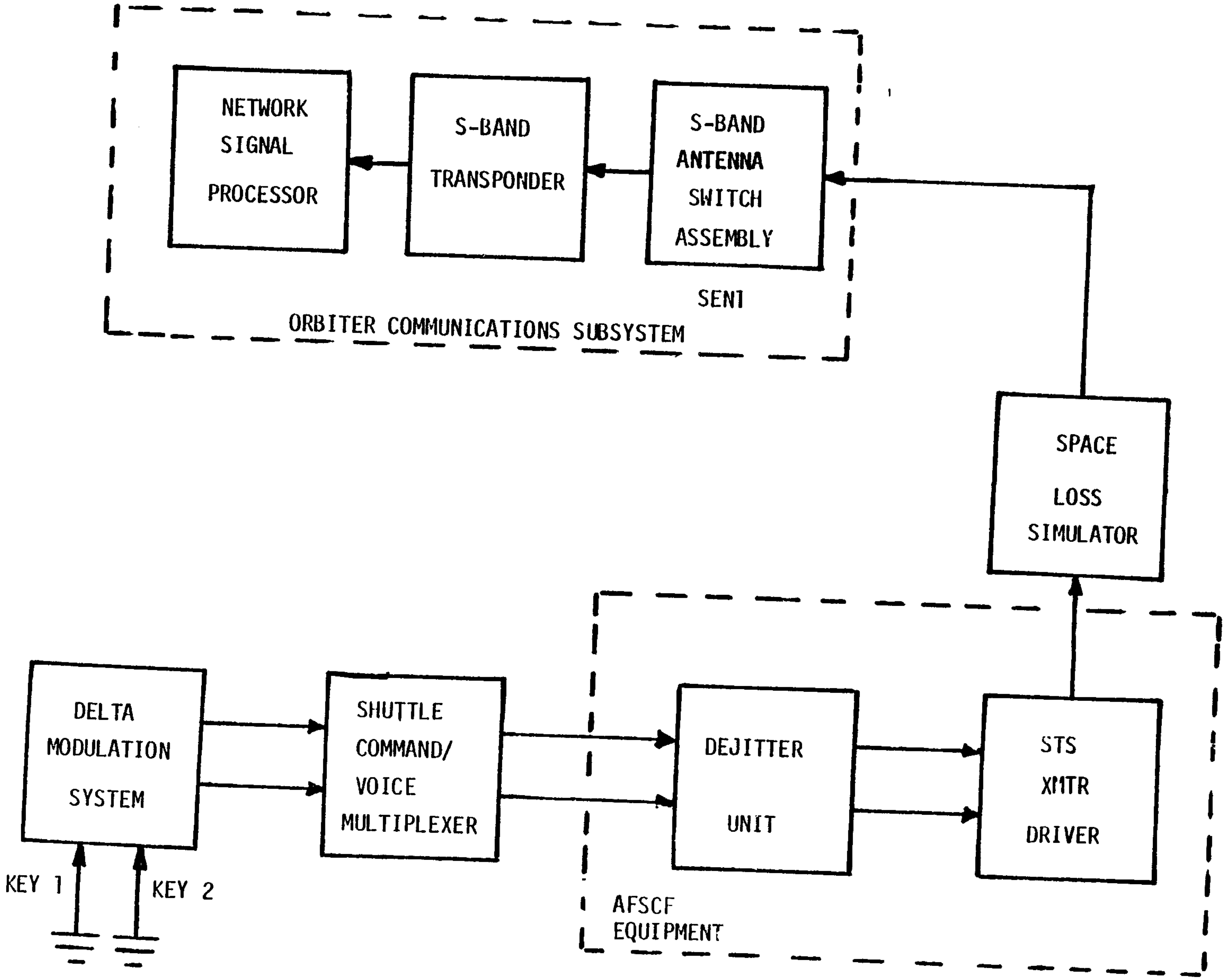

FIGURE 3-6 UPLINK CONFIGURATION FOR DOWNLINK TESTING

TABLE 3-5 REMOTE TRACKING STATION EQUIPMENT CONFIGURATION

GRARE RECEIVER

CHANNEL SELECT	CH. 4 2217.5 MHz CH.18 2287.5 MHz
CONTROL MODE	LOCAL
TRACKING MODE	PHASE LOCK
GAIN CONTROL MODE	AGC
LOOP BANDWIDTH	1000 Hz DURING TRACKING 5000 Hz DURING ACQUISITION
FAULT ISOLATION	OFF
ACQUISITION MODE	AUTO
IF BANDWIDTH	35 MHz
AGC BANDWIDTH	40 Hz

EMR 720 BIT SYNCHRONIZER

CODE IN/OUT	Bi-Ø-L
LBW	2%

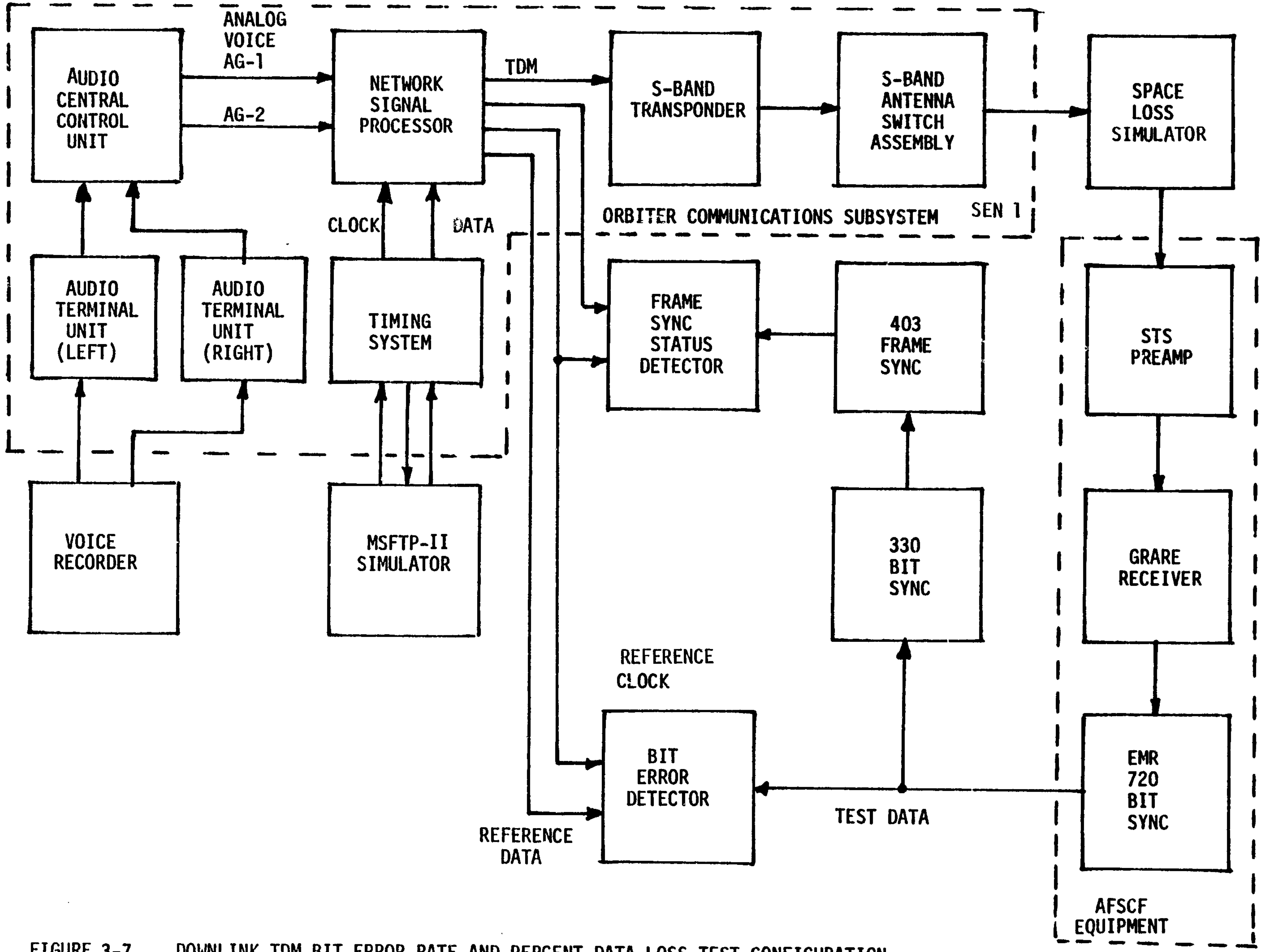

FIGURE 3-7 DOWNLINK TDM BIT ERROR RATE AND PERCENT DATA LOSS TEST CONFIGURATION

ranging subcarrier is determined by which uplink signal combination has been selected and uplink signal combinations involving the ranging subcarrier are not applicable to the AFSCF/RTS, the downlink carrier was modulated by the combination of turnaround noise and downlink TDM data for signal combinations 02 and 03. To determine the effects of the turnaround noise, tests were also accomplished using signal combinations 02' and 03'. In these signal combinations, the ranging channel was disabled.

3.3.1.1 Bit Error Rate Performance

Downlink TDM channel bit error rate tests were conducted using an EMR 720 bit synchronizer. The EMR bit synchronizer is a part of the telemetry data system at the AFSCF/RTS.

Downlink TDM channel BER test results for the downlink signal combinations specified in Table 2-2 are shown in figure 3-8. The 4.2 dB difference in the performance of the downlink for the high and low data rates at the specified BER of 1×10^{-4} was measured as compared to the theoretical prediction of a 3 dB improvement when the data rate is reduced by a factor of two (2). The BER tests also show a performance loss of approximately 2.5 dB, as expected, when ranging channel is enabled in either the high or low data rate mode.

The BER performance of the high data rate mode (UL 24H, DL 03 did not meet the ICD requirement of a 1×10^{-5} BER at a P_{rec}/N_0 of 72.8 dBHz. A BER of 1×10^{-5} was measured at a P_{rec}/N_0 of 73.6 dBHz.

Downlink TDM channel BER were also conducted to determine the degradation, if any, that active voice on the downlink would have on the performance of the downlink TDM channel. There was no detectable degradation in the BER data between the active and inactive voice modes.

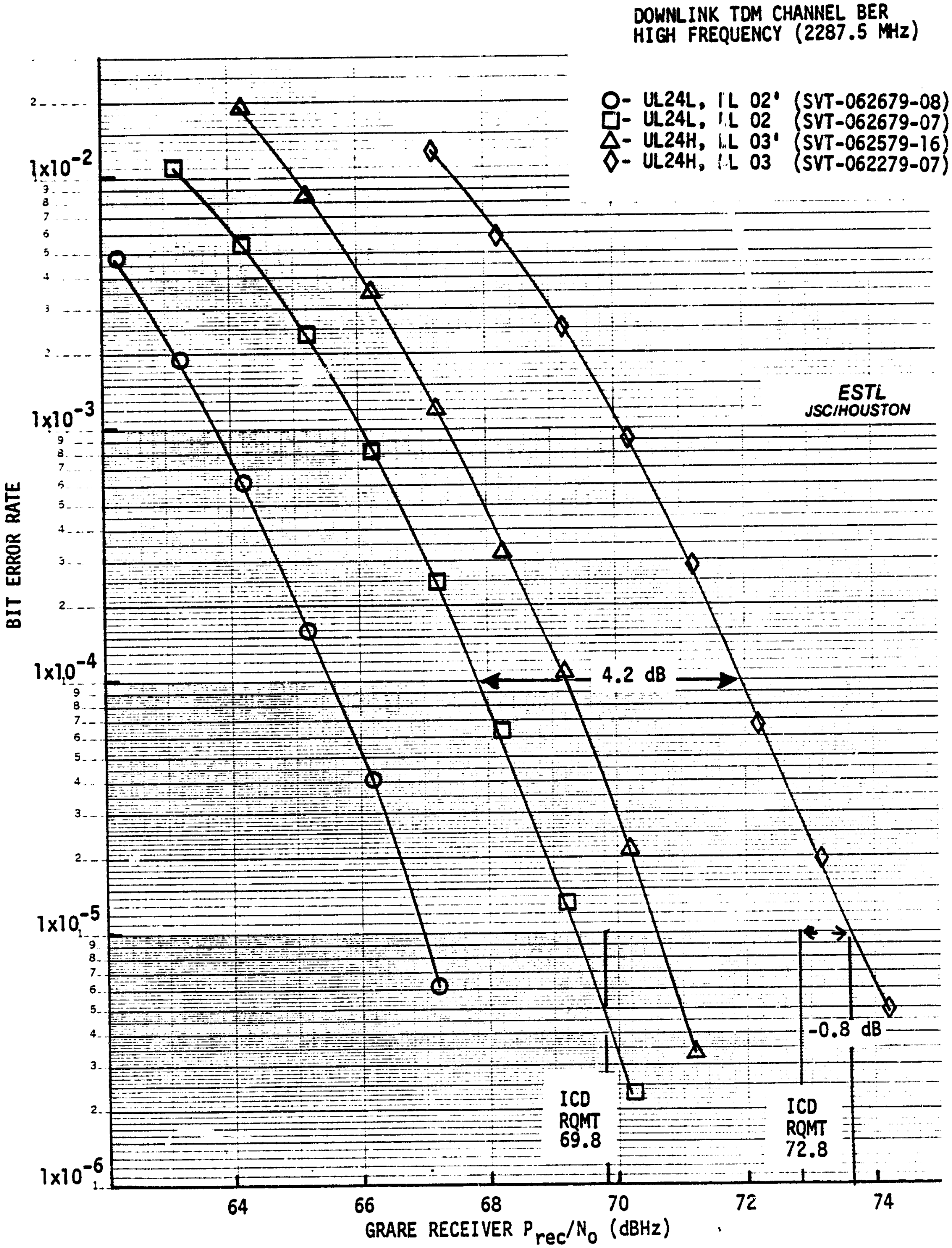

FIGURE 3-8 DOWNLINK TDM CHANNEL BIT ERROR RATE AS A FUNCTION OF GRARE RECEIVER P_{rec}/N_o

Downlink TDM channel BER tests were performed at Doppler offset frequencies of ±52 kHz and ±64.93 kHz for the uplink and downlink, respectively. These tests were conducted for both the low and high frequencies. The results of the various Doppler tests showed that there were no detectable effects on the downlink TDM channel performance.

Radio frequency interference tests were conducted to determine if rf signals from the S-band OI (operation instrumentation) FM transmitter or the S-band DFI (development flight instrumentation) FM transmitter would affect the performance of the downlink TDM channels. The rf paths from the interfering FM transmitters were adjusted so that the rf interference was more than 10 dB above the S-band PM downlink signal. The interfering rf signals had no noticeable effect upon the performance of the downlink TDM channel.

A summary of the circuit margins for the downlink is shown in Table 3-6. Even though the ICD required performance for the high data rate modes was not achieved, the BER performance indicates measured circuit margins of 12.7 dB minimum.

3.3.1.2 Percent Data Loss Performance

Downlink TDM channel percent data loss tests were conducted using GSTDN processing equipment, i.e., Monitor 330 bit synchronizer and 403 frame synchronizer. These two synchronizers are part of the voice delta demodulation system and are the same model bit and frame synchronizers that will be located at the AFSCF/STC. The optimum settings (maximum data recovery) for the monitor 403 frame synchronizer were found to be:

E_S = 2 - No. of allowable errors in search

E_L = 2 - No. of allowable errors in lock

F_L = 3 - No. of successive frames with greater than 2 errors required to lose lock

ESTL
JSC/HOUSTON

TABLE 3-6. PM DOWNLINK CIRCUIT MARGIN SUMMARY

SIGNAL COMBINATION		P_{rec}/N_o REQUIRED FOR 1 x 10^{-5} BER		P_{rec}/N_o FOR 1. x 10^{-4} BER	EXPECTED** P_{rec}/N_o (dBHz)	MEASURED MARGIN FOR 1x10^{-4} BER (dB)	MEASURED MARGIN FOR 1x10^{-5} BER (dB)
UL	DL	ICD*	MEASURED	MEASURED			
24L	02'	-	66.9	65.5	86.3	20.8	19.4
24L	02	69.8	69.4	67.8	86.3	18.5	16.9
24H	03'	-	70.8	69.2	86.3	17.1	15.5
24H	03	72.8	73.6	72.0	86.3	14.3	12.7

*ICD2-0D003 DOD MISSION REQUIREMENTS

**OFT missions - Orbiter transmit power - 3 dBW; Orbiter antenna gain - 3 dB; slant range - 1122 nmi (5^0 elevation for 270 nmi orbit); AFSCF/RTS antenna gain - 47.5 dB.

These settings are recommended for mission operations.

The percent data loss test results for the downlink signal combinations specified in Table 2-2 are shown in figure 3-9. The percent data loss is obtained by counting the number of frames lost and dividing by the number of total frames transmitted, i.e., 118 frames lost, 10,000 frames transmitted equals 1.18 percent data loss.

For each downlink signal combination the P_{rec}/N_o was varied over a range to produce at least 50 percent data loss. At 50 percent data loss both the telemetry and voice channels become unusable.

3.3.2 Downlink Voice Channel Performance

3.3.2.1 Subjective Voice Quality Evaluation (ATU input)

The downlink voice quality evaluation was performed for various uplink/downlink signal combinations. The criteria used to rate the voice quality is shown in Table 3-2. Figure 3-10 presents a block diagram of the test configuration for voice quality and word intelligibility tests. A speech level of 0 dBm was input to the ATU (Audio Terminal Unit) during these tests. The noise environment expected on the Orbiter was not simulated during the voice quality tests. The uplink signal combinations 24H and 24L were used and the uplink rf path was adjusted to provide the P_{rec}/N_o ratio expected at the Orbiter (P_{rec}/N_o = 103.6 dBHz) during missions.

For uplink mode 24H and downlink mode 03', fair quality voice was obtained at a P_{rec}/N_o of 67.2 dBHz. This P_{rec}/N_o corresponded to a BER 1.2×10^{-3}. A fair voice quality rating for uplink mode 24H and downlink mode 03 (ranging channel enabled no ranging subcarrier) was obtained at P_{rec}/N_o of

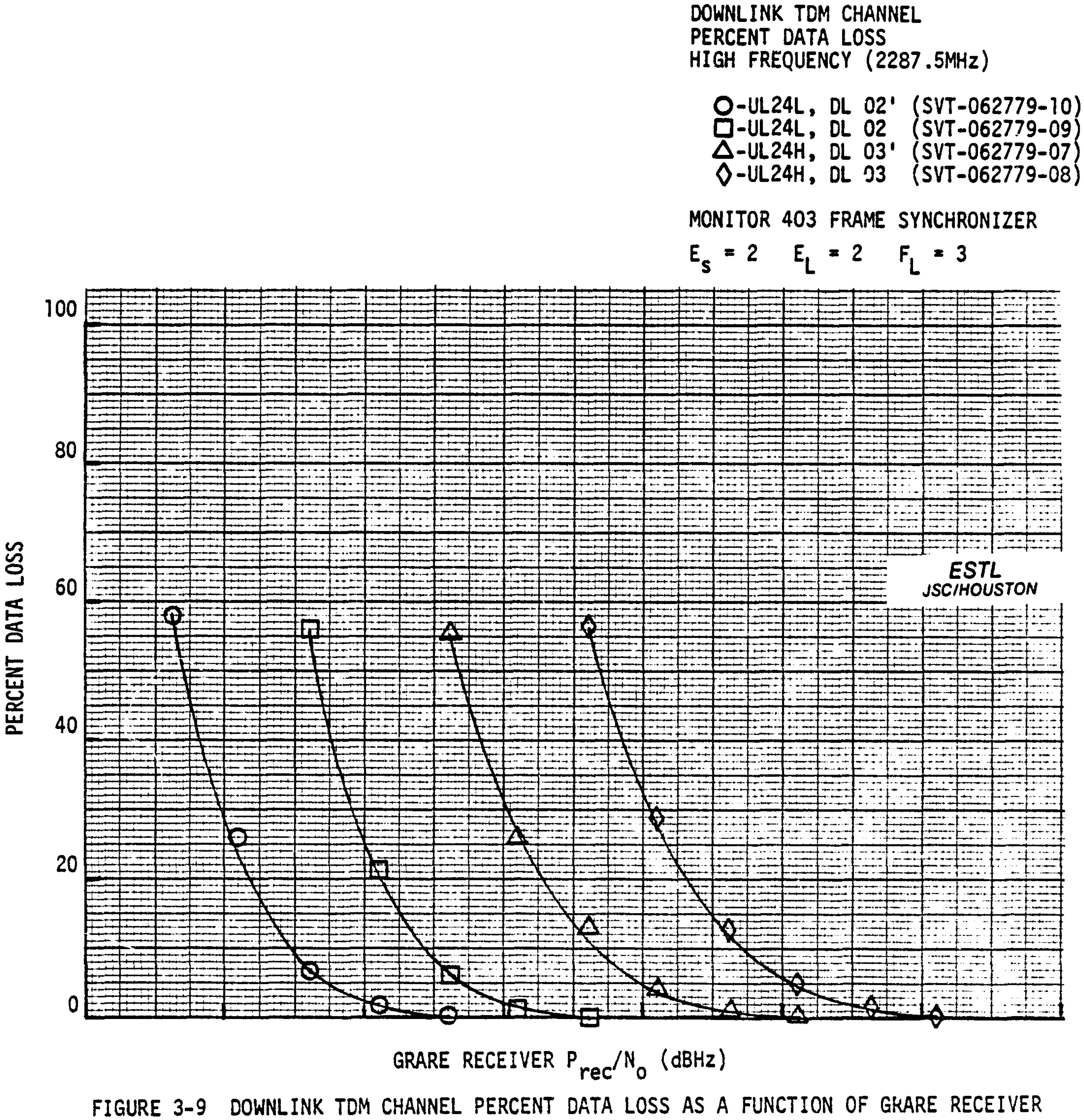

FIGURE 3-9 DOWNLINK TDM CHANNEL PERCENT DATA LOSS AS A FUNCTION OF GRARE RECEIVER P_{rec}/N_o

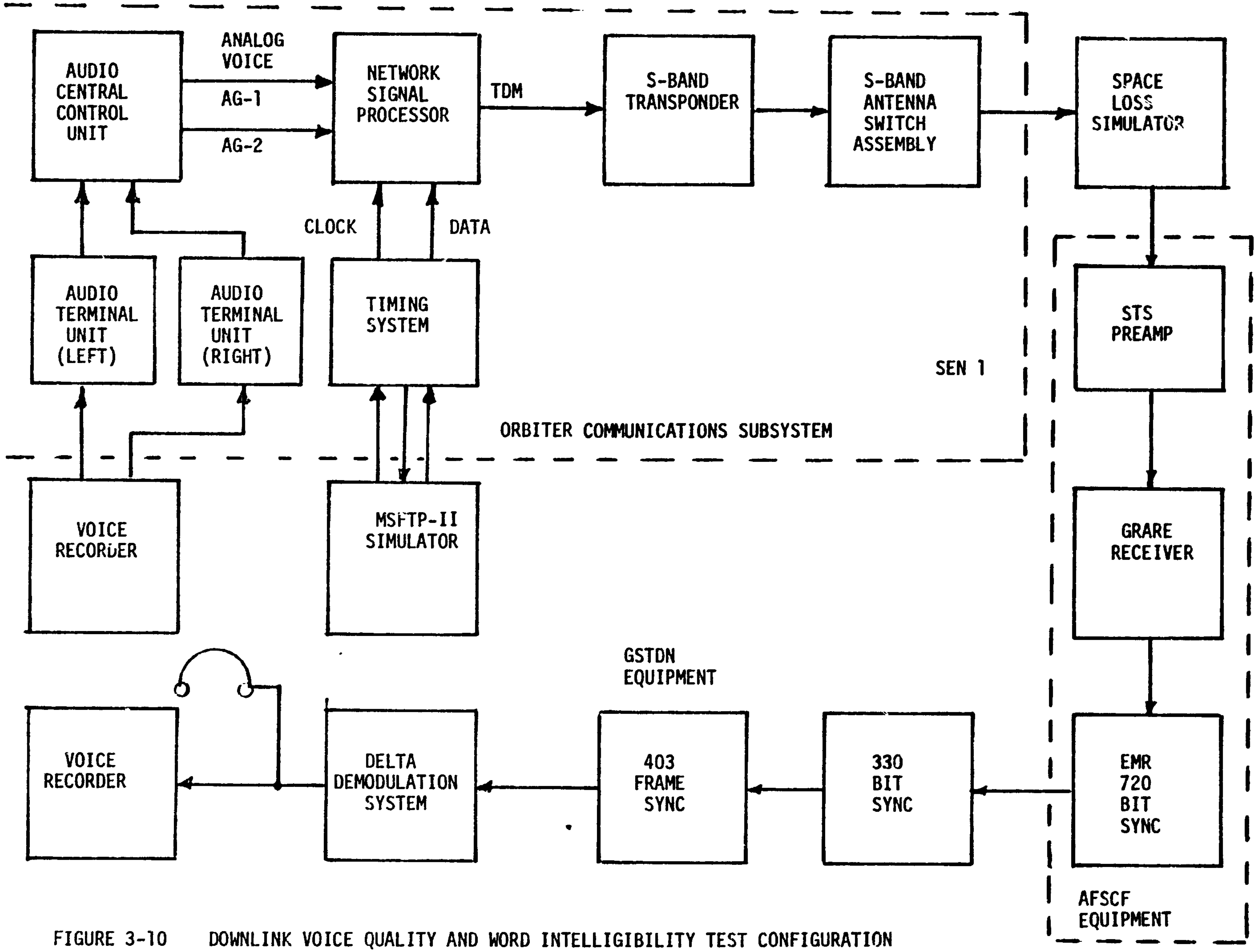

FIGURE 3-10 DOWNLINK VOICE QUALITY AND WORD INTELLIGIBILITY TEST CONFIGURATION

69.2 dBHz. This P_{rec}/N_0 corresponded to a BER of 2.5×10^{-3}. A fair voice quality rating for uplink mode 24L and downlink mode 02' was obtained at a P_{rec}/N_0 of 63.2 dBHz. The BER for this P_{rec}/N_0 was 1.9×10^{-3}. For uplink mode 24L and downlink mode 02 (ranging channel enabled - no ranging subcarrier), a fair voice quality rating was obtained at a P_{rec}/N_0 of 65.2 dBHz. The BER was 2.3×10^{-3}.

3.3.2.2 Word Intelligibility Performance

Word intelligibility tests were performed using source tapes consisting of phonetically balanced word lists. The speech from these source tapes was summed with noise that simulted the on-orbit noise environment of the Orbiter. The noise spectrum was shaped by the frequency response of a Gentex headset. The summed speech signals and noise were played through the system and audio tapes were recorded at the delta demodulator outputs. After the tests, the audio tapes were sent to Fort Huachua, Arizona for word intelligibility evaluation. The word intelligibility tests were performed for a simulated Gentex headset and the following signal combinations:

1. Uplink 24L; downlink 02'
2. Uplink 24L; downlink 02
3. Uplink 24H; downlink 03'
4. Uplink 24H; downlink 03

The speech level at the ATU input was 0 dBm and the resulting speech-to-noise ratio was +36.25 dB. The results of the word intelligibility evaluations are presented in Table 3-7.

Based on the 90% word intelligibility required by ICD 2-0D003 and expected P_{rec}/N_0 of 86.3 dBHz, voice channel circuit margins of 21.1 dB and 19.1 dB were measured for signal combinations 02 and 03, respectively.

TABLE 3-7

DOWNLINK WORD INTELLIGIBILITY RESULTS

ESTL
JSC/HOUSTON

SIGNAL COMBINATION	VOICE QUALITY RATING	P_{rec}/N_o (dBHz)	BER	PERCENT DATA LOSS (%)	AVERAGE WORD INTELLIGIBILITY (PERCENT)
UL24H, DL 03'	Expected (+3.4dB)	89.7	-	-	93.7
	ICD Requirement	70.0	3.0×10^{-5}	0	94.5
	Fair	67.2	1.2×10^{-3}	0.08	96.4
	Poor	65.2	8.6×10^{-3}	1.18	94.4
	Usable	64.2	1.9×10^{-2}	4.02	82.4
UL24H, DL 03	Expected (+3.4dB)	89.7	-	-	97.6
	ICD Requirement	72.4	5.2×10^{-5}	0	97.5
	Fair	69.2	2.5×10^{-3}	0.15	97.0
	Poor	67.2	1.3×10^{-2}	1.35	94.6
	Usable	66.2	-	4.52	84.8
UL24L, DL 02'	Expected (+3.4dB)	89.7	-	-	97.5
	ICD Requirement	67.0	8.6×10^{-5}	-	97.2
	Fair	63.2	1.9×10^{-3}	0	96.8
	Poor	61.2	1.0×10^{-2}	0.38	94.9
	Usable	60.2	-	1.40	90.5
UL24L, DL 02	Expected (+3.4dB)	89.7	-	-	97.2
	ICD Requirement	69.4	9.5×10^{-5}	-	97.3
	Fair	65.2	2.3×10^{-3}	0	97.7
	Poor	63.2	1.1×10^{-2}	0.33	97.4
	Usable	62.2	-	1.41	91.6

3.4 S-band FM Downlink Tests

The purpose of these tests was to evaluate the capability of the Orbiter-AFSCF/RTS FM direct link to meet the Shuttle mission requirements. Two downlink system configurations were tested, an operational instrumentation (OI) downlink and a development flight instrumentation (DFI) downlink. The OI downlink used a separate wideband FM transmitter at a carrier frequency of 2250 MHz to transmit one of three data modes i.e., (playback TDM data, playback TLM data and realtime DOD payload digital data). Tests of the OI link were performed using both the ASGLS and the Microdyne 1100 AR FM receivers. The two types of receivers were used because some AFSCF/RTS have the ASGLS receivers and others have the Microdyne 1100 AR receivers. The Indian Ocean Station which will support OFT has a Microdyne 1100 AR receiver.

The DFI FM transmitter at a carrier frequency of 2205 MHz, transmits 16 subcarriers consisting of one PCM telemetry channel, 14 analog channels and one digital channel. Tests of the DFI link were performed using the Microdyne 1100 AR FM receiver.

3.4.1 FM Receivers IF Predetection Signal-To-Noise Ratio Performance

The IF predetection signal-to-noise ratio (SNR) was measured for both the ASGLS and Microdyne FM receivers. Figure 3-11 is a block diagram of the test configuration and figure 3-12 is a plot of the test results. The results show that the Microdyne receiver with its narrow IF bandwidth has an IF predetection SNR approximately 5 dB greater than the ASGLS receiver. The following bit error performance results shows that the Microdyne receiver performance is approximately 5 dB better than the ASGLS receiver.

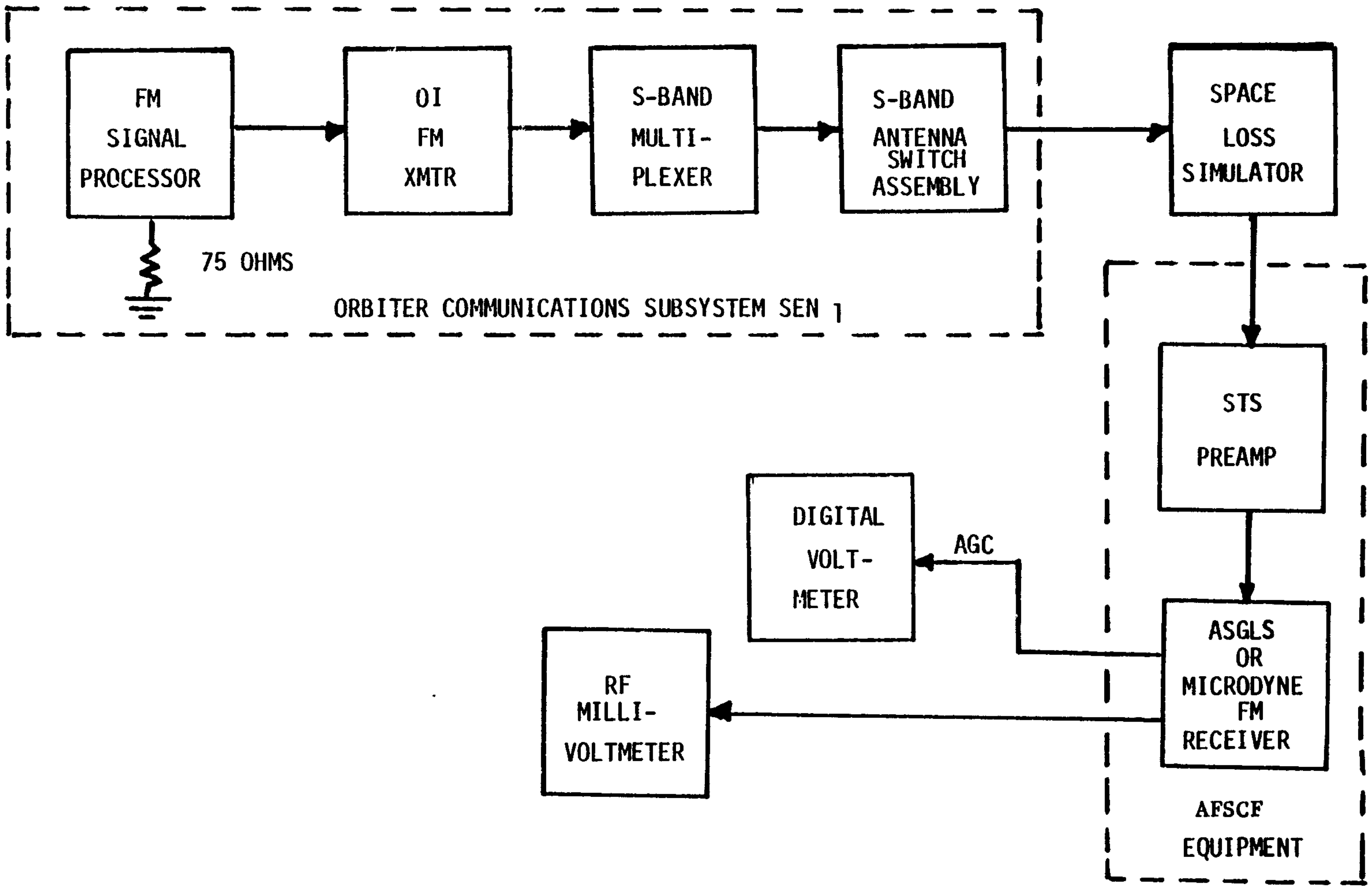

FIGURE 3-11 ASGLS OR MICRODYNE FM RECEIVER IF PREDECTION SIGNAL-TO-NOISE RATIO TEST CONFIGURATION

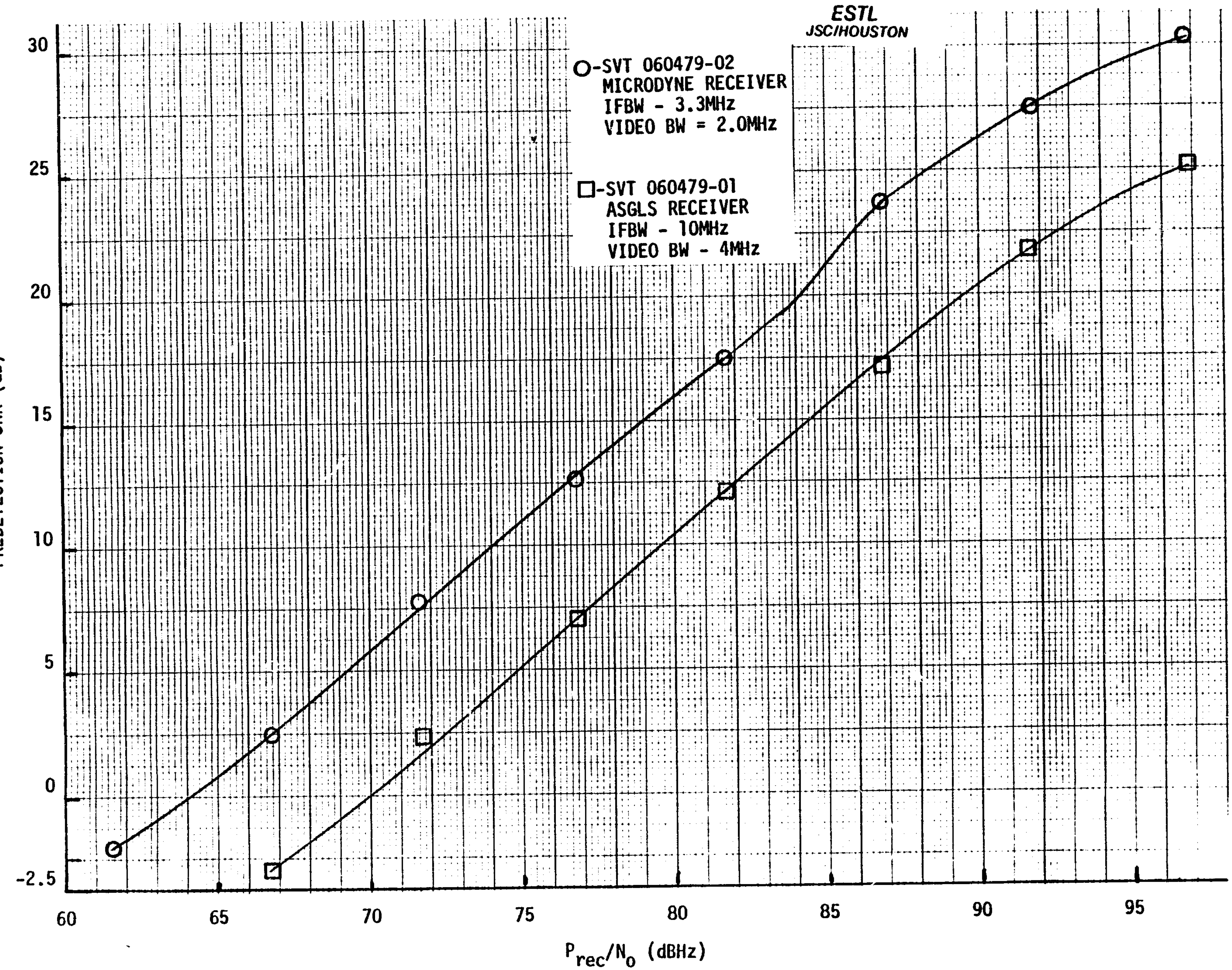

FIGURE 3-12 IF PREDETECTION SIGNAL-TO-NOISE RATIO AS A FUNCTION OF P_{rec}/N_0

3.4.2 Operational Instrumentation Downlink Performance

3.4.2.1 FM Link Playback TDM Data Tests - (OPS Recorder)

The playback TDM from the OPS recorder was evaluated by measurement of BER, percent data loss and voice quality. Both the ASGLS and Microdyne receivers were used. Figure 3-13 is a block diagram of the test configuration. The link was tested using a telemetry data generator to simulate the recorder output (i.e., not using the OPS recorder) and using the OPS recorder in both 1:1 and 5:1 playback. The telemetry data generator was used to establish base line performance data. Evaluation of the tests performed using the data generator as a source and tests performed with 1:1 OPS recorder playback were accomplished without intermediate ground recordings. The 5:1 playback was first recorded on the AFSCF FR-2000 recorder and then played back at a slower speed for evaluation.

Figure 3-14 presents the BER and percent data loss results of playback TDM data (192 kbps) for the Microdyne receiver. The percent data loss at each measurement point is indicated in the parenthesis next to the BER points. For the 5:1 playback, the measured P_{rec}/N_o where a BER of 1×10^{-5} occurred was approximately 2.6 dB better than the ICD requirement. The measured circuit margins were 18.2 dB and 13.5 dB for 1:1 and 5:1 playback, respectively. The measured circuit margins for all AFSCF FM downlink tests are presented in Table 3-8.

Figure 3-15 presents the BER and percent data loss results of playback TDM data (192 kbps) for the ASGLS receiver. The measured P_{rec}/N_o where a BER of 1×10^{-5} occurred was approximately 2.4 dB worse than the ICD requirement. The measured circuit margins were 13.4 dB and 8.4 dB for 1:1 and 5:1 playback, respectively.

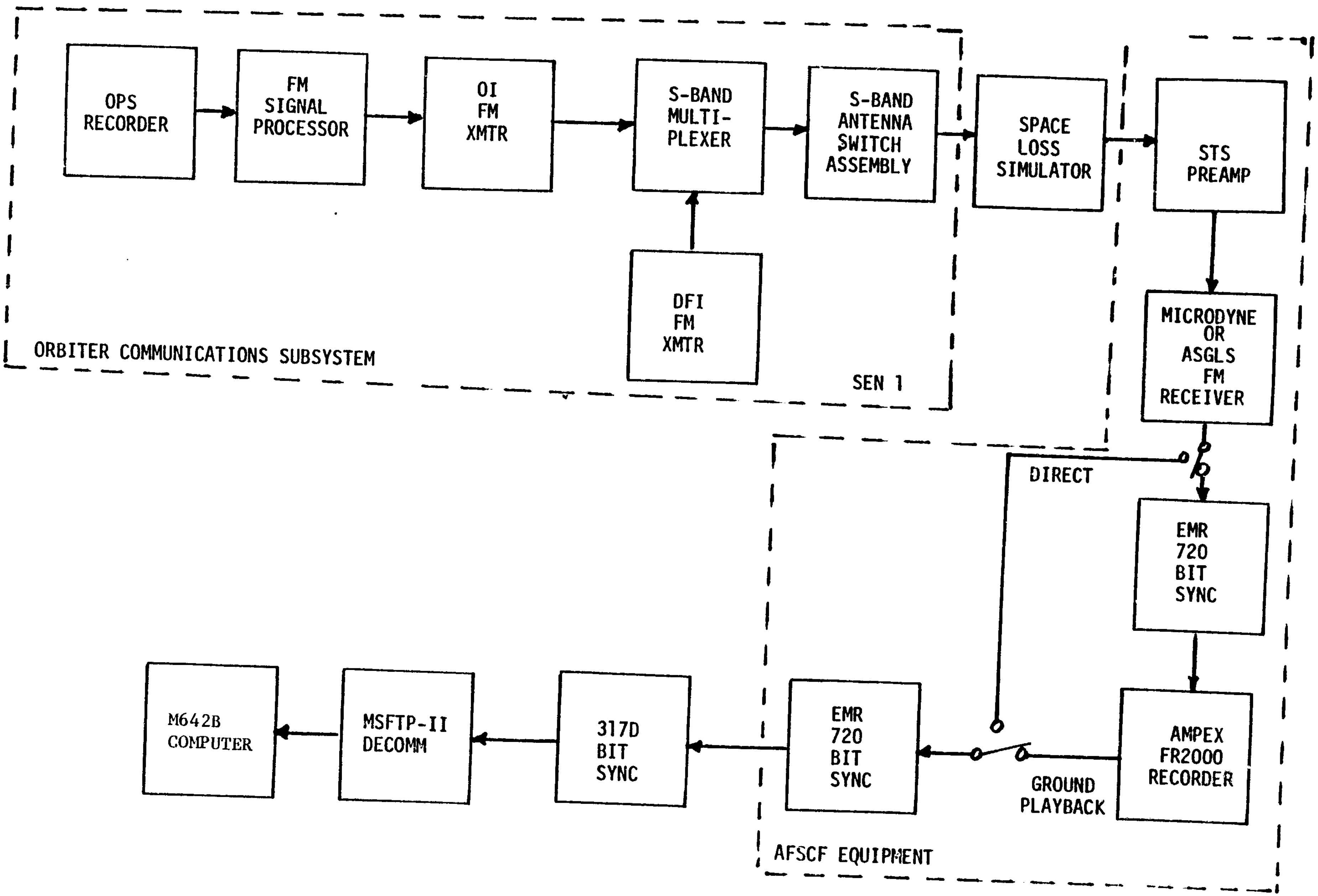

FIGURE 3-13 OPS RECORDER PLAYBACK BER AND PERCENT DATA LOSS TEST CONFIGURATION

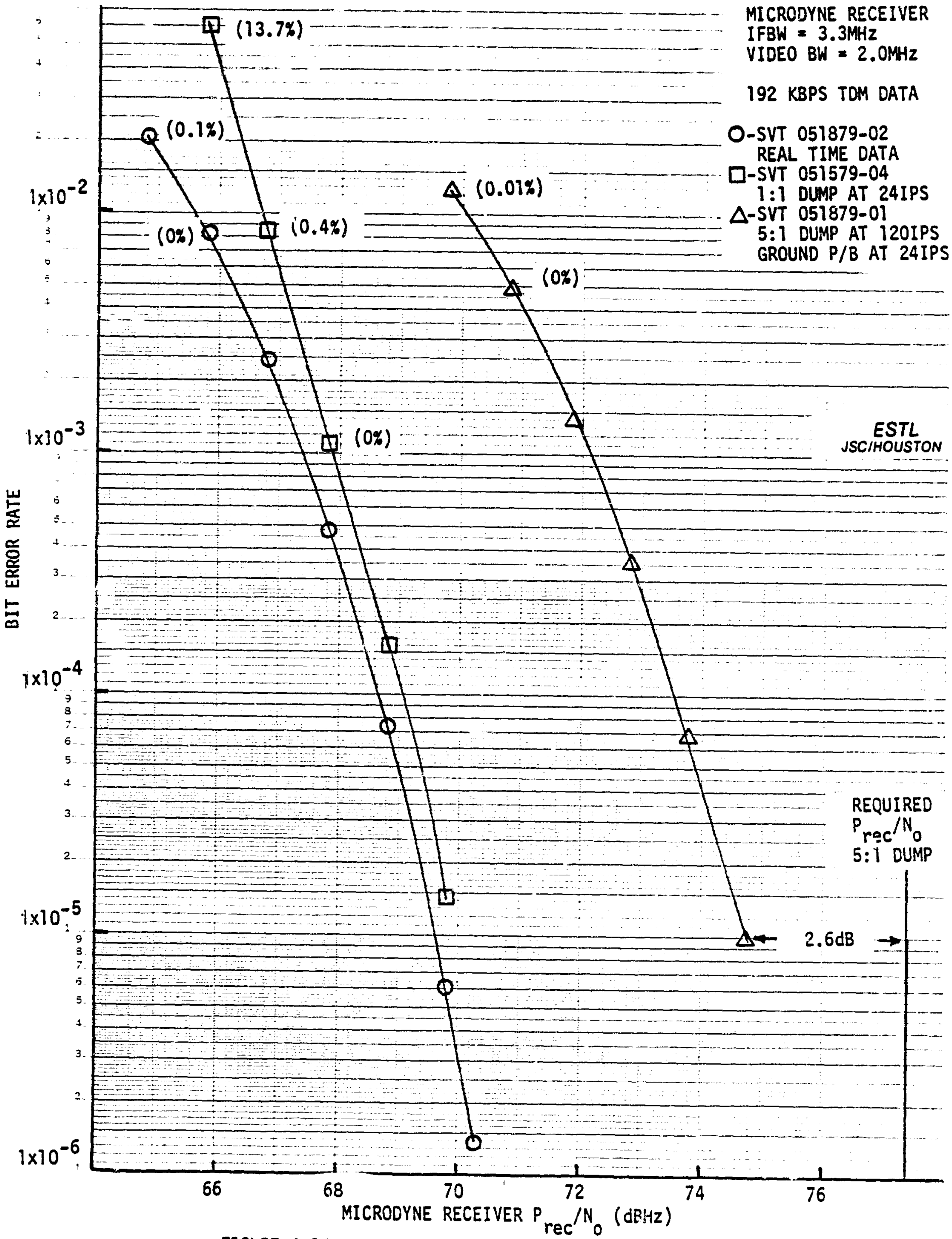

FIGURE 3-14 TDM BIT ERROR RATE AS A FUNCTION OF P_{rec}/N_o

TABLE 3-8 FM DOWNLINK CIRCUIT MARGINS

ESTL
JSC/HOUSTON

DATA	RECEIVER	CONDITIONS	MEASURED P_{rec}/N_o (dBHz) BER - 1×10^{-5}	EXPECTED P_{rec}/N_o (dBHz) BER - 1×10^{-5}	MEASURED CIRCUIT MARGIN (dB)
PLAYBACK TDM DATA (OPS RECORDER)	MICRODYNE	1:1	70.0	88.2	18.2
	"	5:1	74.7	88.2	13.5
	ASGLS	1:1	74.8	88.2	13.4
	"	5:1	79.8	88.2	8.4
PLAYBACK OI TELEMETRY (OPS RECORDER)	ASGLS	1:1 15 IPS	73.6	88.2	14.6
		8:1 15 IPS	79.8	88.2	8.4
		1:1 24 IPS	73.1	88.2	15.1
		5:1 24 IPS	78.6	88.2	9.6
	MICRODYNE	1:1 15 IPS	68.7	88.2	19.5
		8:1 15 IPS	75.2	88.2	13.0
		1:1 24 IPS	68.3	88.2	19.9
		5:1 24 IPS	74.3	88.2	13.9

TABLE 3-8 FM DOWNLINK CIRCUIT MARGINS (CONT'D)

ESTL
JSC/HOUSTON

DATA	RECEIVER	CONDITIONS	MEASURED P_{rec}/N_o (dBHz) BER - 1×10^{-5}	EXPECTED P_{rec}/N_o (dBHz) BER - 1×10^{-5}	MEASURED CIRCUIT MARGIN (dB)
REALTIME DOD PAYLOAD DIGITAL DATA	ASGLS	4 KBPS:NRZ-L	67.5	88.2	20.7
		BI-Ø-L	67.0	88.2	21.2
		256 KBPS:NRZ-L	75.0	88.2	13.2
		BI-Ø-L	75.4	88.2	12.8
	MICRODYNE	250 BPS:NRZ-L	52.6	88.2	35.6
		BI-Ø-L	52.9	88.2	35.3
		4 KBPS:NRZ-L	58.3	88.2	29.9
		BI-Ø-L	58.7	88.2	29.5
		256 KBPS:NRZ-L	70.4	88.2	17.8
		BI-Ø-L	70.6	88.2	17.6
DFI PCM TELEMETRY	MICRODYNE	128 KBPS: REALTIME PLAYBACK	72.0 72.0	83.5 83.5	11.5 11.5
		16 KBPS: REALTIME PLAYBACK	71.8 71.8	83.5 83.5	11.7 11.7

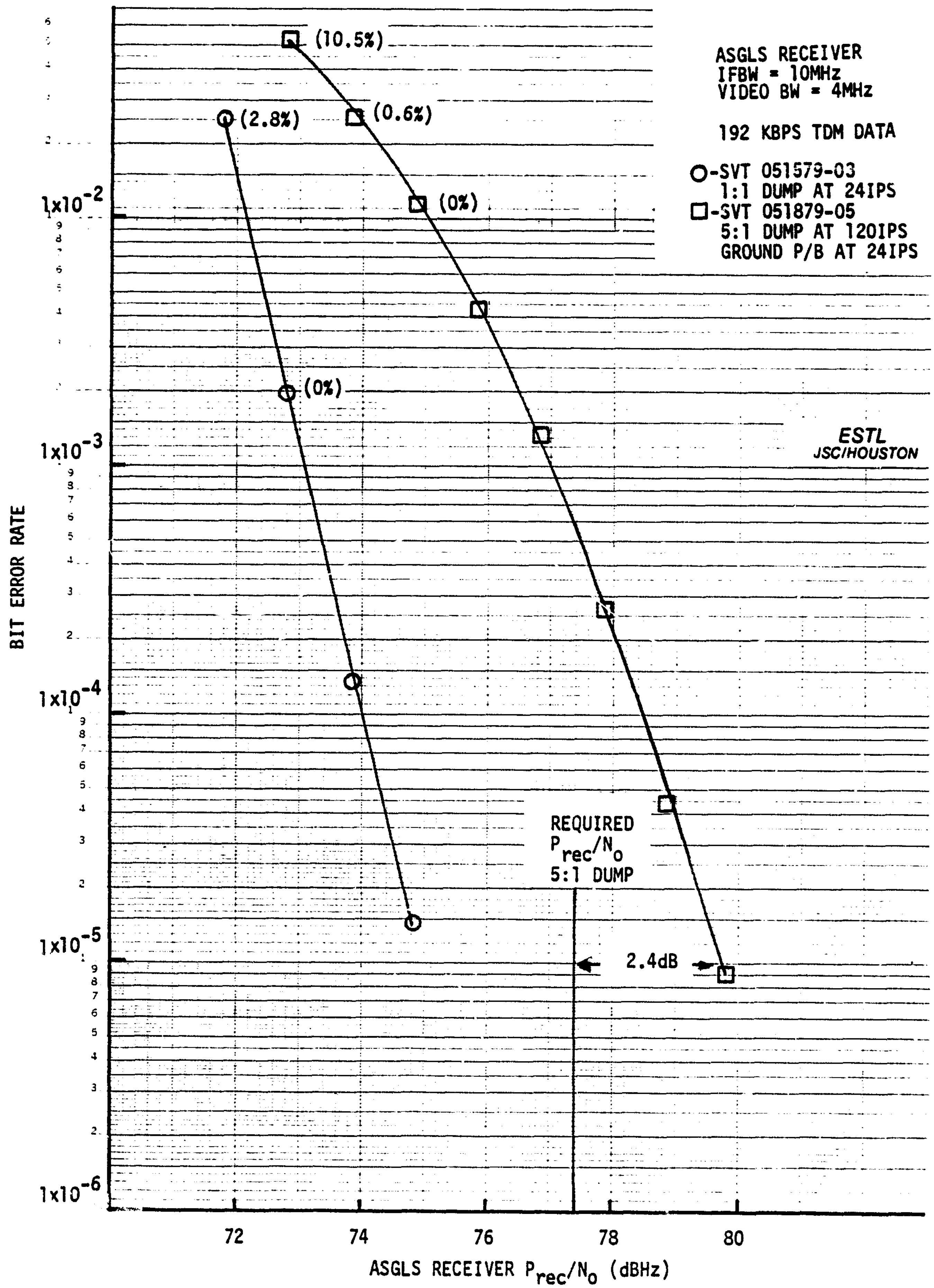

FIGURE 3-15 TDM BIT ERROR RATE AS A FUNCTION OF ASGLS RECEIVER P_{rec}/N_o

The percent data loss tests were run simultaneous with the BER tests and percent data losses greater than 50 percent were obtained for most test conditions. In most cases, data losses greater than 50 percent occurred at BER's of 1×10^{-1} or greater.

Table 3-9 presents the results of the subjective voice quality evaluation for the Microdyne receiver. A subjective voice quality rating of "FAIR" (90 percent word intelligibility or greater) occurred at P_{rec}/N_o of 67.8 dBHz and 69.8 dBHz for 1:1 and 5:1 playback, respectively. These P_{rec}/N_o's are 9.6 dB (77.4 - 67.8) and 7.6 dB better than the ICD required P_{rec}/N_o of 77.4 dBHz.

3.4.2.2 FM Link Playback OI Telemetry Channel Tests

The playback OI telemetry channel was evaluated by performing BER and percent data loss tests on both the ASGLS and Microdyne receiver. Figure 3-13 is a block diagram of the tests configuration. Two speeds, 15 ips and 24 ips, were used to record the 128 kbps telemetry data on the OPS recorder. The 15 ips recording was then evaluated when played back at 1:1 and 8:1 ratios. The 24 ips recording was evaluated at 1:1 and 5:1 playback ratios. Figure 3-16 presents the BER and percent data loss results of the 128 kbps telemetry data for the Microdyne receiver. The measured circuit margins were 19.5 dB and 13.0 dB for 1:1 (15 ips) and 8:1 playback, respectively. The measured circuit margins were 19.9 dB and 13.9 dB for the 1:1 (24 ips) and 5:1 playback, respectively.

Figure 3-17 presents the BER and percent data loss results of the 128kbps telemetry data for the ASGLS receiver. The measured circuit margins were 14.6 dB and 8.4 dB for the 1:1 (15 ips) and 8:1 playback, respectively. The measured circuit margins were 15.1 dB and 9.6 dB for the 1:1 (24 ips) and 5:1 playback, respectively.

TABLE 3-9 DOWNLINK PLAYBACK TDM (OPS RECORDER) SUBJECTIVE VOICE QUALITY-MICRODYNE RECEIVER

ESTL
JSC/HOUSTON

PLAYBACK RATIO	MICRODYNE RECEIVER P_{rec}/N_o* (dBHz)	SUBJECTIVE VOICE QUALITY RATING
1:1	69.8	GOOD
	67.8	FAIR
	66.8	POOR
	65.8	USABLE
	64.8	UNUSABLE
5:1	73.8	GOOD
	69.8	FAIR
	67.8	POOR
	66.8	USABLE
	65.8	UNUSABLE

*ICD Required P_{rec}/N_o = 77.4 dBHz

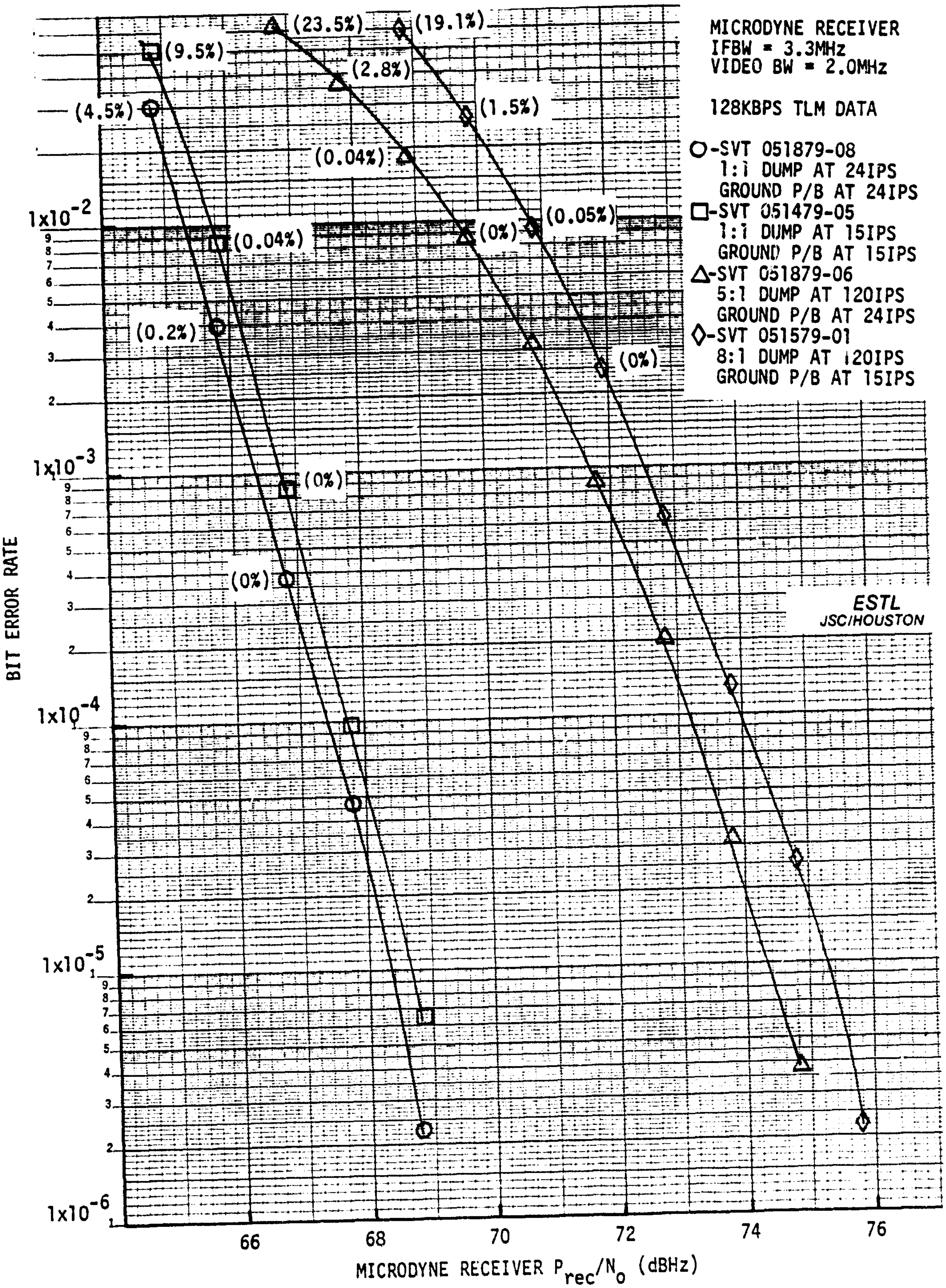

FIGURE 3-16 TELEMETRY BER AS A FUNCTION OF P_{rec}/N_o

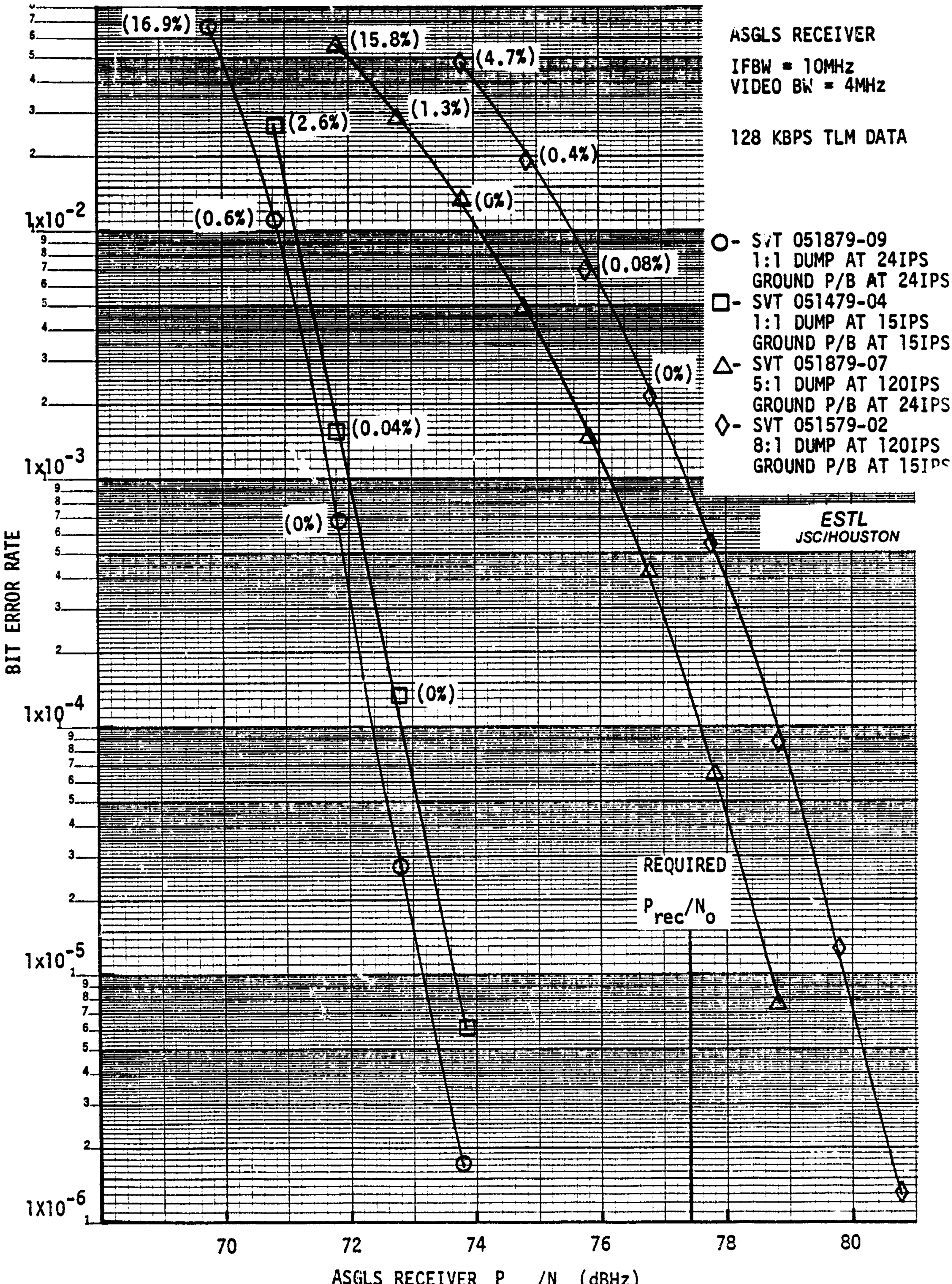

FIGURE 3-17 TELEMETRY BER AS A FUNCTION OF P_{rec}/N_o

3.4.2.3 FM Link Realtime DOD Payload Digital Data

The realtime DOD payload digital data mode was evaluated by measurement of BER and percent data loss. Figure 3-18 is a block diagram of the test configuration. These tests were performed at the maximum and minimum data rates of the selected receiver: From 4 kbps to 256 kbps for the ASGLS and from 250 bps to 256 kbps for the Microdyne. Each bit rate was also tested using NRZ-L and BI-Ø-L data formats.

Figure 3-19 presents the BER and percent data loss test results with 256 kbps data for both the Microdyne and ASGLS receivers. Measured circuit margins for the Microdyne receiver were 17.8 dB and 17.6 dB for the NRZ-L and BIØ-L data formats, respectively. Measured circuit margins for the ASGLS receiver were 13.2 dB and 12.8 dB for the NRZ-L and BIØ-L data formats, respectively. Plots of the results for the 250 bps and 4 kbps (NRZ-L and BIØ-L) tests are not presented in this report. The measured circuit margins are presented in Table 3-8 and are 20 dB or greater for both data formats.

When testing the Microdyne receiver at the lowest bit rate of 250 bps it was observed that when AC coupling was selected on the Microdyne at this bit rate, the BER curve began to tail out. When DC coupling was selected the slope of the BER curve was as expected. DC coupling was selected for the remaining 250 bps tests. In an attempt to further enhance the BER, a wideband amplifier was placed between the receiver and the bit sync. This resulted in only a slight improvement in performance.

3.4.3 Development Flight Instrumentation Downlink Tests

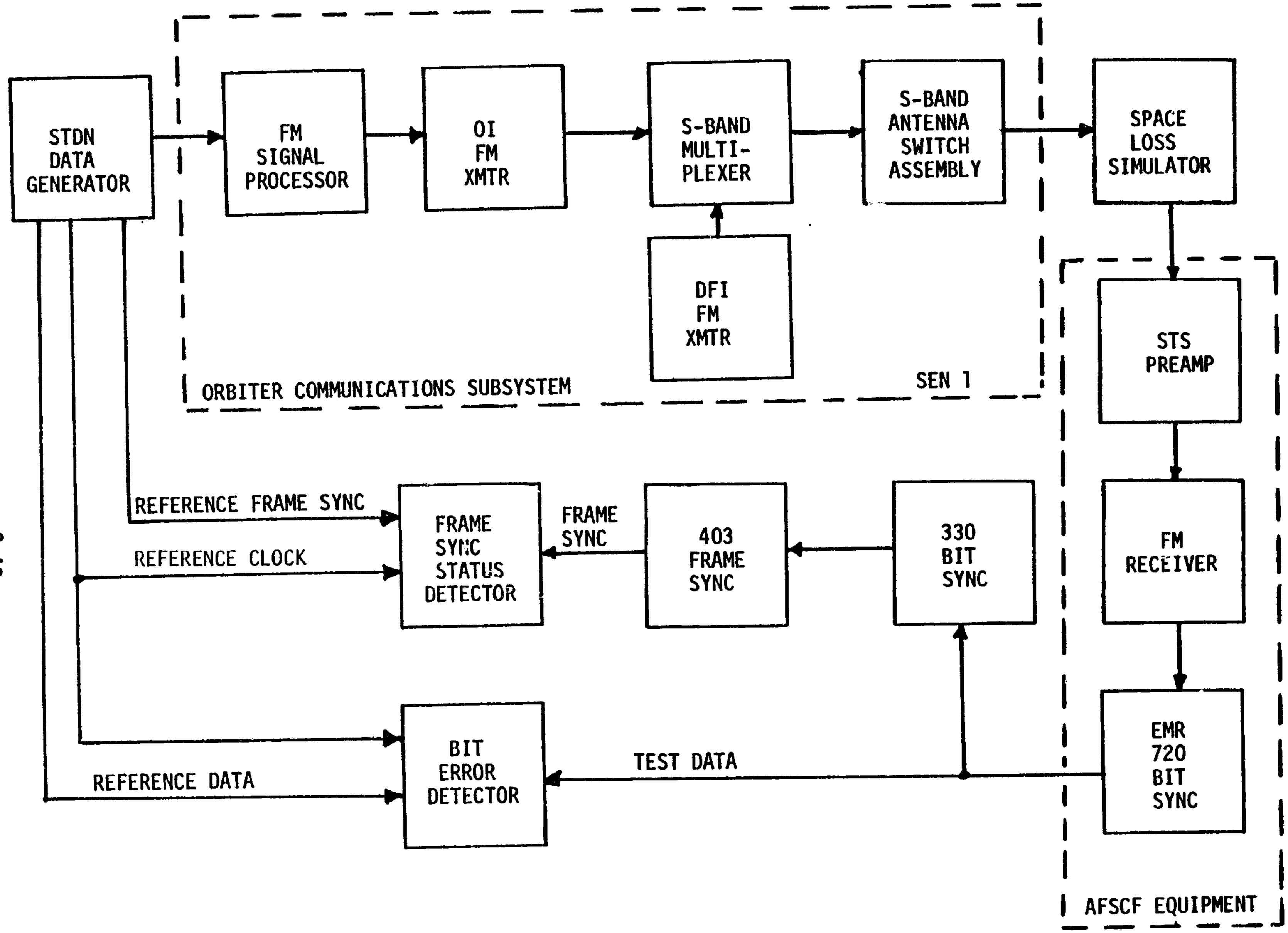

FIGURE 3-18 DOD PAYLOAD DATA BER AND PERCENT DATA LOSS TEST CONFIGURATION

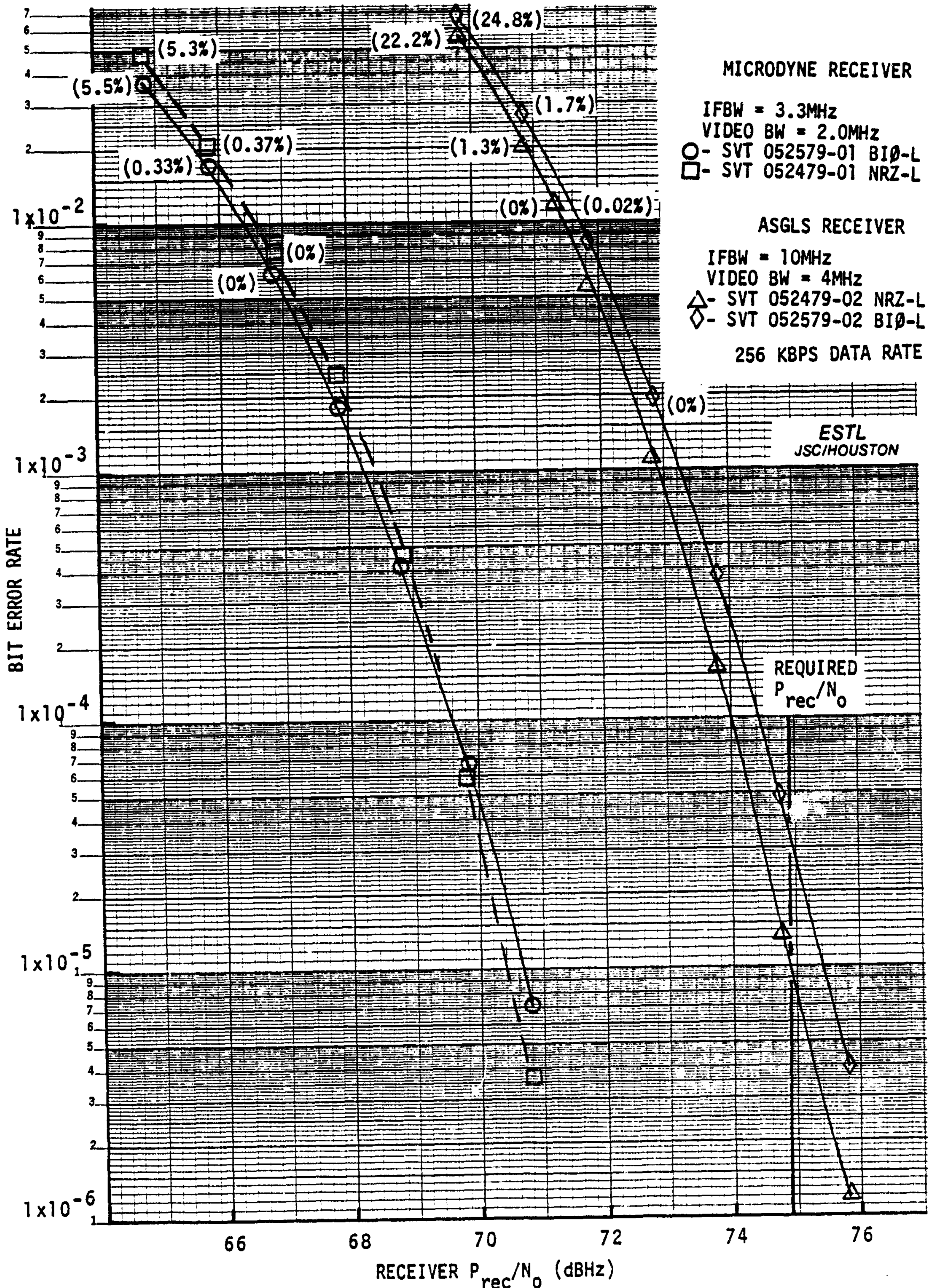

FIGURE 3-19 DOD PAYLOAD DATA BIT ERROR RATE AS A FUNCTION OF P_{rec}/N_o

3.4.3.1 DFI Analog Telemetry - Subcarrier Predetection Signal-To-Noise Ratio Performance

The subcarrier predetection signal-to-noise ratios were measured in these tests for the 1.024 MHz subcarrier and DFI channels 1, 7, 8, 14 and 15. These tests were performed both on realtime and on the playback of the AFSCF FR-2000 recording. The performance of the subcarrier channels (predetection SNR) at a Microdyne receiver P_{rec}/N_o of 77 dBHz is summarized in Table 3-10. The SNR in parenthesis are results from the Orbiter-to-GSTDN tests which are presented for comparison purposes.

3.4.3.2 DFI Analog Telemetry-Subcarrier Post Detection Signal-To-Noise Ratio Performance

The subcarrier post detection SNR was measured in these tests for DFI channels 1, 7, 8, 14 and 15. These tests were performed both on realtime and on the playback of the AFSCF FR-2000 recording. The performance of the subcarrier channels (post detection SNR) at a Microdyne receiver P_{rec}/N_o of 77 dBHz is summarized in Table 3-10.

3.4.3.3 DFI PCM Telemetry Performance

The DFI PCM telemetry was evaluated through measurement of BER and percent data loss for both the realtime and playback signal. Figure 3-20 is a block diagram of the test configuration. Figure 3-21 shows the results of the realtime and playback evaluation. The measured P_{rec}/N_o where BER's of 1×10^{-5} occurred are 5.2 dB better than the ICD requirement for the 16 kbps telemetry data and 5.0 dB better for the 128 kbps telemetry data. The measured circuit margins were 11.5 dB and 11.7 dB for the 128 kbps and 16 kbps telemetry data, respectively.

TABLE 3-10 SUMMARY OF PREDETECTION AND POSTDETECTION SNR TEST (RESULTS FOR DFI SUBCARRIERS AT MICRODYNE RECEIVER P_{rec}/N_o OF 77 dBHz)

ESTL
JSC/HOUSTON

CHANNEL NUMBER	PREDETECTION SNR (dB)		POSTDETECTION SNR (dB)	
	REALTIME	PLAYBACK	REALTIME	PLAYBACK
1	16.7 (14.1)*	14.4	29.0 (25.5)	26.1
7	21.2 (15.3)	16.8	30.0 (25.5)	26.7
8	14.3 (11.1)	10.4	30.3 (22.8)	28.0
14	13.5 (22.5)	**	29.5 (33.0)	28.9
15	15.4 (19.9)	**	36.4 (35.0)	34.0
1.024 MHz	21.1 (13.7)	--	--	--

* ( ) Shows results from Orbiter-GSTDN at MFR P_{rec}/N_o of 76 dBHz

** SNR could not be measured for channels 14 and 15 because of excess jitter on tape recorder playback.

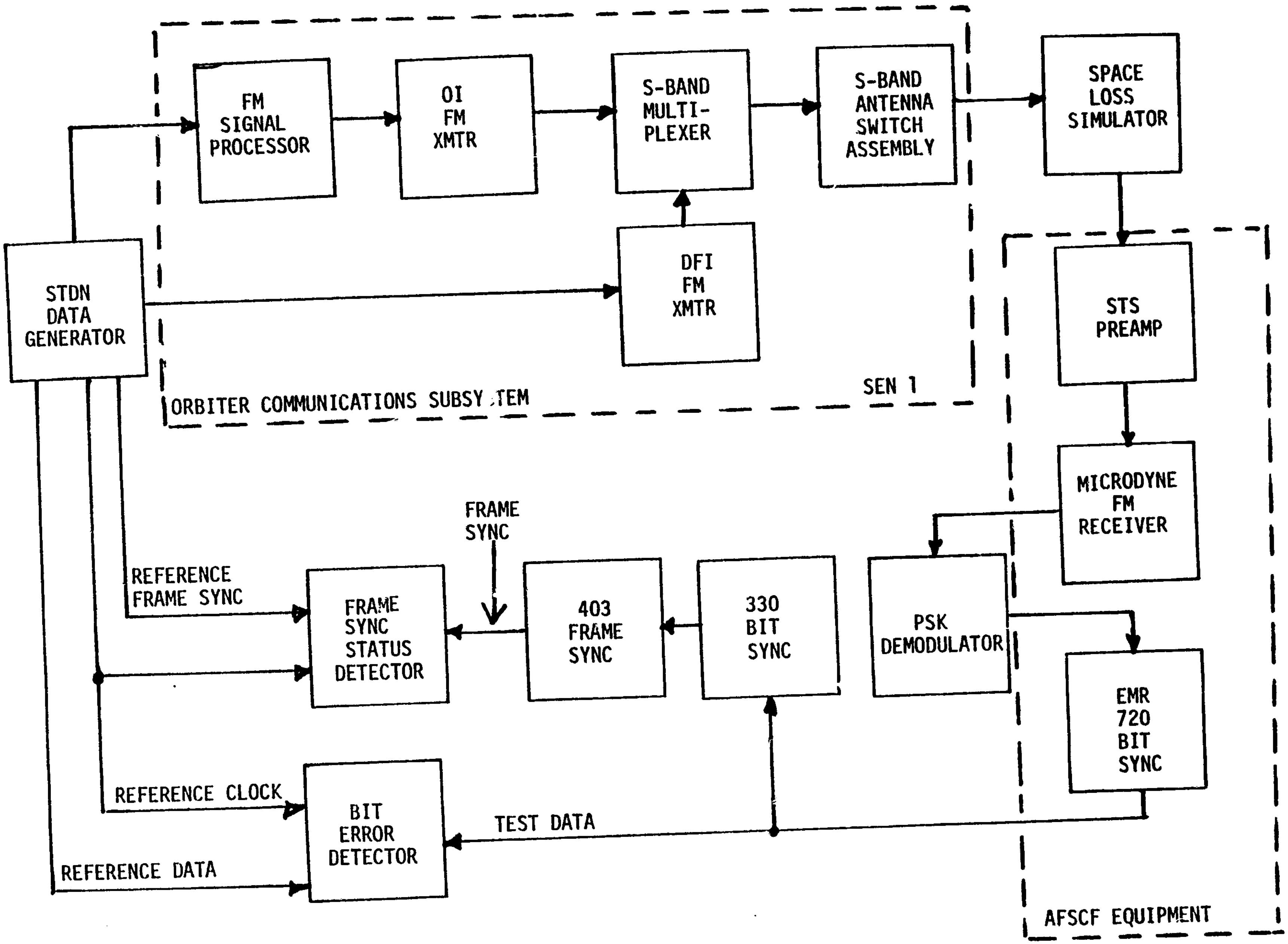

FIGURE 3-20 DFI PCM TELEMETRY TEST CONFIGURATION

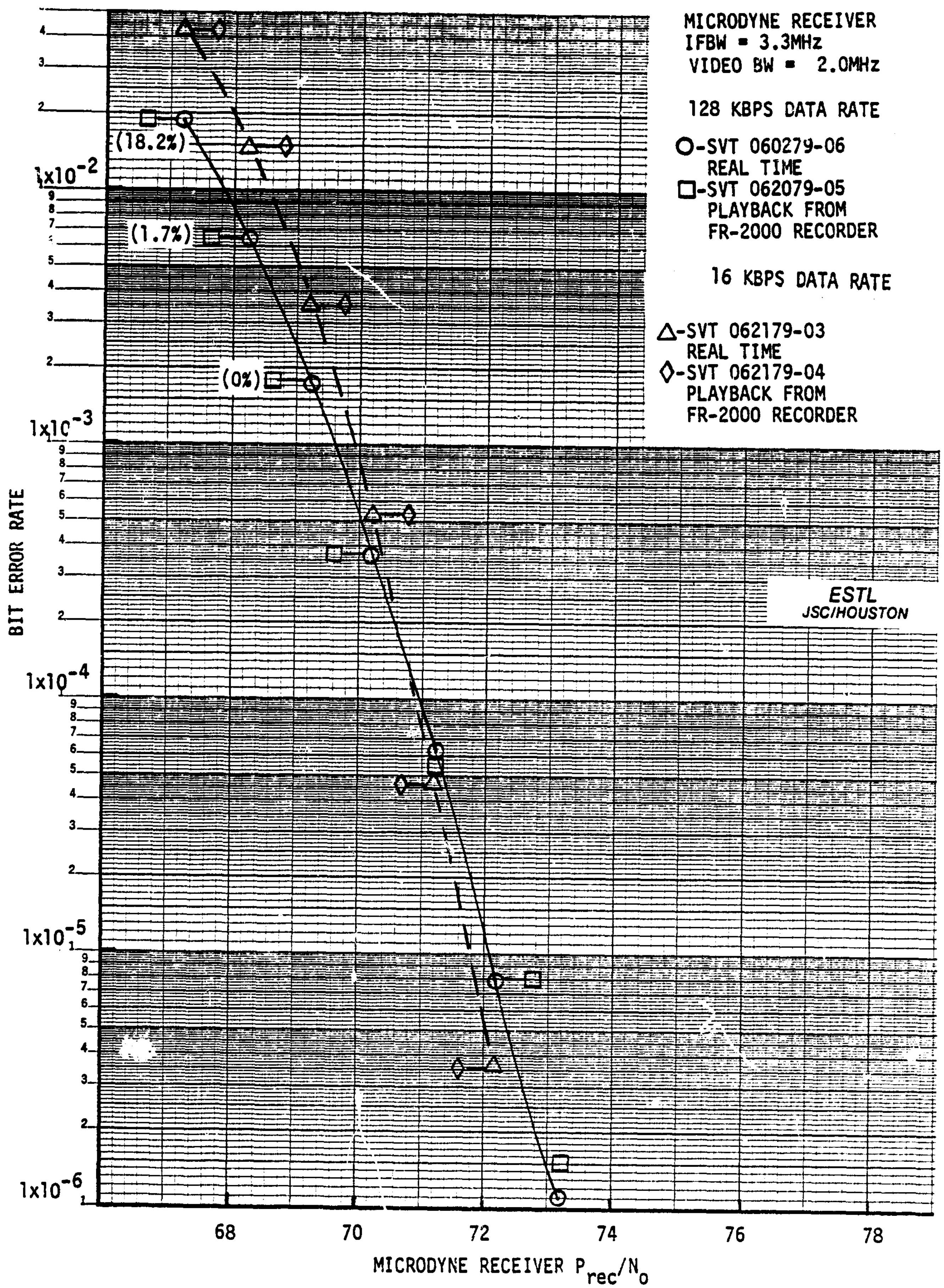

FIGURE 3-21 DFI TELEMETRY BIT ERROR RATE AS A FUNCTION OF P_{rec}/N_o

3.5 RF Acquisition Tests

The purpose of these tests was to evaluate the capability of the Orbiter transponder and the AFSCF/RTS GRARE receiver to provide automatic rf acquisition that meets the Shuttle OFT mission requirements.

The tests were performed with Doppler simulation incorporated through the ERDS (ESTL Range and Doppler Simulator) system. The rf acquisition tests consisted of the uplink rf acquisition, downlink rf acquisition, and two-way rf acquisition. RF carrier tracking threshold tests for the uplink and downlink were also conducted.

3.5.1 Uplink RF Acquisition Performance

The uplink rf acquisition capability was evaluated by determining the probability of acquisition and measuring the time of acquisition as a function of the Orbiter P_{rec}/N_0. Acquisition tests were performed at high and low carrier frequencies and with the maximum expected Doppler rate, positive and negative, imposed on the carrier. A block diagram of the functional configuration for the uplink rf acquisition tests is shown in figure 3-22.

When the Orbiter transponder is not in lock, the transponder sweeps its receive frequency in search of an uplink transmitted signal.

Sweep characteristics, relative to nominal center frequency, of the Orbiter transponder for the low and high uplink frequencies are shown in figure 3-23.

RF carrier tracking threshold measurements were also performed.

Reference 6 shows that the average acquisition time for each acquisition that is started at random points on a triangular sweep will be:

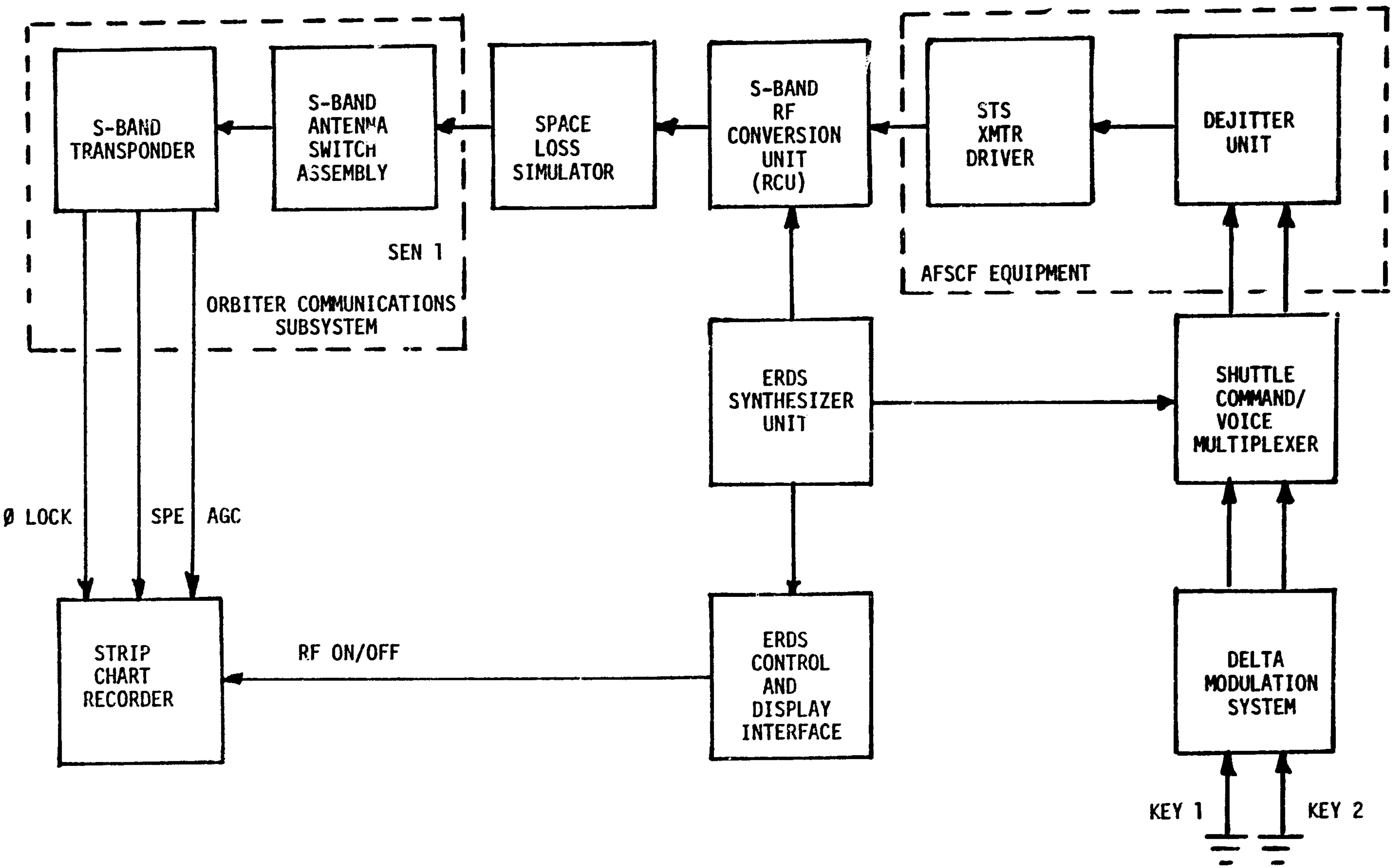

FIGURE 3-22 UPLINK RF ACQUISITION TEST CONFIGURATION

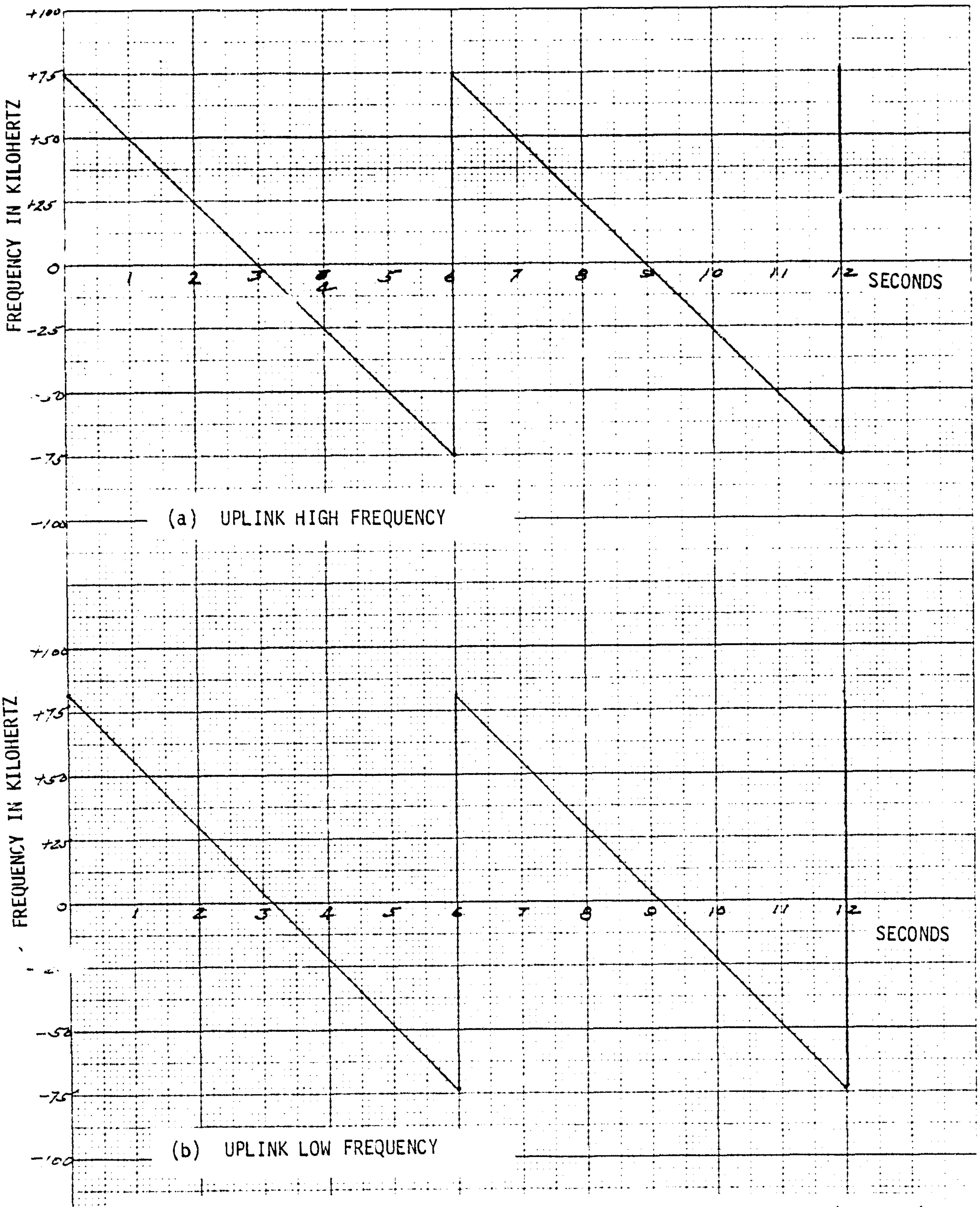

FIGURE 3-23 SWEEP CHARACTERISTICS OF THE ORBITER TRANSPONDER (TYPICAL)

$$\bar{T} = \frac{1}{N_A}\left(\Delta T_1 M_1 + \Delta T_2 M_2\right) + \frac{1}{2T_s}\left(\Delta T_1{}^2 + \Delta T_2{}^2\right) \qquad (1)$$

where, N_A = number of good acquisitions

M_1 = number of misses on positive-going sweep

M_2 = number of misses on negative-going sweep

T_s = scan time in seconds

ΔT_1 = Time loss on positive scan due to miss

ΔT_2 = Time loss on negative scan due to miss

Since the transponder uses a sawtooth sweep (see Figure 3-23):

$$\Delta T_1 = 0$$

$$\Delta T_2 = T_s$$

So that equation (1) becomes

$$\bar{T} = \frac{1}{N_A}\left[T_s M_2\right] + \frac{1}{2T_s}\left(T_s{}^2\right)$$

$$= \frac{T_s M_2}{N_A} + \frac{T_s}{2} \qquad (2)$$

But, since the probability of acquisition, P_A, is

$$P_A = \frac{\text{(number of good acquisitions)}}{\text{(total number of acquisition opportunities)}}$$

$$= \frac{N_A}{N_A + M_2}$$

then

$$M_2 = \frac{N_A\,(1-P_A)}{P_A} \qquad (3)$$

Substituting equation (3) into equation (2) results in

$$\overline{T} = \frac{T_s \left[\dfrac{N_A \, (1-P_A)}{P_A} \right]}{N_A} + \frac{T_s}{2}$$

$$= \frac{T_s \, (1-P_A)}{P_A} + \frac{T_s}{2} \qquad (4)$$

The scan time, T_s, for the transponder is 6 seconds.

Therefore,

$$\overline{T} = 6 \, \frac{(1-P_A)}{P_A} + 3 \qquad (5)$$

The mean acquisition time, $\overline{T}$, as a function of the probability of acquisition is shown in figure 3-24. For a probability of acquisition of 0.9, the mean acquisition time is 3.67 seconds.

3.5.1.1 <u>Uplink RF Acquisition Probability Performance</u>

RF acquisition characteristics for the high frequency uplink are shown in figure 3-25. For a probability of acquisition greater than 90% the P_{rec}/N_o must be greater than 43.2 dBHz. The expected circuit margin at this rf level is 56.9 dB. At the expected P_{rec}/N_o of 100.1 dBHz, probability of acquisition is 1.0 and the average acquisition time was 3 seconds. Figure 3-25 also shows that positive or negative Doppler has no noticeable effect upon the probability of acquisition. The ICD requirement of P_{rec}/N_o of 59.7 dBHz for a BER of $1x10^{-5}$ is noted in figure 3-25. Previous uplink TDM channel BER tests indicated that a BER of $1x10^{-2}$ was obtained with a

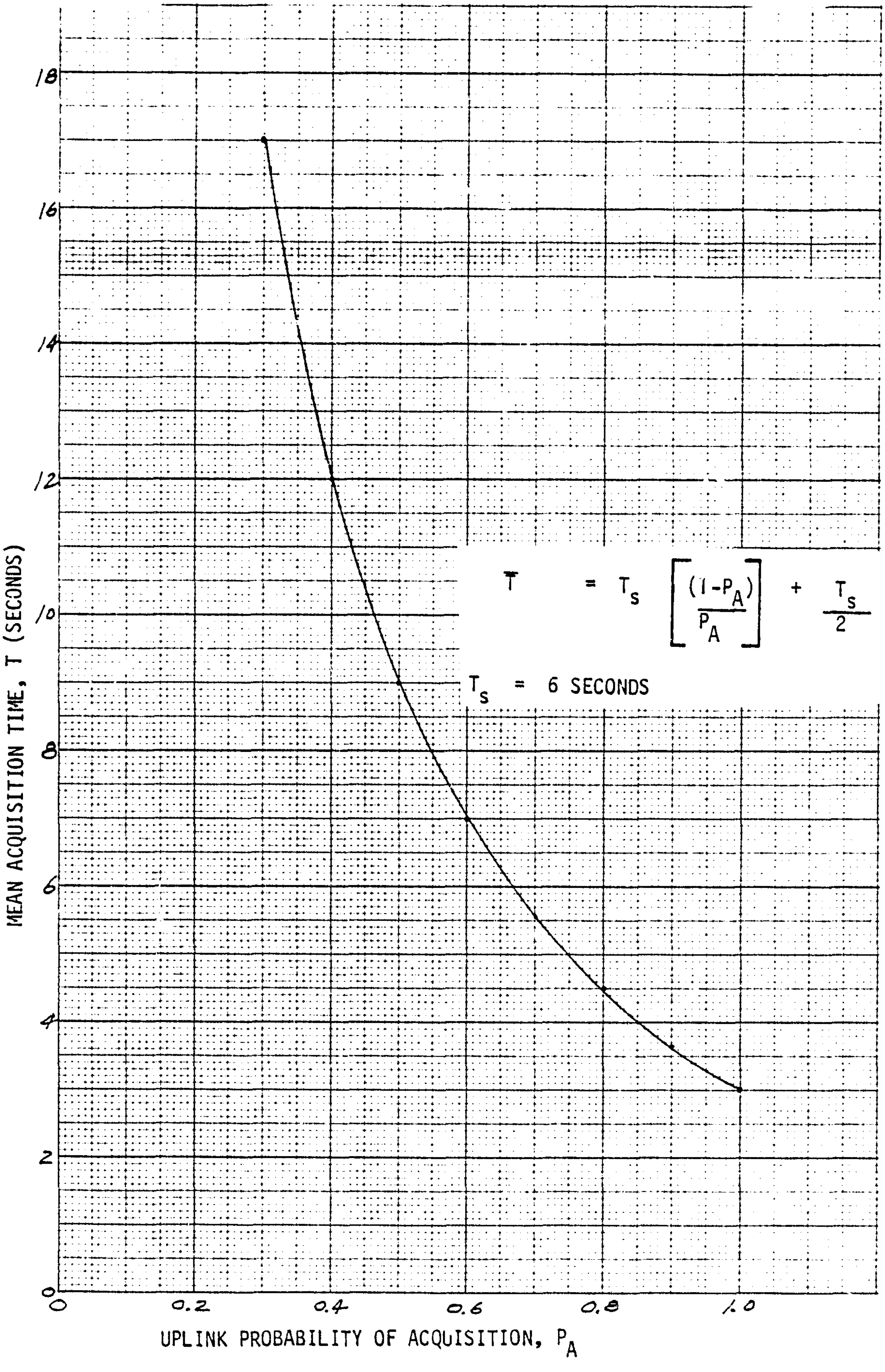

FIGURE 3-24 MEAN ACQUISITION TIME AS A FUNCTION OF PROBABILITY OF ACQUISITION

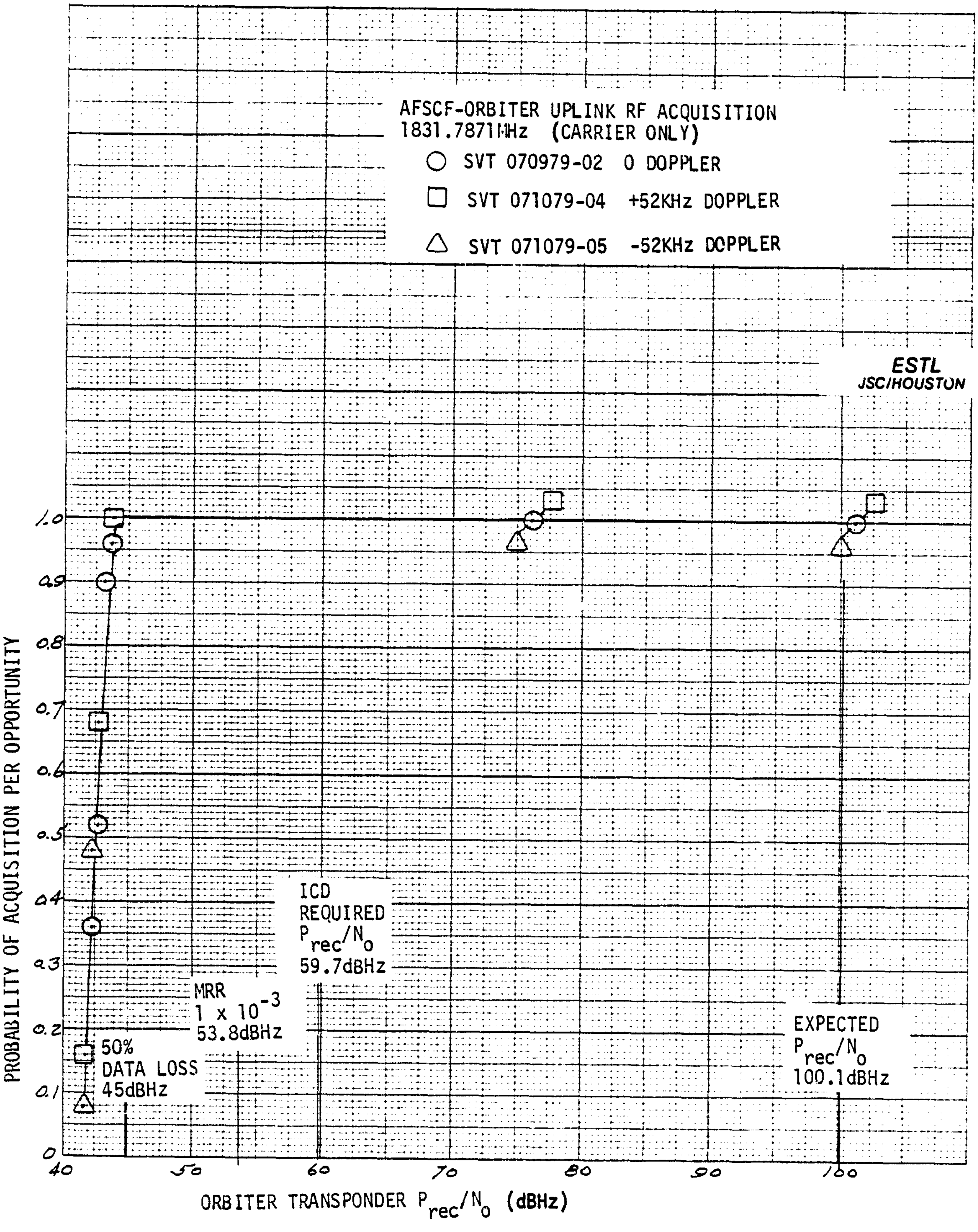

FIGURE 3-25 UPLINK RF ACQUISITION PROBABILITY (CARRIER ONLY) AS A FUNCTION OF ORBITER TRANSPONDER P_{rec}/N_o (HIGH FREQUENCY)

P_{rec}/N_o of 51.0 dBHz. Although an unmodulated rf uplink carrier can be acquired for a P_{rec}/N_o less than 51.0 dBHz, when modulation is applied, the BER would be such that the demodulated commands and voice are unusable. MRR of $1x10^{-3}$ occurs at the P_{rec}/N_o of 53.8 dBHz. The uplink TDM channel 50 percent data loss occurs at a P_{rec}/N_o of 45.0 dBHz.

RF acquisition characteristics for the low frequency uplink are shown in figure 3-26. For a probability of acquisition greater than 90%, the P_{rec}/N_o is 43.7 dBHz. Circuit margin at this rf level is 56.7 dB. At the expected P_{rec}/N_o of 100.4 dBHz, probability of acquisition is 1.0 and the average acquisition time is 3 seconds.

RF acquisition characteristics with modulation on the uplink carrier are shown in figure 3-27. Acquisition probabilities greater than 90% are possible only at a very small range (<8dB) of weak signal levels. From a study of figure 3-27 it can be concluded that the probability of the Orbiter transponder either acquiring or reacquiring a modulated uplink carrier with a true lock is very low. Therefore, for the operational missions it will be necessary to remove modulation from the carrier during all acquisition or reacquisition attempts.

3.5.1.2 Uplink Carrier Tracking Threshold Performance

Threshold of the costas loop in the transponder was determined by finding the rf level at which the loop could maintain lock for one minute at least 50 percent of the time. A summary of the threshold test results is shown in Table 3-11.

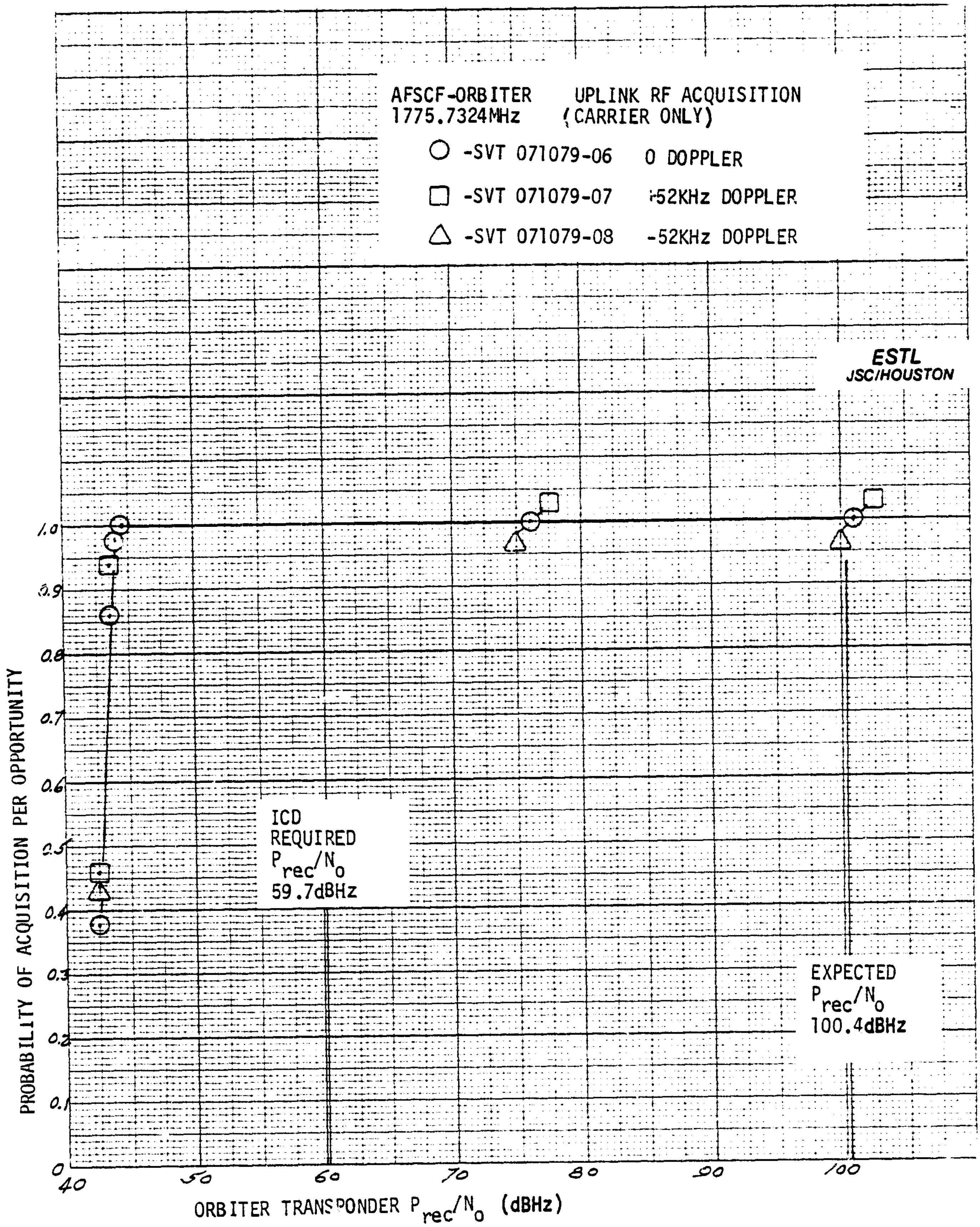

FIGURE 3-26 UPLINK RF ACQUISITION PROBABILITY (CARRIER ONLY) AS A FUNCTION OF ORBITER TRANSPONDER P_{rec}/N_o (LOW FREQUENCY)

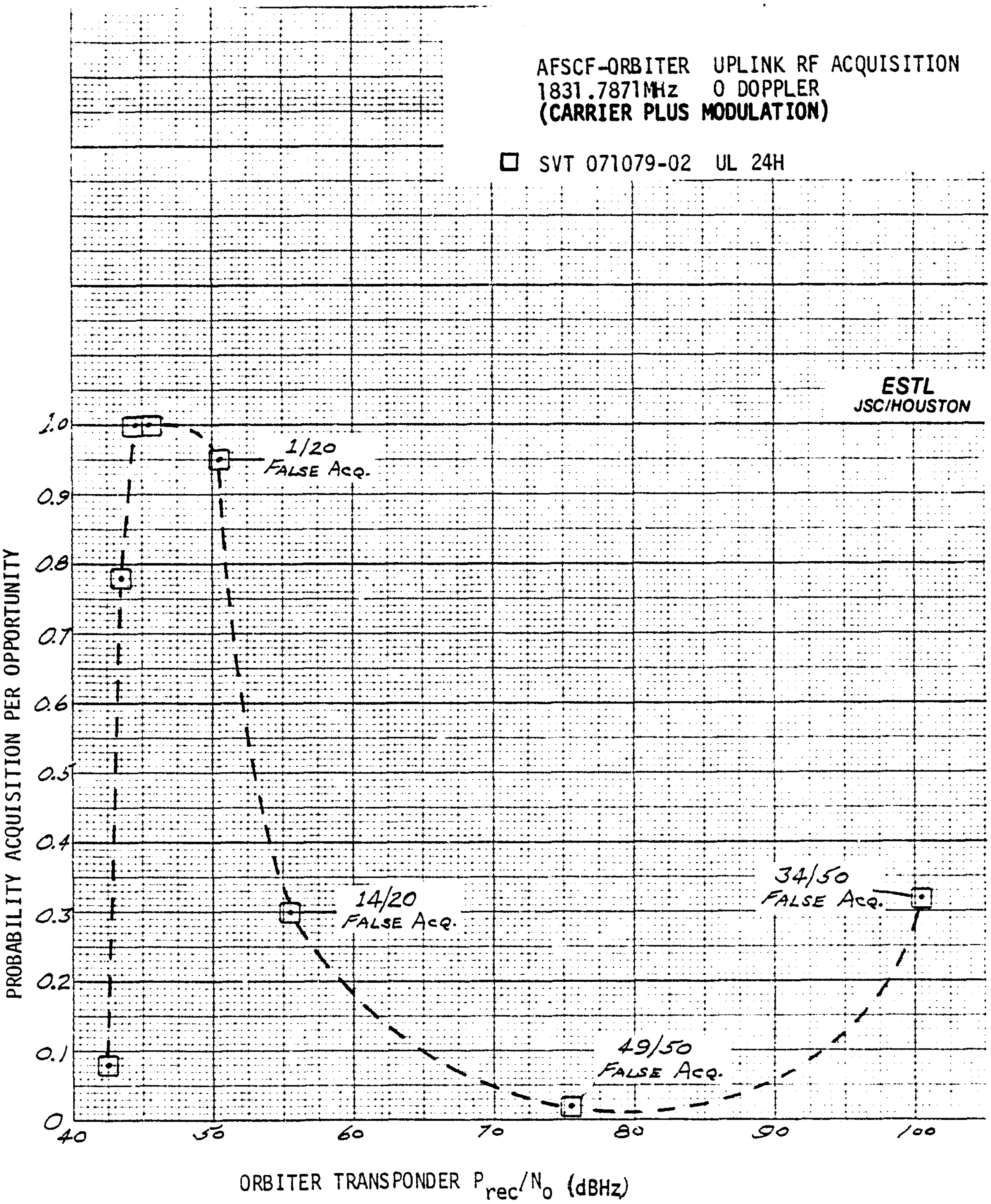

FIGURE 3-27 UPLINK RF ACQUISITION PROBABILITY (UL24H) AS A FUNCTION OF ORBITER TRANSPONDER P_{rec}/N_o (HIGH FREQUENCY)

TABLE 3-11 **UPLINK RF CARRIER TRACKING THRESHOLD SUMMARY**

ESTL
JSC/HOUSTON

UPLINK SIGNAL COMBINATION	FREQUENCY (MHz)	DOPPLER (kHz)	THRESHOLD TRP (dBm)	THRESHOLD P_{rec}/N_o (dBHz)	Expected P_{rec}/N_o (dBHz)	Expected Margin (dB)
000	1831.7871	0	-125.33	40.67	100.1	59.43
000	1775.7324	0	-124.99	41.01	100.4	59.39
24H	1831.7871	0	-124.3	41.7	100.1	58.4
24H	1831.7871	+52	-124.37	41.63	100.1	58.47
24H	1831.7871	-52	-124.23	41.77	100.1	58.33
24L	1831.7871	0	-124.52	41.48	100.1	58.62
24H	1775.7324	0	-124.22	41.78	100.4	58.62
24H	1775.7324	+52	-124.23	41.77	100.4	58.63
24H	1775.7324	-52	-124.2	41.8	100.4	58.6

*** AFSCF/RTS Transmit Power 30.0 dBW, Antenna Gain 45.0 dB Range 966 nmi (slant range for 5° elevation and 225 nmi orbit) Orbiter Receive Antenna Gain -2.0 dB.**

3.5.2 Downlink RF Acquisition Tests

The downlink rf acquisition capability was evaluated by determining the probability of acquisition and the time for acquisition as a function of the P_{rec}/N_o. Acquisition tests were performed at high and low carrier frequencies and with the maximum expected Doppler rate, positive and negative, imposed on the carrier. A block diagram of the functional configuration for the downlink rf acquisition test is shown in figure 3-28.

In order to maintain coherent operation of the transponder during the rf downlink acquisition test, the uplink signal was maintained as carrier only at a P_{rec}/N_o of 96 dBHz.

Downlink rf carrier tracking threshold measurements were also conducted.

3.5.2.1 Downlink RF Acquisition Probability Performance

RF acquisition characteristics for signal combination 03' on the downlink are shown in figure 3-29. For a probability of acquisition greater than 90 percent the P_{rec}/N_o must be greater than 49.5 dBHz. The expected circuit margin at this P_{rec}/N_o is 38.1 dB. Figure 3-29 also shows that neither positive nor negative Doppler has any effect upon the probability of acquisition. The ICD requirement of a P_{rec}/N_o of 70.0 dBHz is for a BER of 1×10^{-5}. Although the modulated downlink carrier can be acquired on 90% of attempts at a P_{rec}/N_o of 49.5 dBHz, the demodulated telemetry data and voice would be unusable (low data rate TDM BER of 1×10^{-3} occurs at P_{rec}/N_o of 63.8 dBHz). The rf acquisition characteristics for downlink signal combination 03' are shown in figure 3-30.

The rf acquisition characteristics for the low frequency and signal combination 03' are shown in figure 3-31.

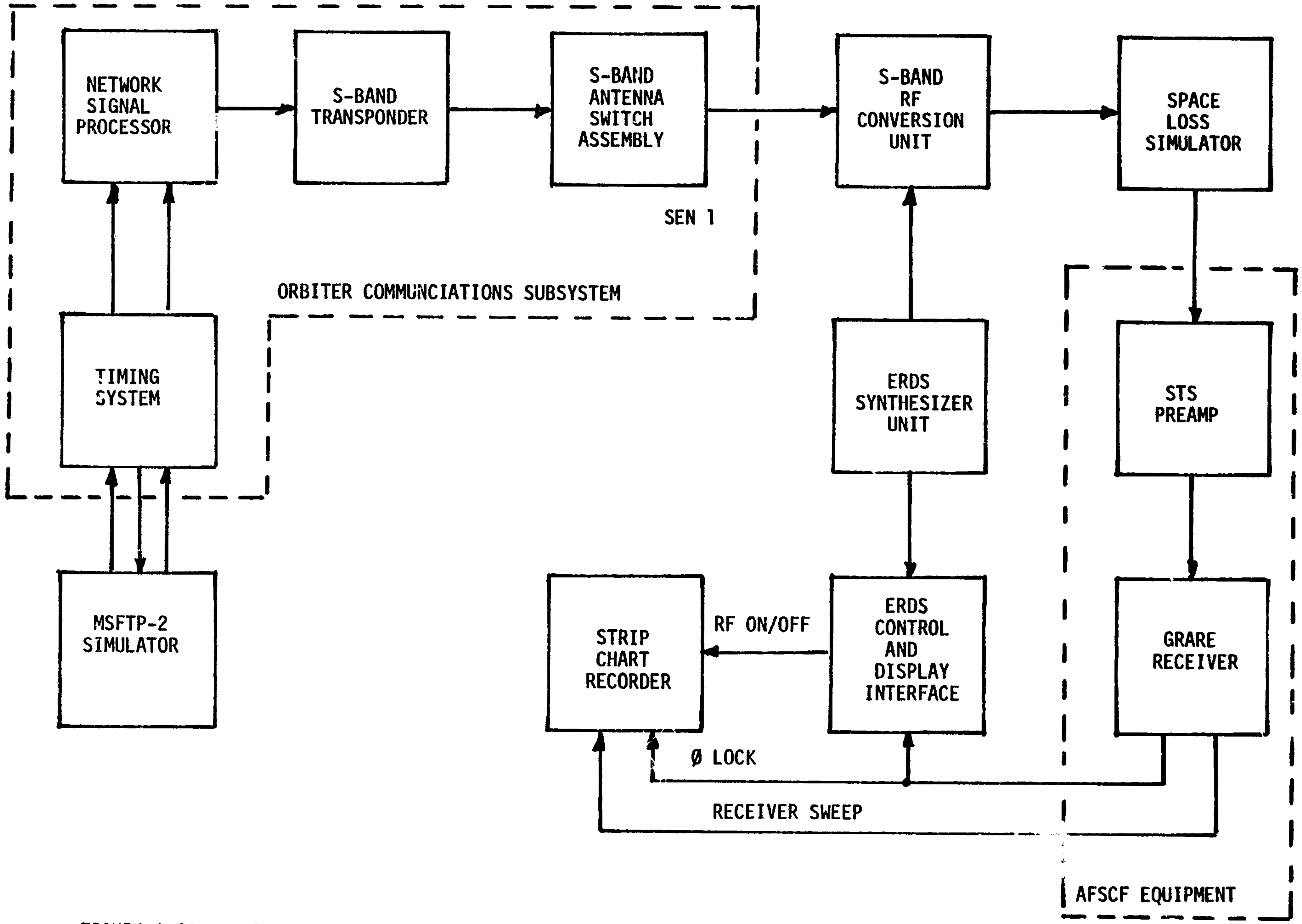

FIGURE 3-28 DOWNLINK RF ACQUISITION TEST CONFIGURATION

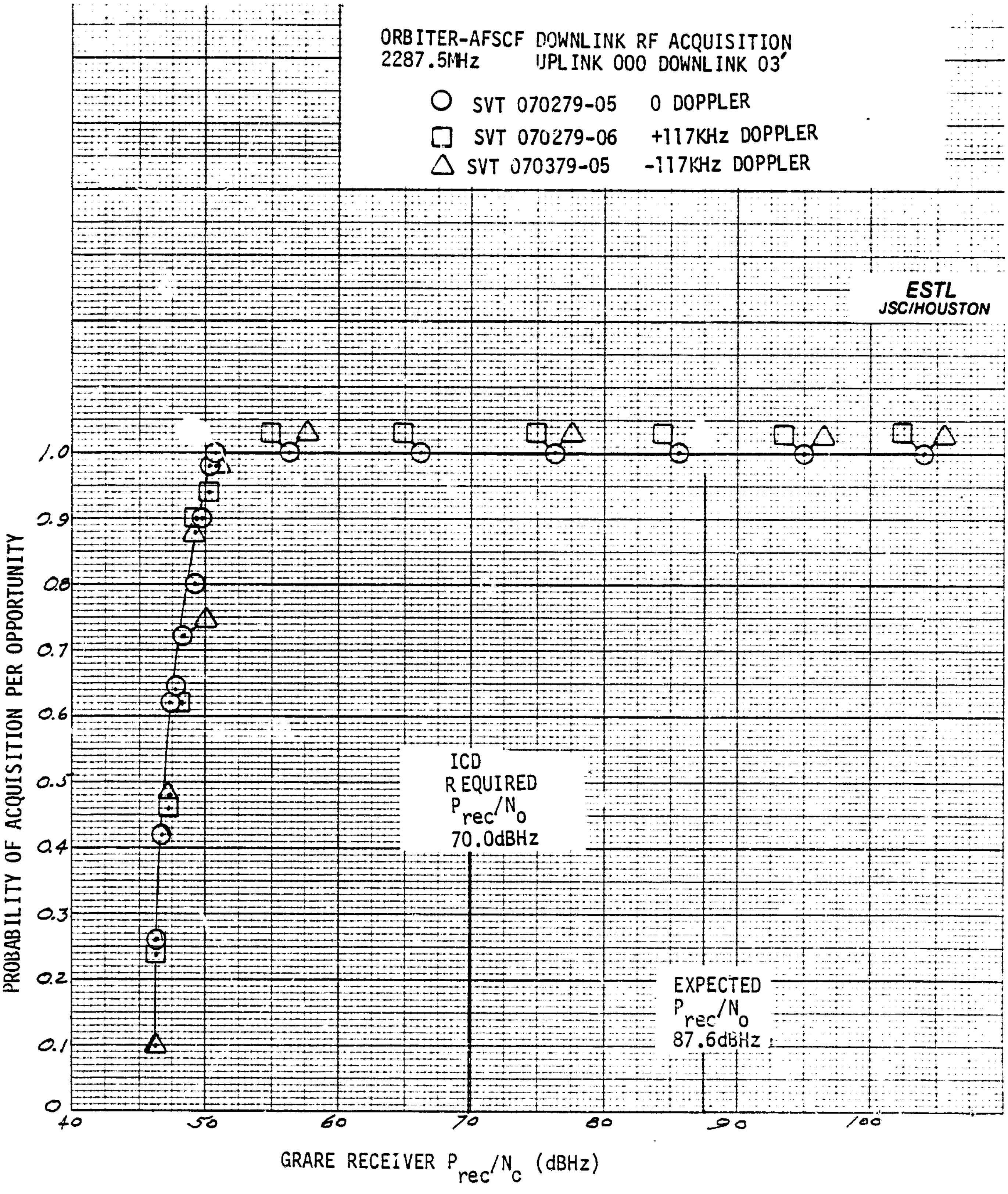

FIGURE 3-29 DOWNLINK RF ACQUISITION PROBABILITY AS A FUNCTION OF GRARE RECEIVER P_{rec}/N_o (HIGH FREQUENCY)

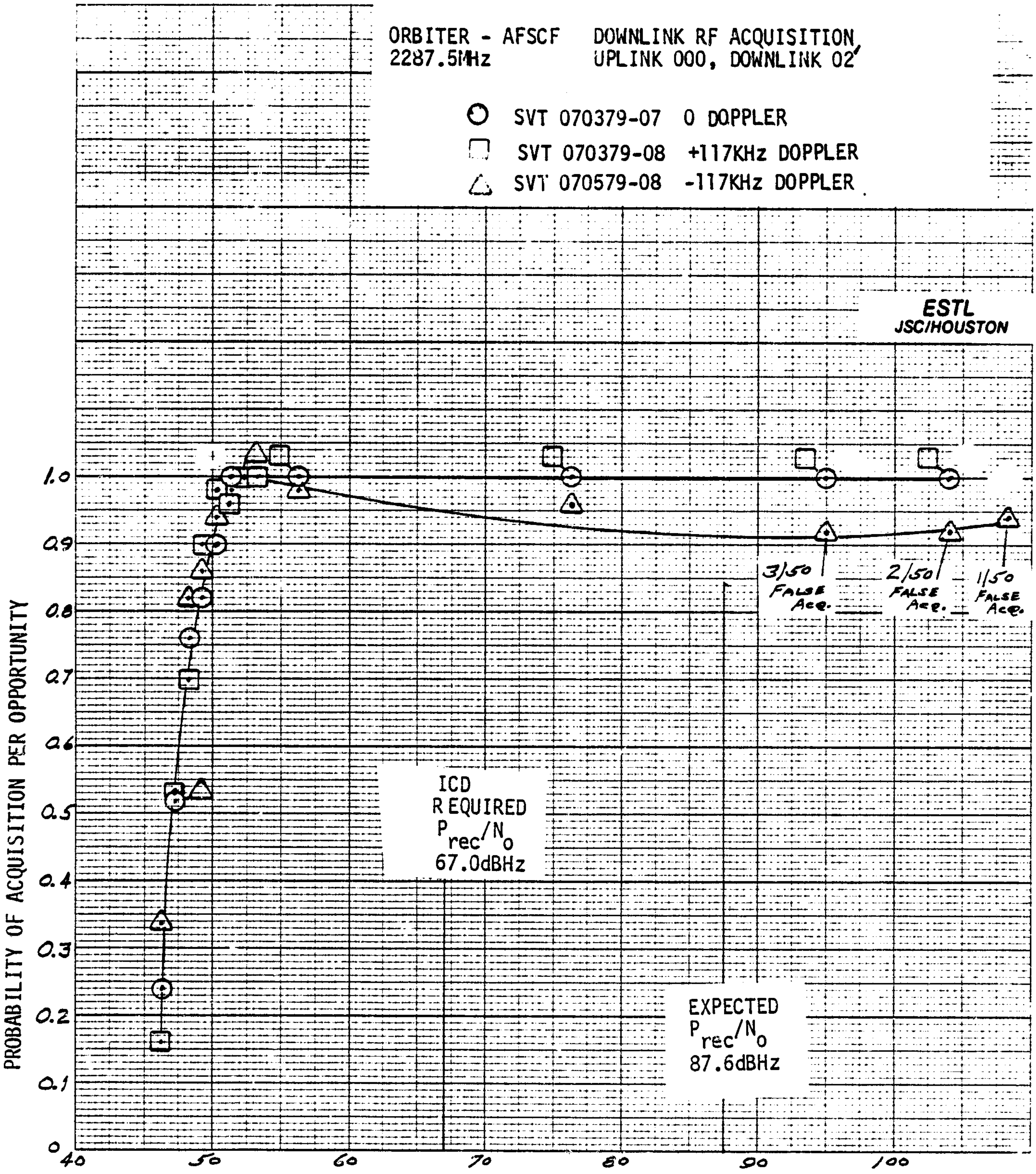

FIGURE 3-30 DOWNLINK RF ACQUISITION PROBABILITY AS A FUNCTION OF GRARE RECEIVER P_{rec}/N_o (HIGH FREQUENCY)

C-2

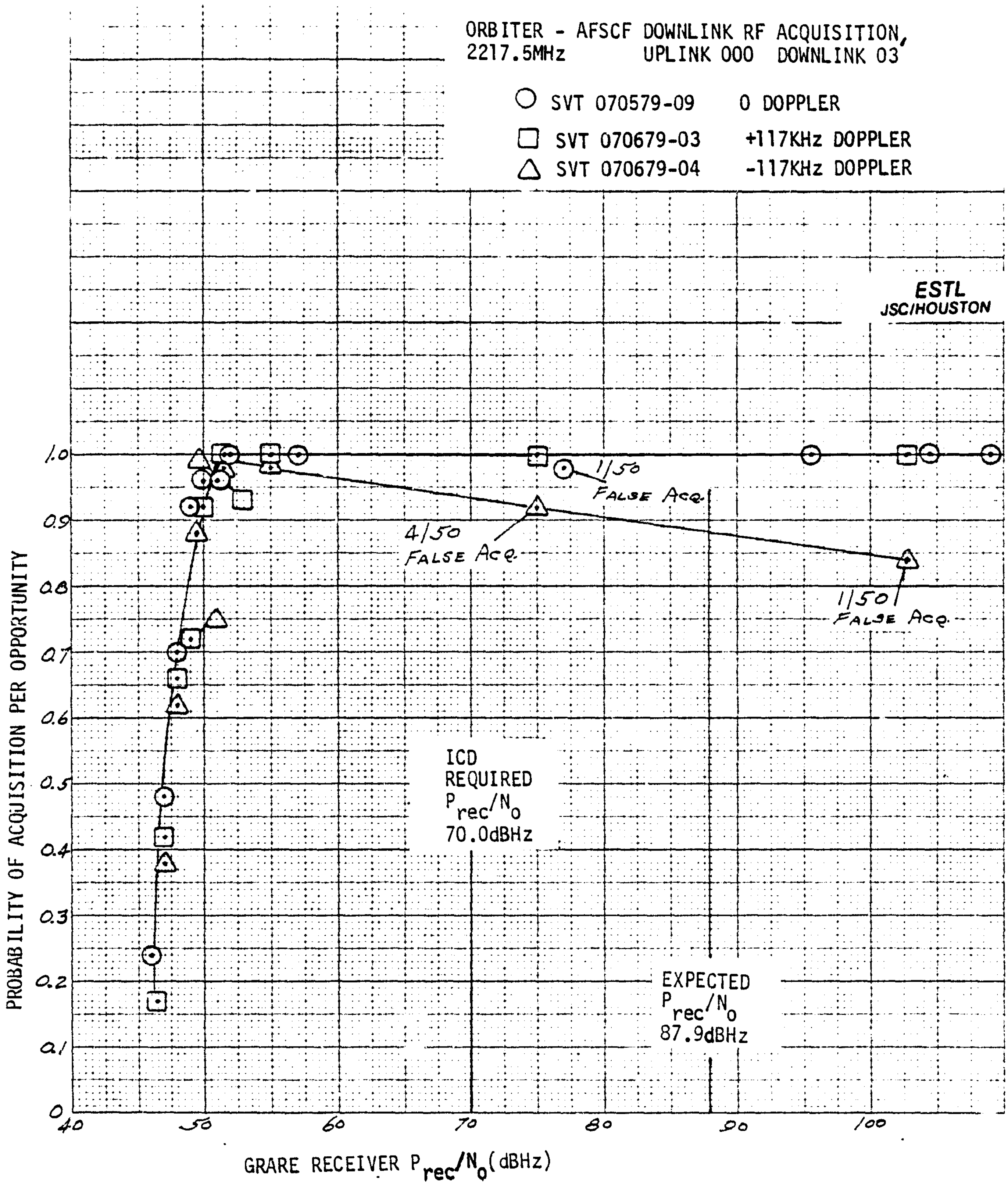

FIGURE 3-31 DOWNLINK RF ACQUISITION PROBABILITY AS A FUNCTION OF GRARE RECEIVER P_{rec}/N_o (LOW FREQUENCY)

The rf acquisition characteristics of the high frequency, high data rate mode, with the ranging channel enabled and no ranging subcarrier present are shown in figure 3-32. It is noted, that for certain Doppler frequencies, the GRARE receiver main carrier acquisition unit (anti-sideband lock) is not 100% effective in preventing false locks.

3.5.2.2 Downlink Carrier Tracking Threshold Performance

Downlink threshold tests were conducted to determine the threshold of the carrier tracking loop in the AFSCF/RTS GRARE receiver. Threshold was considered to be the rf level at which the tracking loop would maintain lock 50 percent of the time for at least one minute. A summary of the GRARE receiver rf carrier tracking threshold tests is shown in Table 3-12.

3.5.3 Two-way RF Acquisition Tests

The purpose of the two-way rf acquisition tests was to determine the total two-way acquisition time and to evaluate the proposed operational procedures for two-way acquisition and reacquisition.

3.5.3.1 Two-way RF Acquisition Time

In the two-way rf acquisition tests the uplink carrier is initially unmodulated (mode 000). After the Orbiter transponder has acquired the unmodulated carrier the uplink signal is switched to mode 24H (HDR without ranging). During these tests the downlink carrier was in mode 03 (HDR with ranging enabled but without the 1.7 MHz uplink subcarrier). Tests were performed with zero Doppler and with plus and minus 129.874 kHz of two-way Doppler. The results of these tests indicated that the probability of the GRARE receiver acquiring lock first is nearly 100% This high probability

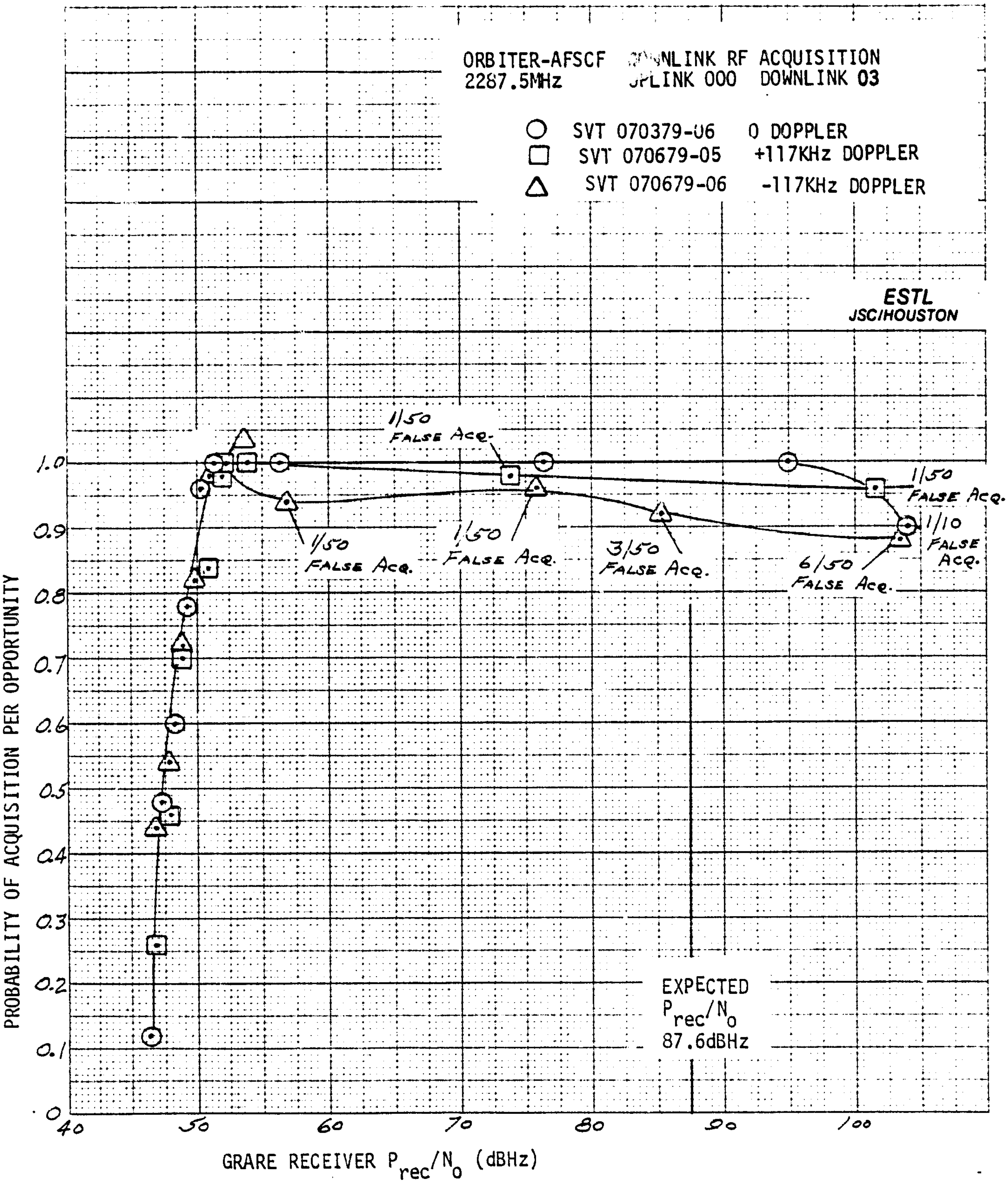

FIGURE 3-32 DOWNLINK RF ACQUISITION PROBABILITY AS A FUNCTION OF GRARE RECEIVER P_{rec}/N_o (HIGH FREQUENCY)

TABLE 3-12 AFSCF/RTS GRARE RECEIVER RF CARRIER TRACKING THRESHOLD SUMMARY

DOWNLINK SIGNAL COMB.	FREQUENCY (MHz)	DOPPLER (kHz)			THRESHOLD		EXPECTED* P_{rec}/N_o (dBHz)	EXPECTED MARGIN (dB)
		UPLINK	DOWN-LINK	TWO-WAY	TRP (dBm)	P_{rec}/N_o (dBHz)		
000	2287.5	0	0	0	-143.67	28.33	87.6	59.27
000	2217.5	0	0	0	-140.6	31.4	87.9	56.5
03	2287.5	0	0	0	-140.96	31.04	87.6	56.56
03	2287.5	+52.0	+64.937	+129.874	-140.81	31.19	87.6	56.41
03	2287.5	-52.0	-64.937	-129.874	-141.58	30.42	87.6	57.18
02	2287.5	0	0	0	-141.46	30.54	87.6	57.06
03	2217.5	0	0	0	-138.6	33.4	87.9	54.5
03	2217.5	+52.0	+64.937	+129.874	-139.4	32.6	87.9	55.3
03	2217.5	-52.0	-64.937	-129.874	-139.3	32.7	87.9	55.2
05	2287.5	0	0	0	-139.29	32.71	87.6	55.89

* Orbiter Transmit Power 3.0 dBw and Antenna Gain 3.0 dB, Range 966 nmi (slant range for 5° elevation and 225 nmi orbit) AFSCF/RTS Receive Antenna Gain 47.5 dB

is very reasonable considering that the sweep time of the transponder is about 6 seconds per acquisition opportunity whereas the GRARE receiver sweep is about 0.65 seconds per acquisition opportunity. It was also found that the time required for the transponder to switch over from the AUX OSC to the VCO was approximately 1.15 seconds. In those few cases when the transponder acquired lock first, the GRARE receiver would lock or acquire within 1.15 seconds of the transponder acquisition. Therefore, the GRARE receiver would be initially locked to the AUX OSC and would be affected by the switchover from the AUX OSC to the VCO. For cases when the GRARE receiver had locked on to the AUX OSC signal, a loss of downlink lock occurred when the transponder switched from the AUX OSC to the VCO. At strong signal levels the GRARE receiver reacquired at the next acquisition opportunity, 0.65 seconds later.

A summary of the two-way rf acquisition tests is shown in Table 3-13. Figure 3-33 is a flow diagram of the recommended initial acquisition procedure to be used at AFSCF/RTS. This procedure has been developed to maximize the probability of valid two-way rf acquisition in the minimum time.

3.5.3.2 Two-way RF Reacquisition Time

Initial acquisition will usually occur when the Orbiter comes into line-of-sight with the ground station from an occluded part of its Orbit. Reacquisition is required anytime uplink or downlink signal lock is broken after an initial acquisition has occurred.

A summary of the rf reacquisition time is shown in Table 3-14. The uplink was in mode 24H and the downlink is mode 03' for the reacquisition tests. It was noted that when a loss of lock was caused by an interruption in the uplink signal, it was usually necessary to break GRARE receiver lock

TABLE 3-13 TWO-WAY RF ACQUISITION TEST SUMMARY

ESTL
JSC/HOUSTON

UPLINK DOPPLER (KHz)	TWO-WAY DOPPLER (KHz)	UPLINK P_{rec}/N_0 (dBHz)	DOWNLINK P_{rec}/N_0 (dBHz)	% OF TIME GRARE LOCKED FIRST	T_0 (SEC.)	T_s (SEC.)	T_{total} (SEC.)
0	0	100.1	84.1	100	0.64	1.24	6.60
0	0	81.3	65.3	100	0.62	1.24	6.00
0	0	66.3	50.3	100	0.70	1.12	6.52
0	0	65.3	49.3	90	1.05	1.18	6.38
0	0	64.3	48.3	100	1.00	1.15	6.59
0	0	63.3	47.3	90	2.30	1.18	8.02
0	0	62.8	46.8	90	3.97	1.18	8.93
+52.0	+129.874	100.1	84.1	(1)			
+52.0	+129.874	81.3	65.3	(1)			
+52.0	+129.874	65.3	49.3	100	0.73	1.13	6.34
+52.0	+129.874	64.3	48.3	100	0.88	1.02	6.96
+52.0	+129.874	63.3	47.3	100	1.55	1.13	7.22
+52.0	+129.874	62.3	46.3	(2)			
-52.0	-129.874	100.1	84.1	(3)			
-52.0	-129.874	81.3	65.3	(1)			
-52.0	-129.874	65.3	49.3	100	0.97	1.15	7.01
-52.0	-129.874	64.3	48.3	80	1.12	1.15	6.55
-52.0	-129.874	63.3	47.3	100	2.22	1.15	8.20
-52.0	-129.874	62.3	46.3	90	3.31	1.14	8.89

T_0 = time GRARE receiver is out of lock due to AUX OSC switchover

T_s = time required for AUX OSC to VCO switchover

T_{total} = total acquisition time

(1) GRARE locked correctly from AUX OSC, then false locked after switchover to VCO

(2) GRARE false locked from AUX OSC, then locked correctly after switchover to VCO

(3) GRARE false locked from AUX OSC, then false locked after switchover to VCO

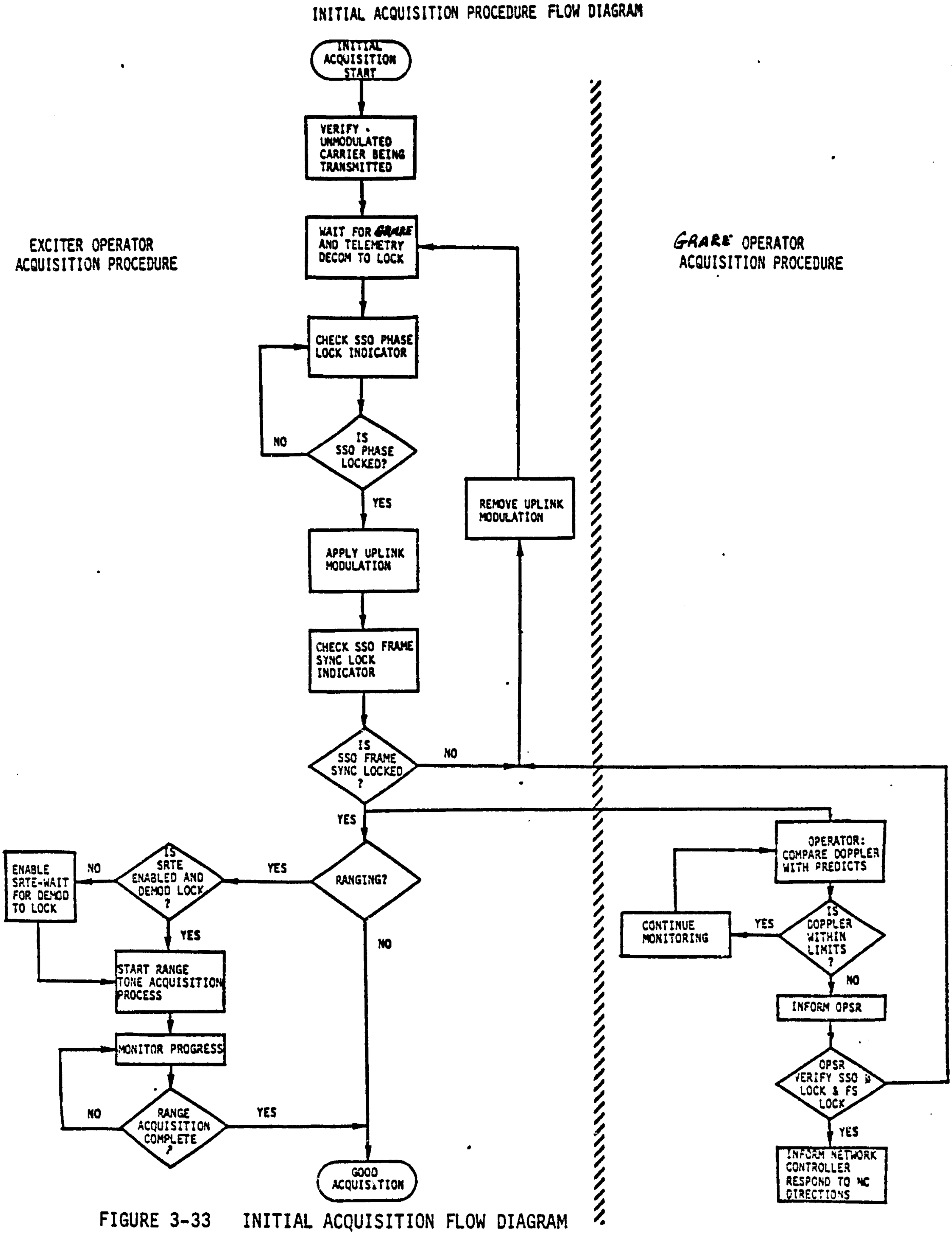

FIGURE 3-33 INITIAL ACQUISITION FLOW DIAGRAM

TABLE 3-14 TWO-WAY RF REACQUISITION TEST SUMMARY

ESTL
JSC/HOUSTON

UPLINK P_{rec}/N_o (dBHz)	DOWNLINK P_{rec}/N_o (dBHz)	UPLINK DOPPLER (KHz)	DOWNLINK DOPPLER (KHz)	REACQUISITION TIME (Second)		
				LOSS OF UPLINK	LOSS OF DOWNLINK	LOSS OF U.L.& D.L.
100.1	84.1	0	0	11.52	0.31	10.36
100.1	84.1	+52.0	+129.874	9.62	0.40	12.17
100.1	84.1	-52.0	-129.874	10.50	0.30	11.91

before true lock could be obtained on the downlink reacquisition.

Figure 3-34 is a flow diagram of the recommended reacquisition procedures to be used at AFSCF/RTS.

REACQUISITION PROCEDURE FLOW DIAGRAM

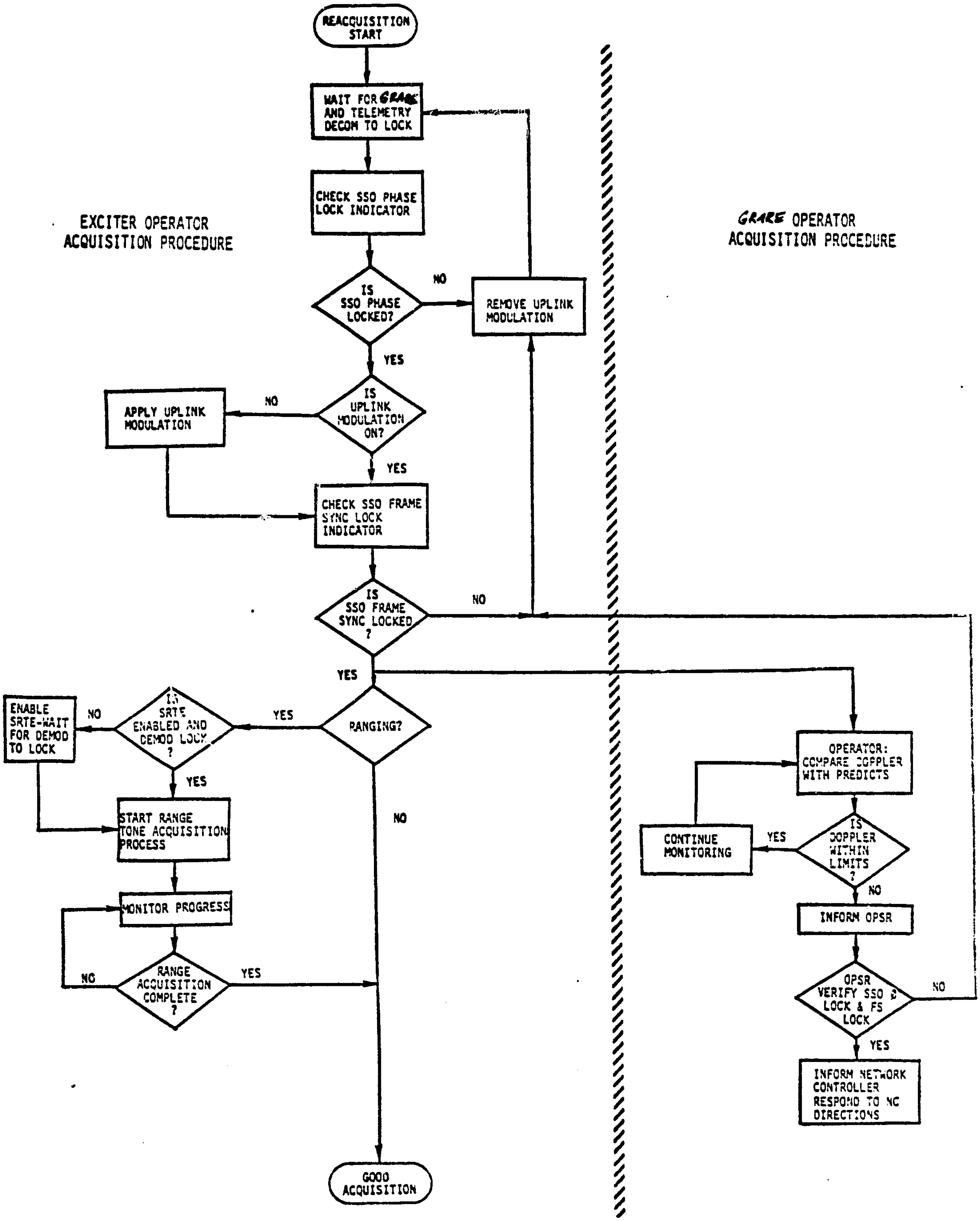

FIGURE 3-34 REACQUISITION PROCEDURE FLOW DIAGRAM

3.6 Doppler Tests

The purpose of these tests was to evaluate the capability of the AFSCF equipment and the orbiter transponder to provide a two-way Doppler tracking capability which meets the Shuttle OFT mission requirements.

3.6.1 Two-way Doppler Accuracy Performance

The two-way Doppler capability was evaluated by measuring the AFSCF/RTS RRE (range rate extractor) output accuracy as a function of two-way Doppler offsets and P_{rec}/N_0 for both links.

Figure 3-35 is a block diagram of the uplink configuration for the two-way Doppler accuracy tests. Figure 3-36 is a block diagram of the downlink configuration for the two-way Doppler accuracy test.

The AFSCF/RTS RRE Doppler accuracy was determined through the measurement of the mean and standard deviation of the Doppler error. These parameters were calculated using a sample field of 100 trials with each trial consisting of 2 seconds of Doppler data.

The RRE Doppler was received in units of Hertz. These values can be converted into units of meters/seconds (m/sec) by the formula:

$$X/_{m/sec} = (S/_{Hz}) \left(\frac{C}{2f_c}\right)$$

where C = Speed of Light

= 3×10^8 m/sec

f_c = Carrier Frequency

= 2287.5 MHz for High Frequency

= 2217.5 MHz for Low Frequency

X = Doppler in m/sec

S = Doppler in Hertz

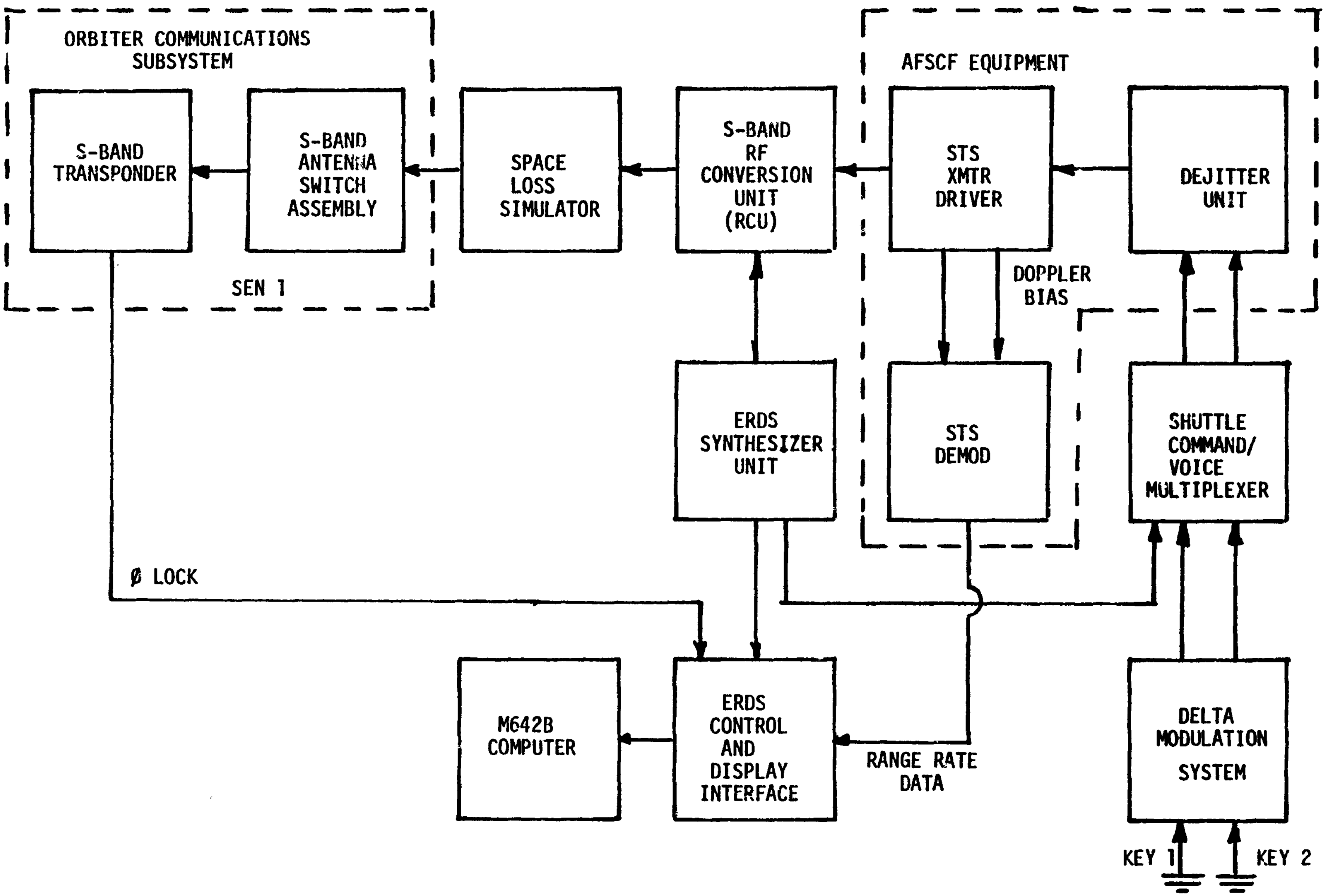

FIGURE 3-35 UPLINK CONFIGURATION FOR TWO-WAY DOPPLER ACCURACY TESTS

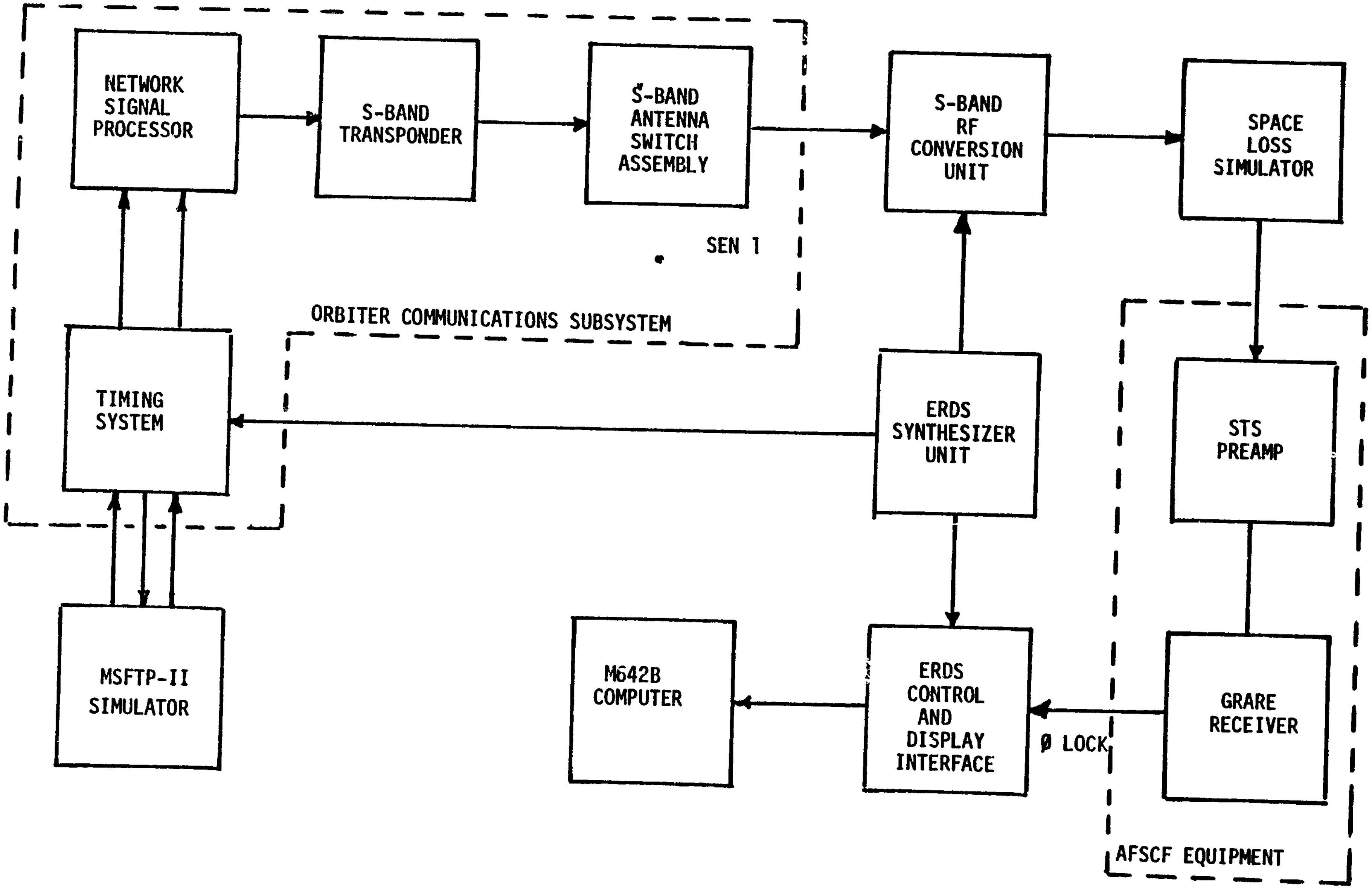

FIGURE 3-36 DOWNLINK CONFIGURATION FOR TWO-WAY DOPPLER ACCURACY TESTS

The TRAS for AFSCF Direct Link (JSC 13022 Rev. A) gives the success criteria as:

σ < TBD for: Orbiter P_{rec}/N_o <59.7 dBHz

AFSCF P_{rec}/N_o <65.4 dBHz

for high data rate, and

σ < TBD for: Orbiter P_{rec}/N_o <56.2 dBHz

AFSCF P_{rec}/N_o <62.4 dBHz

for low data rate.

Figures 3-37 and 3-38 show the test results for the high data rate mode and with high frequency, low power selected. As can be seen in figure 3-37, the various Doppler offsets seemed to have an increasing effect on the mean error. However, as seen in figure 3-38, Doppler had less effect on the standard deviation of Doppler error. At the levels given in the TRAS, the standard deviation at worst case is less than .112 Hz (.00734 m/sec).

Figures 3-39 and 3-40 give the test results for the high data rate mode with ranging enabled (but no range tones on uplink), and with high frequency and low power selected. Once again Doppler offset has a greater effect on mean error than standard deviation. This was found to be the case in all subsequent testing. At the levels given in the TRAS, the worst case standard deviation is less than .097 Hz (.00636 m/sec).

Figures 3-41 and 3-42 show the test results for the low data rate mode, with high frequency and low power selected. At the given levels in the TRAS, the worst case standard deviation is less than .128 Hz (.0089 m/sec).

Figures 3-43 and 3-44 give the results for a high data rate mode with the low frequency, low power selected. At the levels given in the TRAS, the worst case standard deviation is less than 0.123 Hz (.00832 m/sec).

A summary of the two-way Doppler accuracy test is shown in Table 3-15.

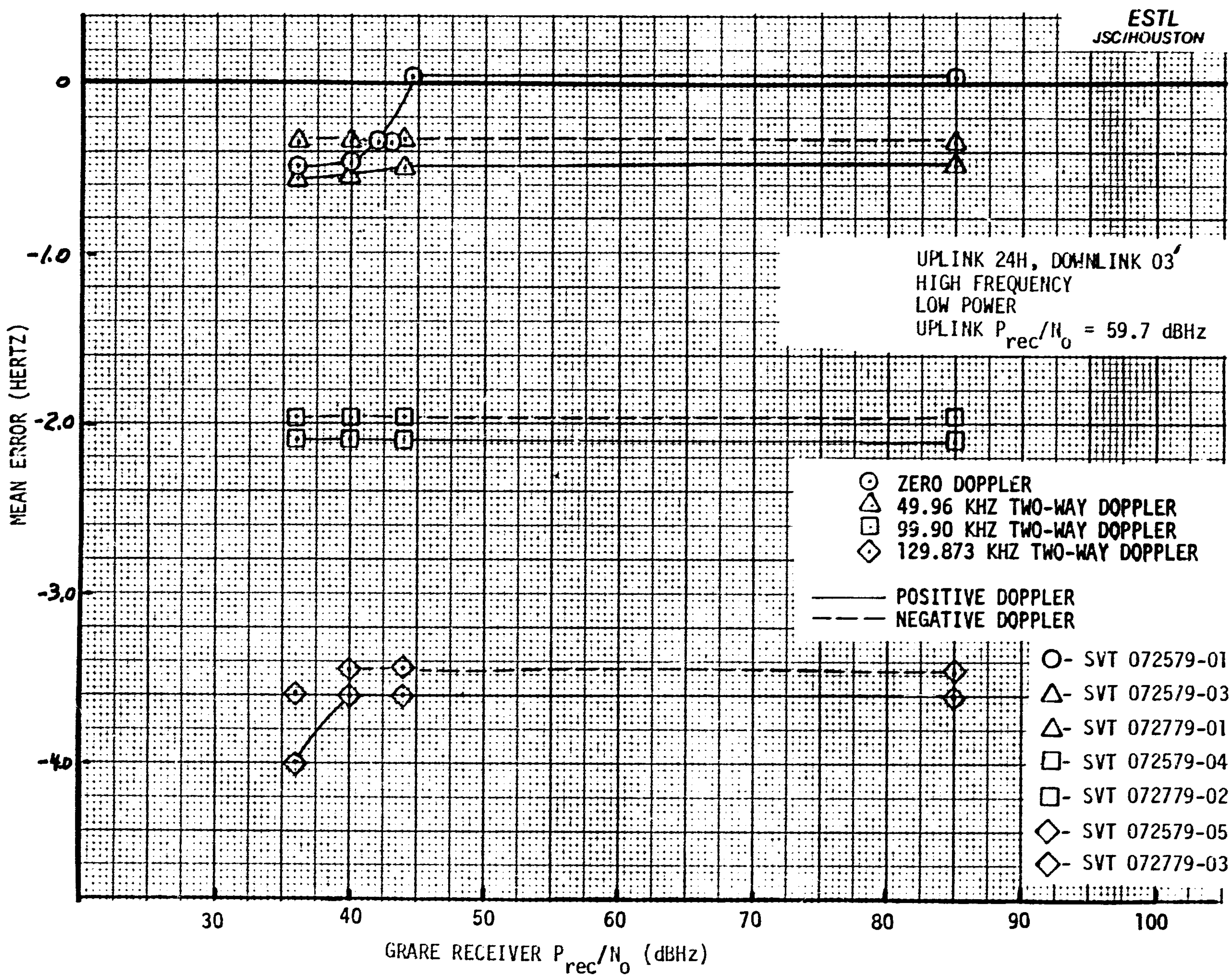

FIGURE 3-37 MEAN ERROR OF TWO-WAY DOPPLER AS A FUNCTION OF GRARE RECEIVER P_{rec}/N_o

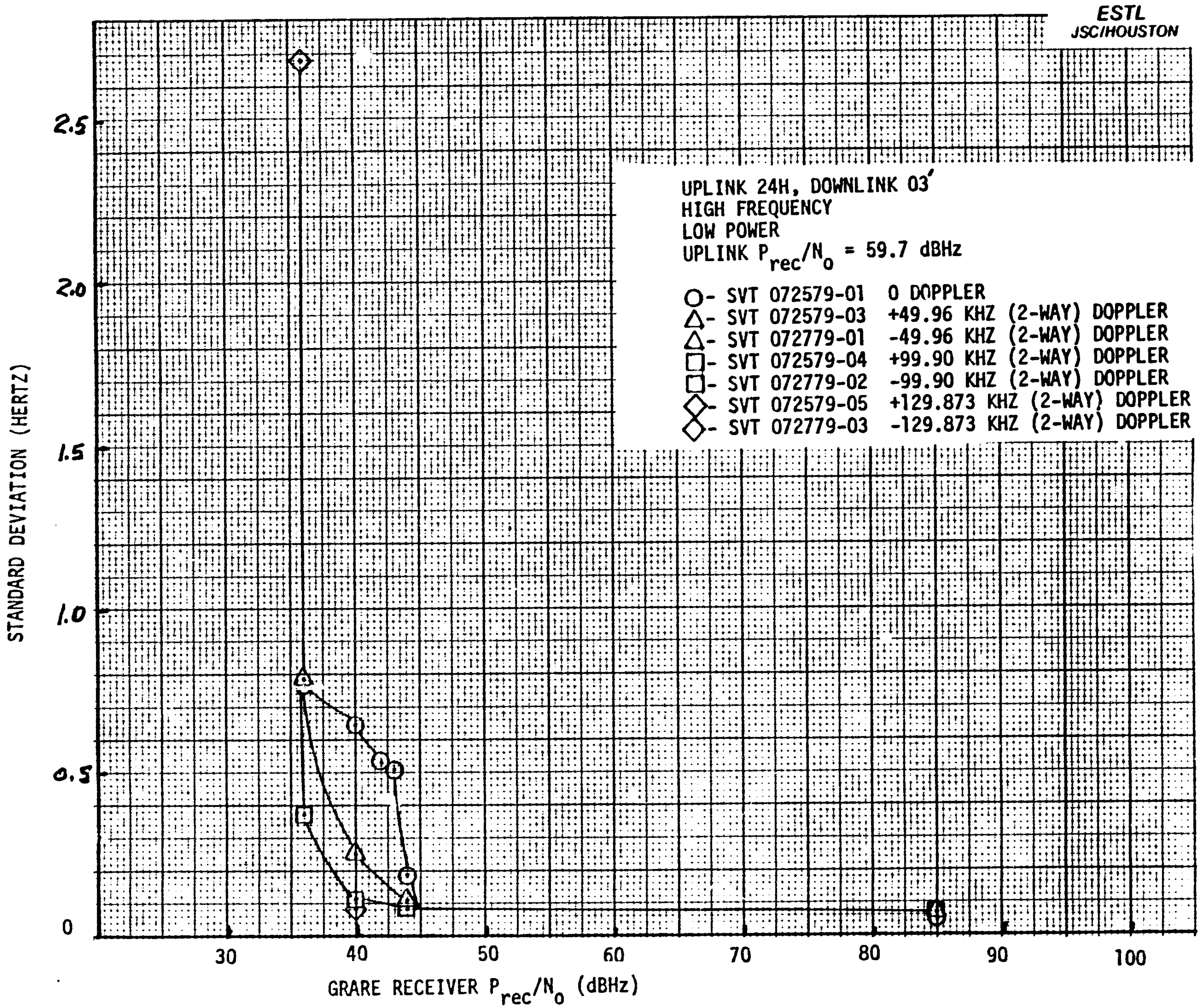

FIGURE 3-38 STANDARD DEVIATION OF TWO-WAY DOPPLER AS A FUNCTION OF GRARE RECEIVER P_{rec}/N_o

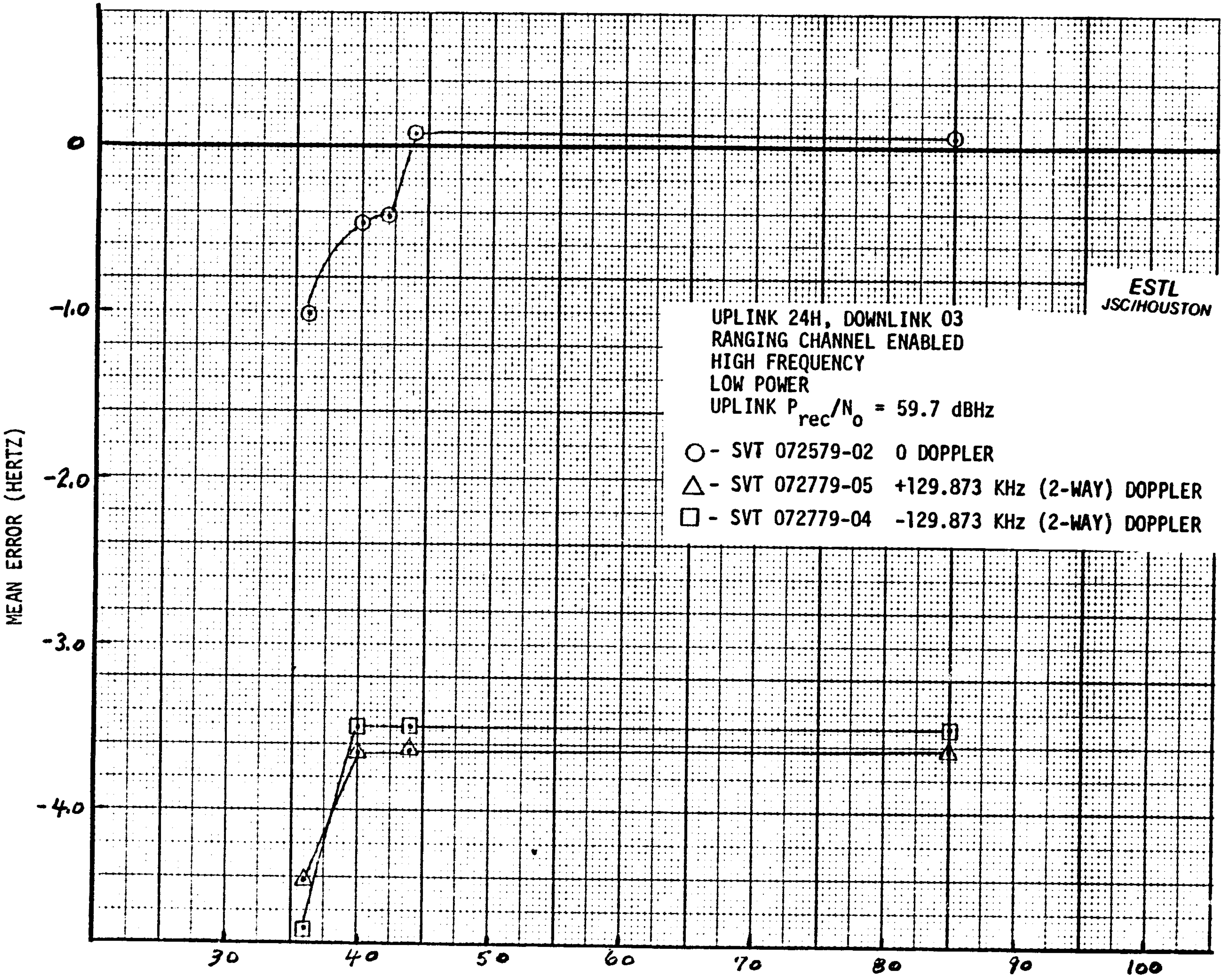

FIGURE 3-39 MEAN ERROR OF TWO-WAY DOPPLER AS A FUNCTION OF GRARE RECEIVER P_{rec}/N_o

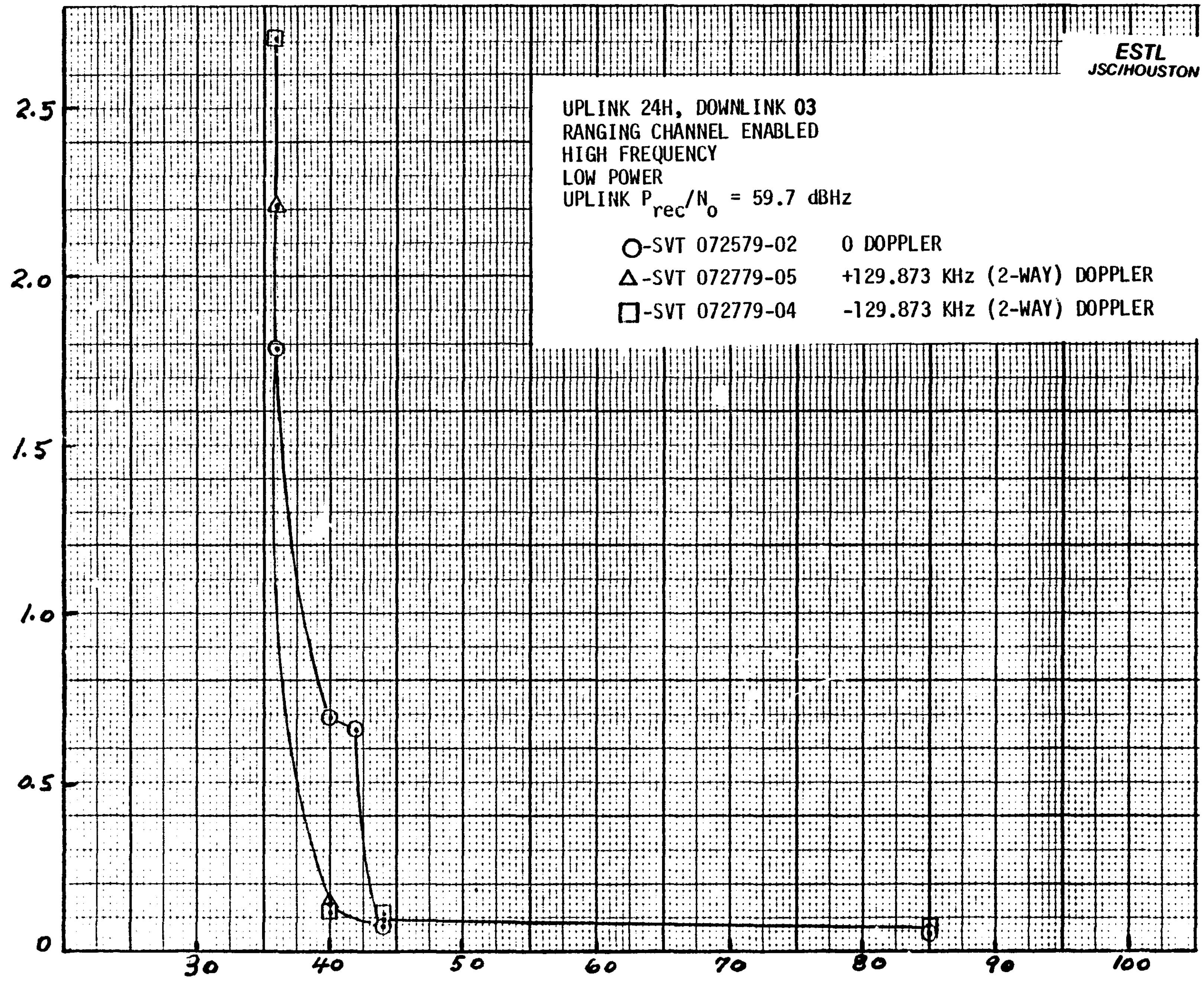

FIGURE 3-40 STANDARD DEVIATION OF TWO-WAY DOPPLER AS A FUNCTION OF GRARE RECEIVER P_{rec}/N_o

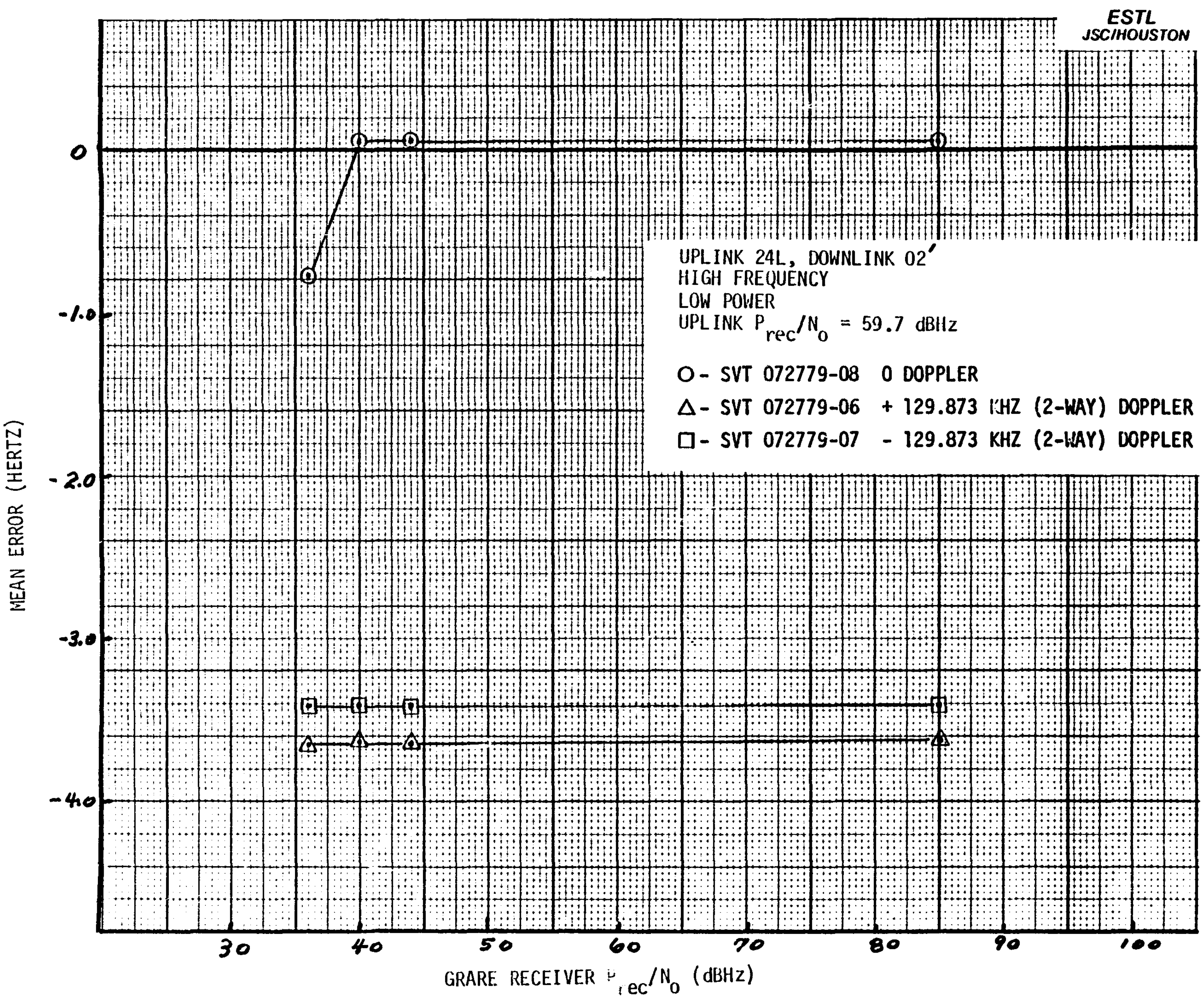

FIGURE 3-41 MEAN ERROR OF TWO-WAY DOPPLER AS A FUNCTION OF GRARE RECEIVER P_{rec}/N_o

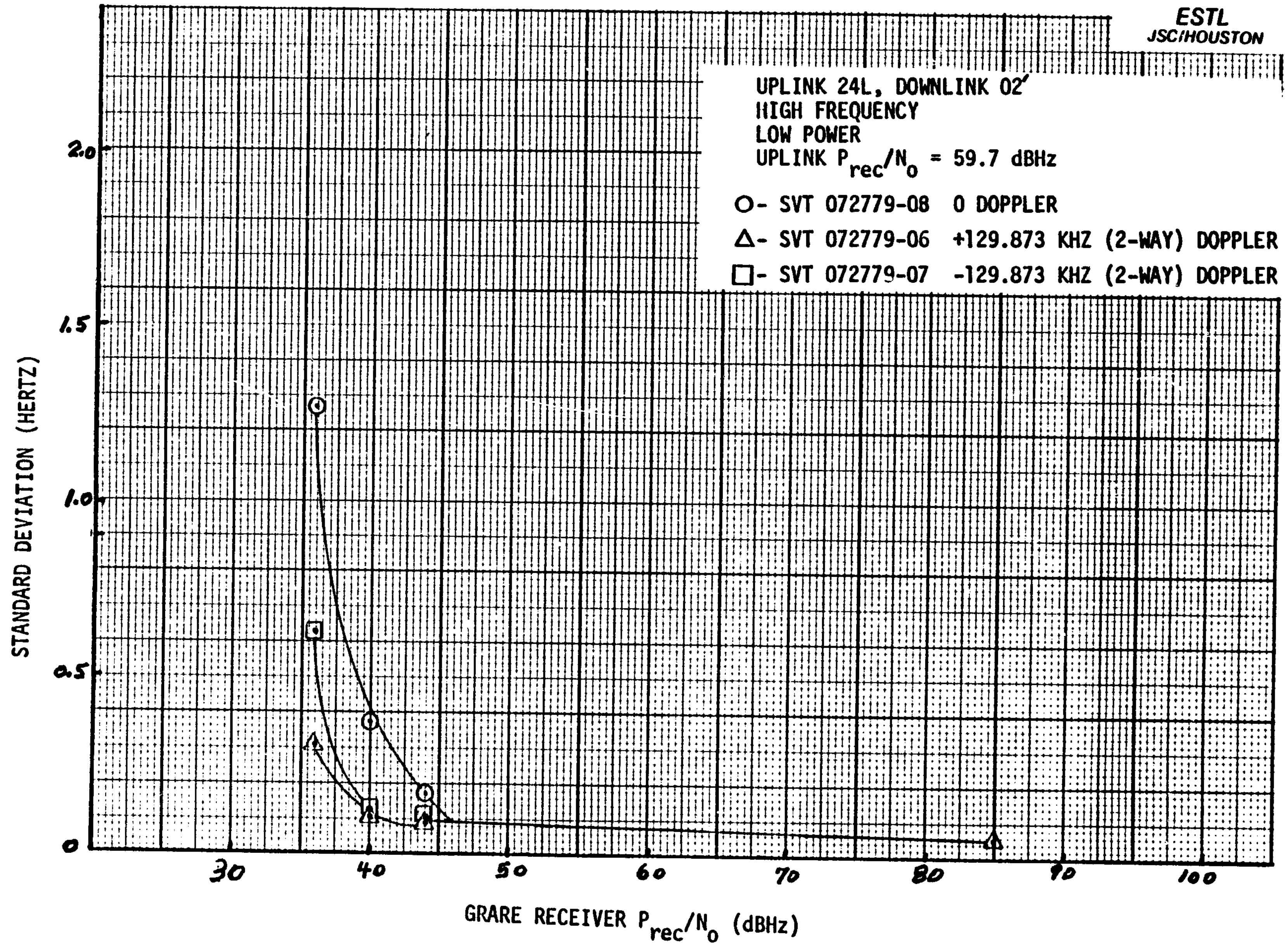

FIGURE 3-42 STANDARD DEVIATION OF TWO-WAY DOPPLER AS A FUNCTION OF GRARE RECEIVER P_{rec}/N_o

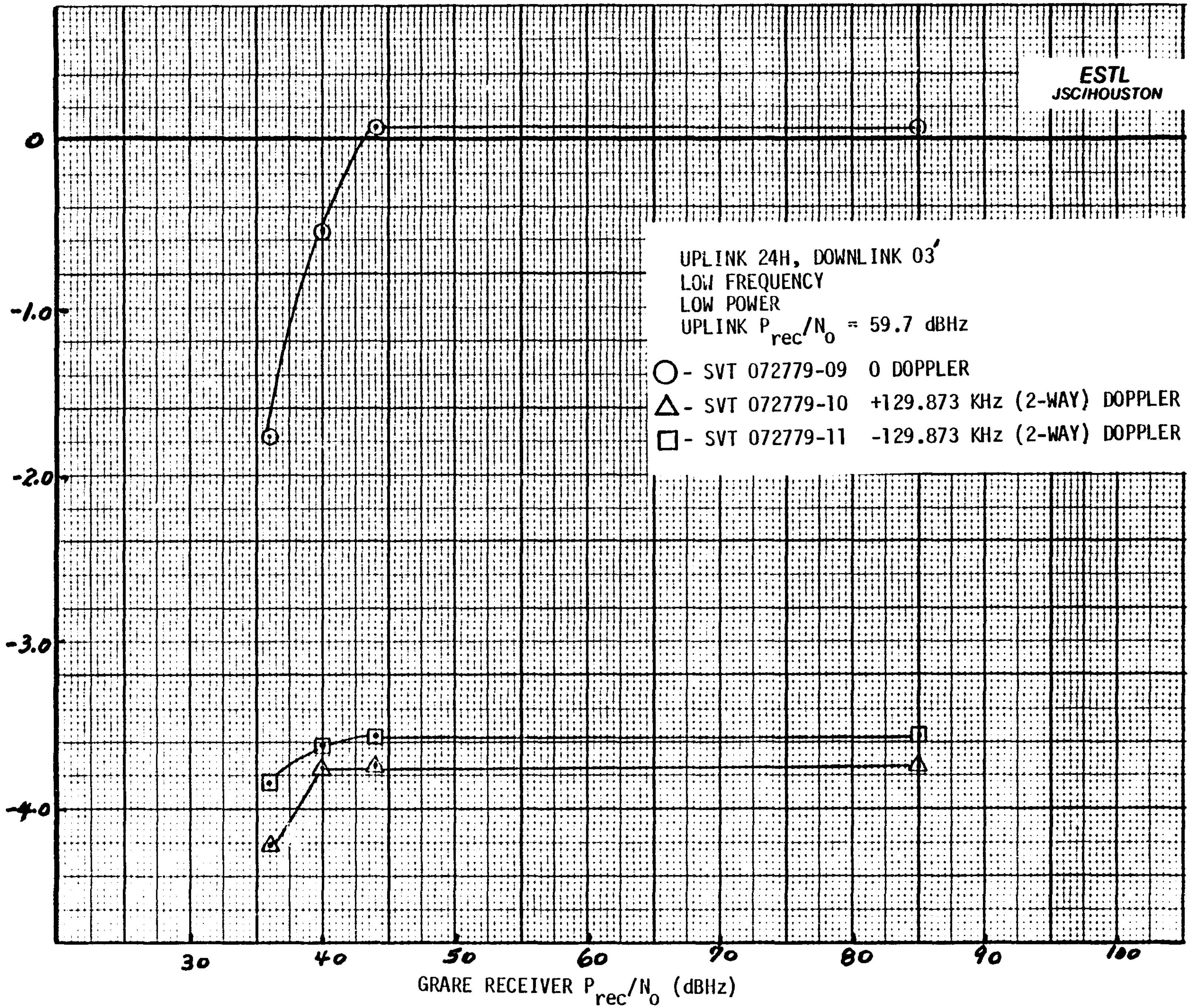

FIGURE 3-43 MEAN ERROR OF TWO-WAY DOPPLER AS A FUNCTION OF GRARE RECEIVER P_{rec}/N_o

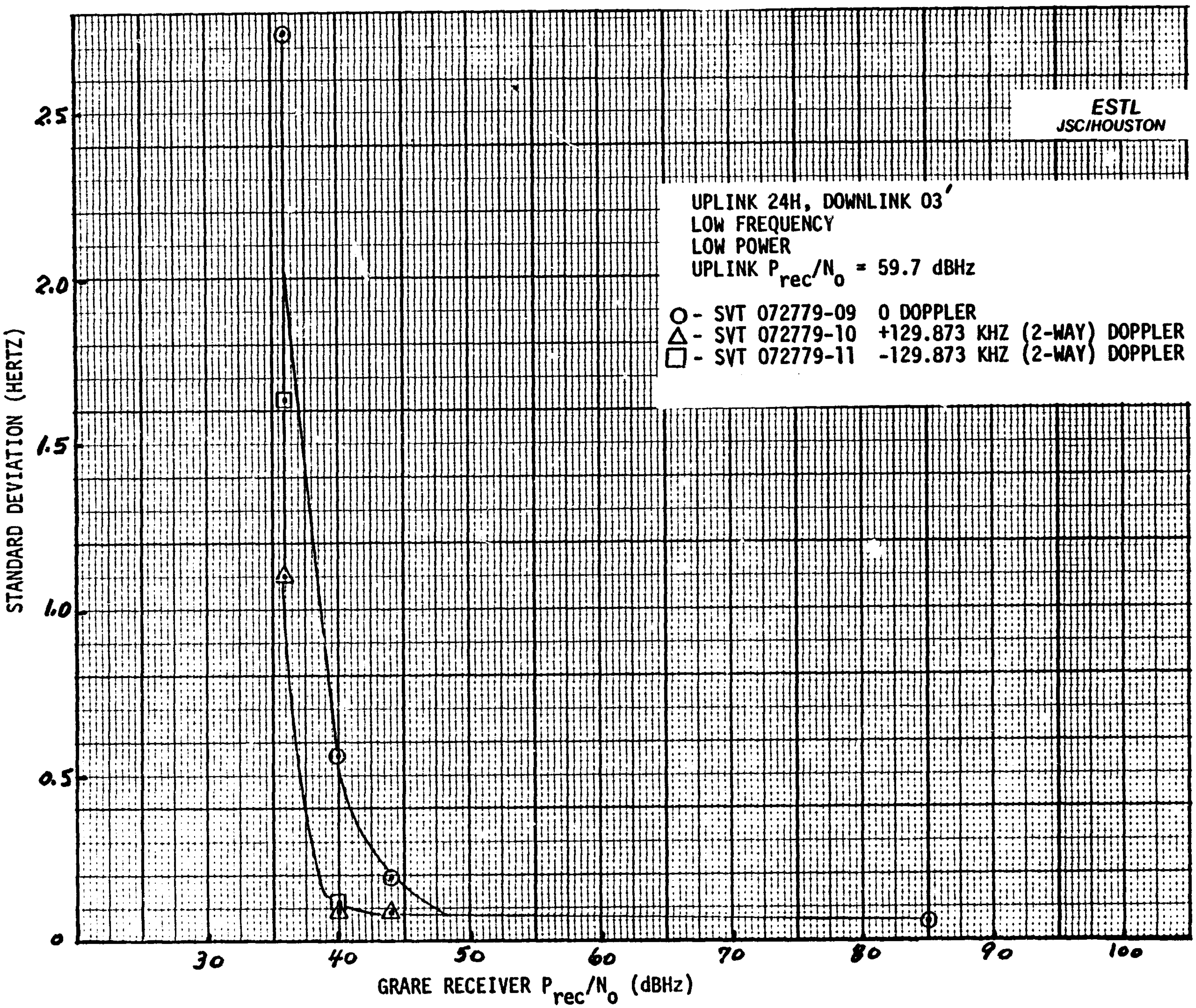

FIGURE 3-44 STANDARD DEVIATION OF TWO-WAY DOPPLER AS A FUNCTION OF GRARE RECEIVER P_{rec}/N_o

TABLE 3-15 TWO-WAY DOPPLER ACCURACY TEST SUMMARY

ESTL
JSC/HOUSTON

CONDITIONS		UPLINK P_{rec}/N_o (dBHz)	DOWNLINK P_{rec}/N_o (dBHz)	MEAN ERROR Hz	MEAN ERROR M/Sec	σ Hz	σ M/Sec
UL 24H	DOPPLER						
	0	100.0	65.4	.068	4.46×10^{-3}	.058	3.80×10^{-3}
DL 03	0	59.7	65.4	.057	3.74×10^{-3}	.112	7.34×10^{-3}
HIGH	49.96 KHZ	59.7	65.4	-.496	-3.25×10^{-3}	.090	5.90×10^{-3}
FREQUENCY	99.90 KHZ	59.7	65.4	-2.107	-1.38×10^{-1}	.081	5.31×10^{-3}
	129.873 KHZ	59.7	65.4	-3.624	-2.38×10^{-1}	.079	5.18×10^{-3}
	-49.96 KHZ	59.7	65.4	-0.232	-1.52×10^{-2}	.093	6.10×10^{-3}
	-99.90 KHZ	59.7	65.4	-1.966	-1.29×10^{-1}	.080	5.25×10^{-3}
	-129.873 KHZ	59.7	65.4	-3.459	-2.27×10^{-1}	.079	5.18×10^{-3}
UL 24H	DOPPLER						
DL 05	0	59.7	65.4	.070	4.59×10^{-3}	.063	4.13×10^{-3}
HIGH	57.753 KHZ	59.7	65.4	-3.625	-2.38×10^{-1}	.083	5.44×10^{-3}
FREQUENCY	-57.753 KHZ	59.7	65.4	-3.486	-2.29×10^{-1}	.097	6.36×10^{-3}
UL 24L	DOPPLER						
DL 02	0	56.2	62.4	-.065	-4.26×10^{-3}	.128	8.39×10^{-3}
HIGH	57.753 KHZ	56.2	62.4	-3.632	-2.38×10^{-1}	.075	4.92×10^{-3}
FREQUENCY	-57.753 KHZ	56.2	62.4	-3.459	-2.27×10^{-1}	.087	5.70×10^{-3}
UL 24H	DOPPLER						
DL 03	0	59.7	65.4	.079	5.34×10^{-3}	.123	8.32×10^{-3}
LOW	+57.753 KHZ	59.7	65.4	-3.743	-2.53×10^{-1}	.068	4.60×10^{-3}
FREQUENCY	-57.753 KHZ	59.7	65.4	-3.576	-2.42×10^{-1}	.077	5.21×10^{-3}

4. REFERENCES

1. JSC/USAF Space Shuttle/SCF RF Communications and Tracking, ICD 2-0D003, August 1977

2. System Verification Test Procedures for AFSCF S-band Direct Link, EE7-79-103, April 1979

3. System Development Test Requirement and Status Report for AFSCF Direct Link, JSC 13022, April 1978

4. System Verification Test Plan for Orbiter/AFSCF S-band Direct Link, JSC 13910, March 1978

5. System Verification Test Data Package for AFSCF S-band Direct Link, EE7-79-708, September 1979

APPENDIX A

A. EFFECTS OF CRYPTOGRAPHIC PROCESS ON SYSTEM PERFORMANCE

A.1 General

The performance evaluation contained in this appendix is presented in a manner which can be correlated with the results in Section 3. The subject areas in order of discussion are as follows:

- PM Uplink Channel
- PM Downlink Channel
- FM OI Downlink Channel

The tests results presented in this appendix have been extracted from the test data package (reference 5). In general, selected test results have been plotted and presented in a format more suitable for evaluation.

A.2 S-band PM UPlink Tests

The S-band PM uplink tests were conducted to determine the performance of the uplink TDM channel, the uplink command channel, and the uplink voice channels.

A.2.1 Uplink TDM Channel Performance

The performance of the uplink TDM channel was determined by a series of bit error rate and percent data loss tests.

The uplink TDM channel bit error rate tests were conducted for uplink combinations 24L and 24H. As can be seen in figure A-1, the performance achieved with uplink signal combination 24H is 2.1 better than the ICD requirement of P_{rec}/N_0 of 59.7 dBHz at a BER of $1x10^{-5}$. For signal combination 24L, the performance is 1.8 dB better than the ICD requirement. The encryption/decryption process degrades the uplink BER performance by

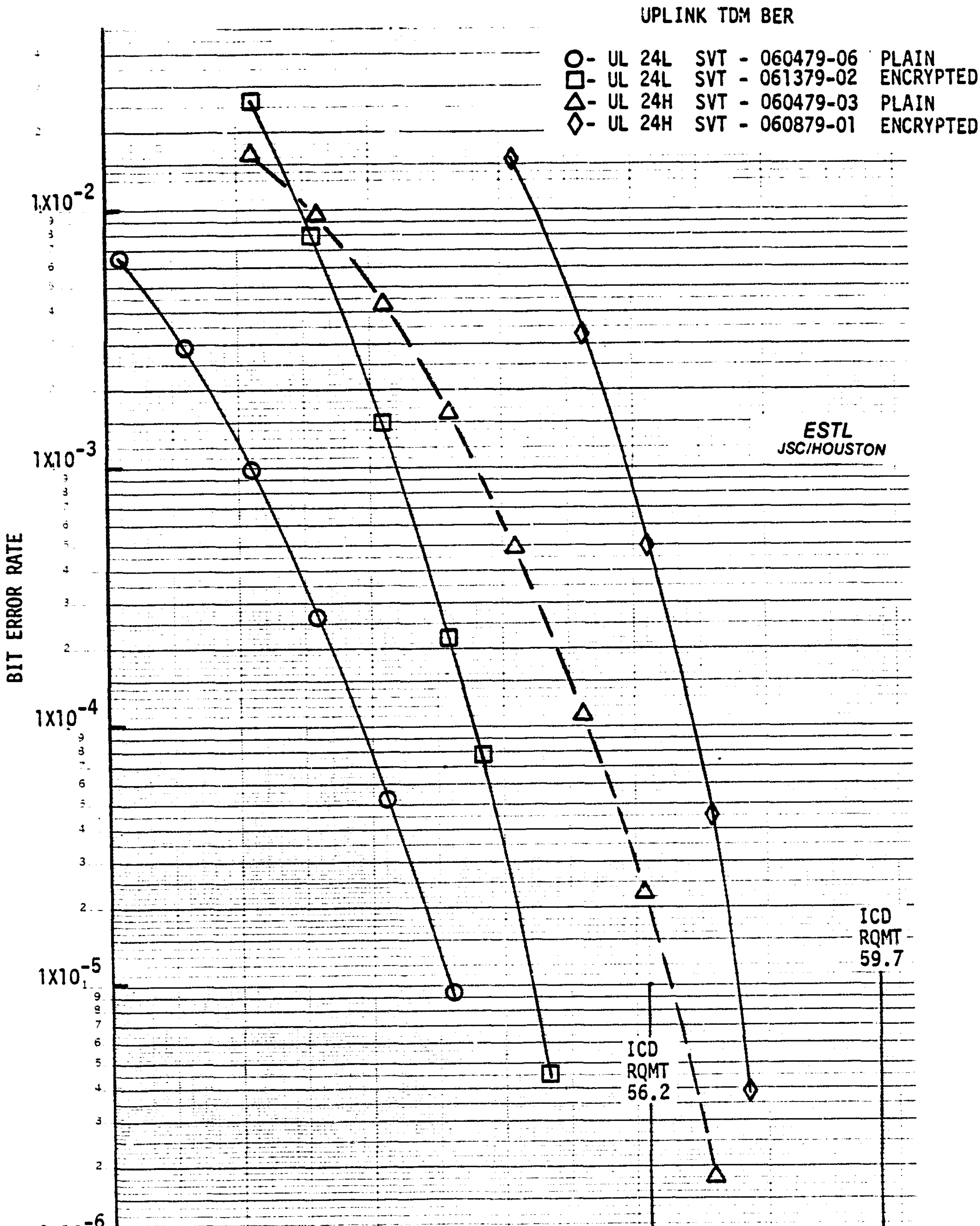

FIGURE A-1 UPLINK BIT ERROR RATE (COMPARISON OF ENCRYPTED AND PLAIN DATA) AS A FUNCTION OF P_{rec}/N_o

1.0 to 1.5 dB. Table A-1 presents the measured circuit margins for both the plain and encrypted data.

Uplink BER performance was not affected by the following conditions

1. Presence or absence of voice
2. Transponder mode-receive only vs. transpond
3. Frequency Selected
4. Presence of Doppler

A.2.2 Uplink Command Channel Performance

The performance of the uplink command channel was evaluated by measuring the message rejection rate for uplink signal combinations 24H and 24L. Results of the message rejection rate tests are shown in figure A-2. As can be seen in figure A-2 the encryption/decryption process degrades the command channel MRR performance by approximately 1.0 dB for both the HDR and LDR modes.

A.2.3 Uplink Voice Channel Performance

The performance of the uplink voice channel was determined by conducting subjective voice quality tests and word intelligibility tests as a function of the Orbiter P_{rec}/N_o.

A.2.3.1 Subjective Voice Quality Evaluation

A summary of the results of these tests for signal combinations 24H and 24L is shown in Table A-2. The encryption/decryption process degrades the voice quality approximately 5.0 dB for both the HDR and LDR modes.

TABLE A-1 UPLINK CIRCUIT MARGIN SUMMARY

UPLINK SIGNAL COMBINATION	Expected P_{rec}/N_o * (dBHz) FOR 1×10^{-5} BER	Measured P_{rec}/N_o (dBHz) FOR 1×10^{-5} BER ** (PLAIN)	Measured P_{rec}/N_o (dBHz) FOR 1×10^{-5} BER ** (ENCRYPTED)	CIRCUIT MARGIN (dB)	
				PLAIN	ENCRYPTED
24L	100.1	53.1	54.5	47.0	45.6
24H	100.1	56.5	57.6	43.6	42.5

* AFSCF/RTS Transmit Power of 30 dBW, AFSCF/RTS Antenna Gain of 45 dB, Slant Range of 966 nmi (Slant Range for 5° Elev. and 255 nmi Orbit), and Orbiter Antenna Gain of -2 dB

** Based on Specified Noise Figure of 8 dB

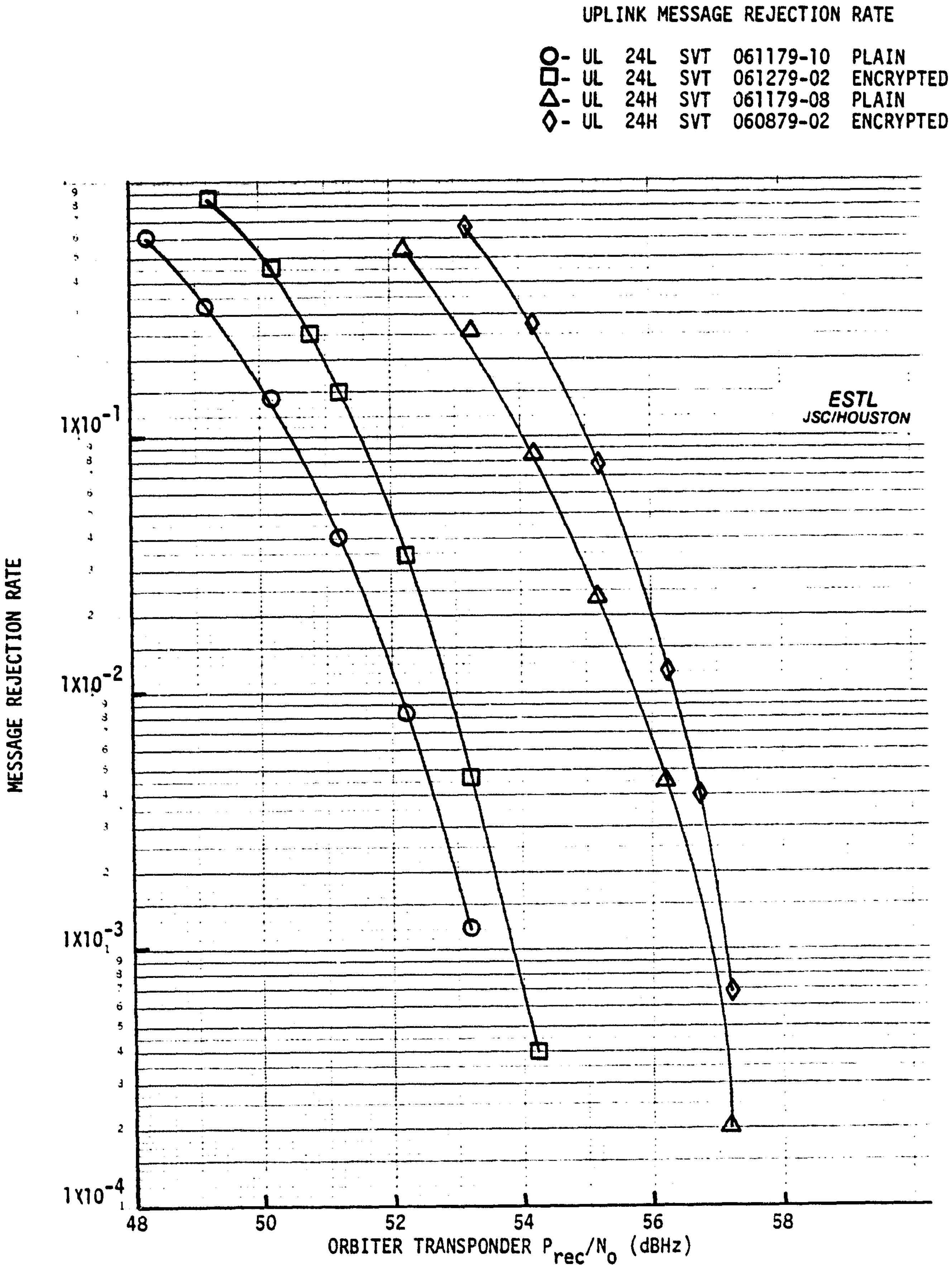

FIGURE A-2 MESSAGE REJECTION RATE (COMPARISON OF ENCRYPTED AND PLAIN DATA) AS A FUNCTION OF P_{rec}/N_o

TABLE A-2

UPLINK VOICE QUALITY AND WORD INTELLIGIBILITY TEST RESULTS

ESTL
JSC/HOUSTON

Signal Combination	Voice Quality Rating	P_{rec}/N_o (dBHz)	Bit Error Rate	Word Intelligibility (Percent)
24H	-	100.1*	-	97.1
24H	-	59.7**	-	97.9
24H	Good	57.2	4.5×10^{-5}	97.7
24H	Fair	54.2	1.6×10^{-2}	96.3
24H	Poor	53.2	5.2×10^{-2}	91.5
24H	Usable	52.2	1.3×10^{-1}	-
24H	Unusable	51.2	2.5×10^{-1}	-
24L	-	100.1*	-	97.0
24L	-	59.7*	-	96.8
24L	Good	53.7	7.6×10^{-5}	94.8
24L	Fair	50.7	1.3×10^{-2}	94.0
24L	Poor	49.7	4.7×10^{-2}	91.7
24L	Usable	48.7	1.2×10^{-1}	-
24L	Unusable	47.7	2.4×10^{-1}	-

* EXPECTED P_{rec}/N_o

** ICD REQUIRED P_{rec}/N_o

A.2.3.2 Word Intelligibility Tests

The word intelligibility tests are summarized in Table A-2. Based on the specified word intelligibility of 90%, the test data indicates that circuit margins of 50.4 dB and 45.9 dB were achieved for signal combinations 24L and 24H, respectively. The test data also shows that BER's less than or equal to 1×10^{-2} provided word intelligibility greater than 90%, in accordance with ICD requirements.

A.3 S-band PM Direct Downlink Tests

The S-band PM direct downlink tests were conducted to determine the performance of the downlink TDM channel and the downlink voice channels. The results presented in this section are with the Orbiter transponder "RANGING DISABLED". Test with the encryption/decryption equipment were performed for ranging disabled mode only.

A.3.1 Downlink TDM Channel Performance

The performance of the AFSCF S-band downlink channel was determined by a series of bit error rate tests for the different combinations of uplink and downlink signals.

A.3.1.1 Bit Error Rate Performance

Downlink TDM channel bit error rate tests were conducted using an EMR 720 bit synchronizer. The EMR bit synchronizer is a part of the telemetry data system at the AFSCF/RTS.

Downlink TDM channel Ber test results are shown in figure A-3. The performance of the downlink for the high and low data rates at the specified BER of 1×10^{-5} is degraded 2 dB by the encryption/decryption process. The

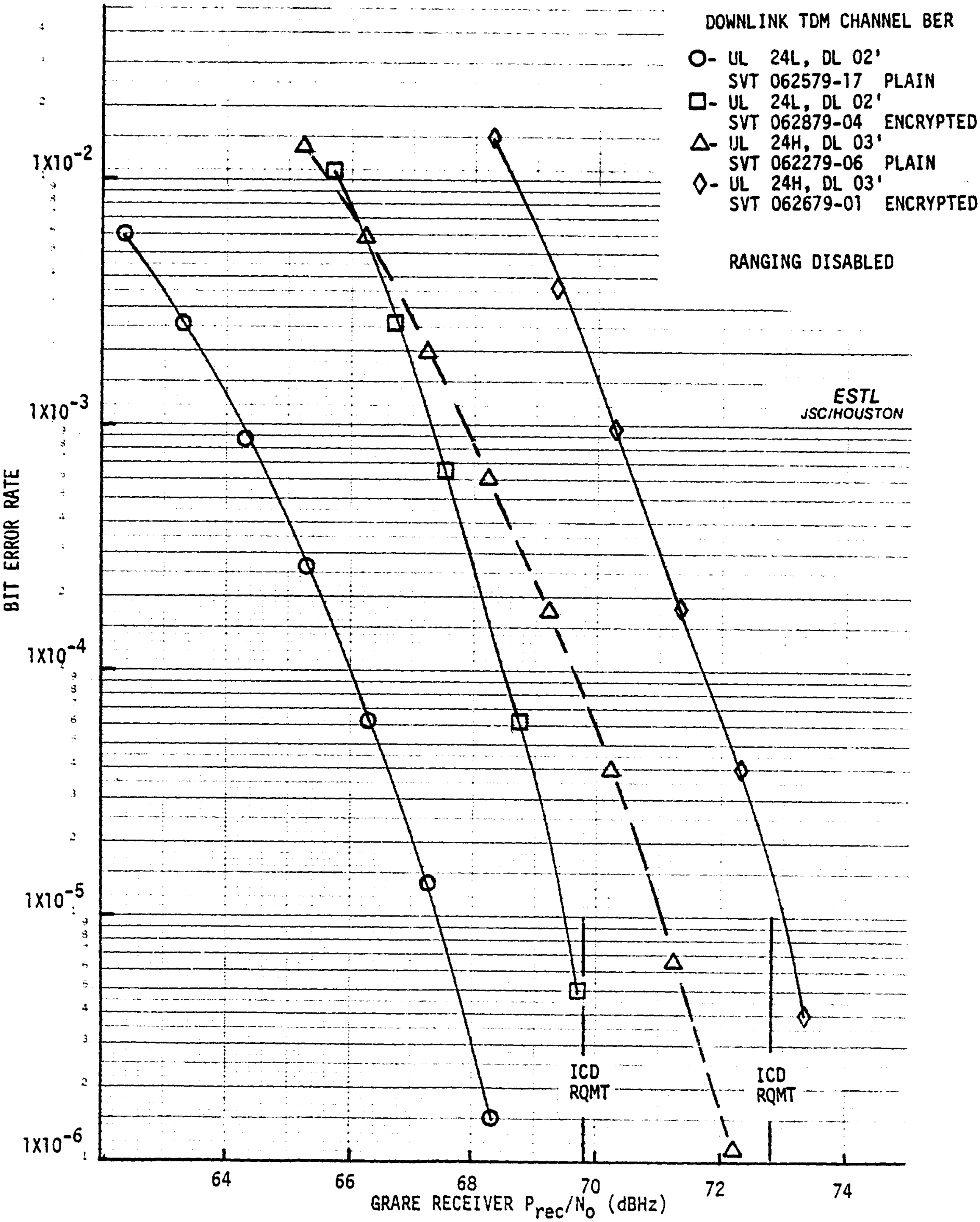

FIGURE A-3 DOWNLINK TDM CHANNEL BIT ERROR RATE (COMPARISON OF ENCRYPTED AND PLAIN DATA) AS A FUNCTION OF P_{rec}/N_o

downlink performance would also be degraded 2.8 dB for ranging enabled. Downlink BER performance was not affected by the following conditions:

1. Presence or absence of voice
2. Presence or absence of FM interference
3. Frequency selected
4. Presence of Doppler

A summary of the circuit margins is shown in Table A-3.

A.3.1.2 Percent Data Loss Performance

Downlink TDM Channel percent data loss tests were conducted using GSTDN processing equipment, i.e., Monitor 330 bit synchronizer and 403 frame synchronizer. These two synchronizers are part of the voice delta demodulation system and are the same model bit and frame synchronizers that will be located at the AFSCF. The optimum settings recommended for the Monitor 403 frame synchronizer were

E_S = 2 - No. of allowable errors in search

E_L = 2 - No. of allowable errors in lock

E_L = 3 - No. of successive frames with greater than 2 errors required to lose lock

The percent data loss test results for the downlink signal combinations tested are shown in figure A-4. The percent data loss is obtained by counting the number of frames lost and dividing by the number of total frames transmitted.

For each downlink signal combination the P_{rec}/N_0 was varied over a range to produce at least 50 percent data loss. At 50 percent data loss both the telemetry and voice channels become unusable.

TABLE A-3 PM DOWNLINK CIRCUIT MARGIN SUMMARY

ESTL
JSC/HOUSTON

SIGNAL COMBINATION (RANGING DISABLED)	EXPECTED P_{rec}/N_o* (dBHz) FOR $1x10^{-5}$ BER	MEASURED P_{rec}/N_o (dBHz) FOR $1x10^{-5}$ BER (PLAIN)	MEASURED P_{rec}/N_o (dBHz) FOR $1x10^{-5}$ BER (ENCRYPTED)	CIRCUIT MARGIN (dB)	
				PLAIN	ENCRYPTED
UP 24L, DL 02'	87.6	67.4	69.4	20.2	18.2
UP 24H, DL 03'	87.6	71.0	73.0	16.6	14.6

* Orbiter Transmit Power = 3 dBW; Orbiter Transmit Antenna Gain = 3 dB;
Slant Range = 966 nmi (Slant Range for 5° Elev. and 225 nmi Orbit);
AFSCF/RTS Receive Antenna Gain - 47.5 dB

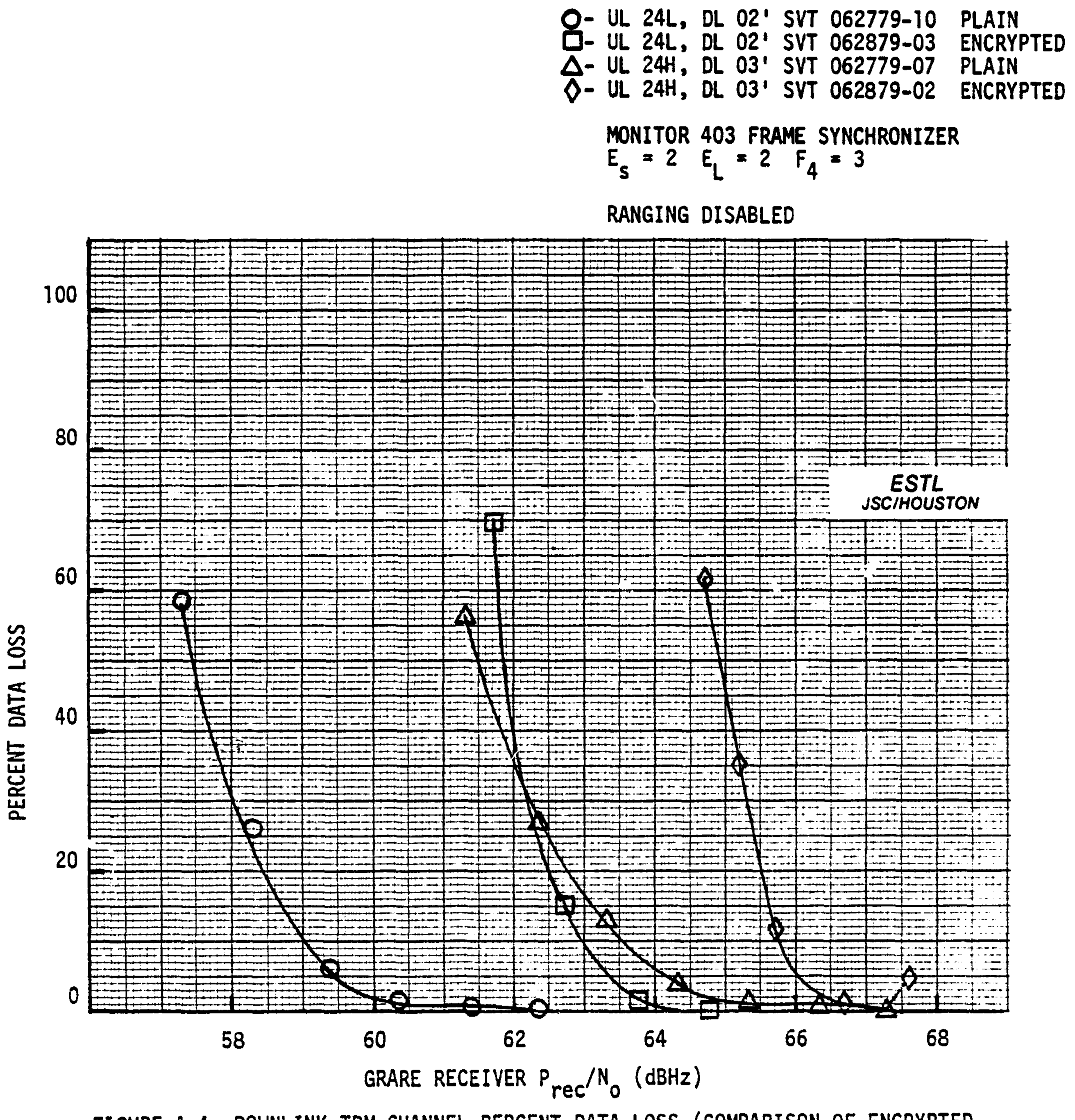

FIGURE A-4 DOWNLINK TDM CHANNEL PERCENT DATA LOSS (COMPARISON OF ENCRYPTED AND PLAIN DATA) AS A FUNCTION OF P_{rec}/N_o

A.3.2 Downlink Voice Channel Performance

The performance of the downlink voice channel was determined by conducting subjective voice quality tests and word intelligibility tests as a function of the GRARE receiver P_{rec}/N_0.

A.3.2.1 Subjective Voice Quality Evaluation (ATU Input)

A summary of the results of these tests is presented in Table A-4. The encryption/decryption process degrades the voice quality approximately 2.5 dB for both the HDR and LDR modes.

A.3.2.2 Word Intelligibility Tests

The word intelligibility tests are summarized in Table A-4. Based on the specified word intelligibility of 90%, the test data indicates that circuit margins of 22.6 and 17.6 dB were measured for signal combinations 02' and 03', respectively.

A.4 Operational Instrumentation Downlink Tests

A.4.1 FM Link Playback TDM Data Performance - (OPS Recorder)

The playback TDM from the OPS recorder was evaluated by measurement of BER, percent data loss and voice quality for both the ASGLS and Microdyne receivers. The link was tested using direct data (i.e., not using the OPS recorder) and using the OPS recorder in both 1:1 and 5:1 playback. The direct and 1:1 playback was evaluated directly from the receivers. The 5:1 playback was first recorded on the AFSCF FR-2000 recorder and then played back at a slower speed for evaluation.

TABLE A-4

DOWNLINK VOICE QUALITY AND WORD INTELLIGIBILITY TEST RESULTS

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Signal Combination	Voice Quality Rating	P_{rec}/N_o (dBHz)	Bit Error Rate	Word Intelligibility (Percent)
UL24L, DL02'	-	89.7*	-	98.0
UL24L, DL02'	-	67.0**	1.6×10^{-3}	98.2
UL24L, DL02'	Good	68.7	6.7×10^{-5}	-
UL24L, DL02'	Fair	65.7	1.7×10^{-2}	96.3
UL24L, DL02'	Poor	63.7	1.0×10^{-1}	90.6
UL24L, DL02'	Usable	62.7	2.2×10^{-1}	40.1
UL24L, DL02'	Unusable	61.7	3.4×10^{-1}	-
UL24H, DL03'	-	89.7*	-	95.6
UL24H, DL03'	-	70.0**	1.5×10^{-3}	96.0
UL24H, DL03'	Good	71.7	9.5×10^{-5}	96.9
UL24H, DL03'	Fair	68.7	9.3×10^{-3}	91.9
UL24H, DL03'	Poor	66.7	8.5×10^{-2}	68.9
UL24H, DL03'	Usable	65.7	1.8×10^{-1}	-
UL24H, DL03'	Unusable	64.7	3.1×10^{-1}	-

* EXPECTED P_{rec}/N_o

** ICD REQUIRED P_{rec}/N_o

Figure A-5 presents the BER results achieved with the Microdyne receiver for playback TDM (192 Kbps) data. The measured P_{rec}/N_o where a BER of $1x10^{-5}$ occurred was approximately 0.8 dB better than the ICD requirement for the Microdyne receiver for the 5:1 playback. The measured circuit margins were 20.6 dB and 16.0 dB for 1:1 and 5:1 playback, respectively. The measured circuit margins are presented in Table A-5.

Figure A-6 presents the BER results achieved with the ASGLS receiver for playback TDM (192 Kbps) data. The measured P_{rec}/N_o where a BER of $1x10^{-5}$ occurred was approximately 3.7 dB worse than the ICD requirement for the ASGLS receiver. The measured circuit margins were 15.3 dB and 10.9 dB for 1:1 and 5:1 playback, respectively.

The percent data loss tests were run simultaneous with the BER tests and percent data loss greater than 50 percent was obtained for most test conditions. In most cases data loss of greater than 50 percent occurs at BER's of $1x10^{-1}$ or greater.

Table A-6 presents the results of the subjective voice quality evaluation for the Microdyne receiver. A subjective voice quality rating of "FAIR" occurred at P_{rec}/N_o of 68.8 dBHz and 72.8 dBHz for 1:1 and 5:1 playback, respectively. These P_{rec}/N_o's are 8.6 dB and 4.6 dB better than the ICD required P_{rec}/N_o of 77.4 dBHz.

A.4.2 FM Link Realtime DOD Payload Digital Data Performance

The realtime DOD payload digital data mode was evaluated by measurement of BER and percent data loss. These tests were performed at the maximum data rate (256 Kbps) for both the ASGLS and the Microdyne receivers.

Figure A-7 presents the BER of the 256 Kbps (BIØ-L) data rate for both the Microdyne and ASGLS receivers. Measured circuit margins for the

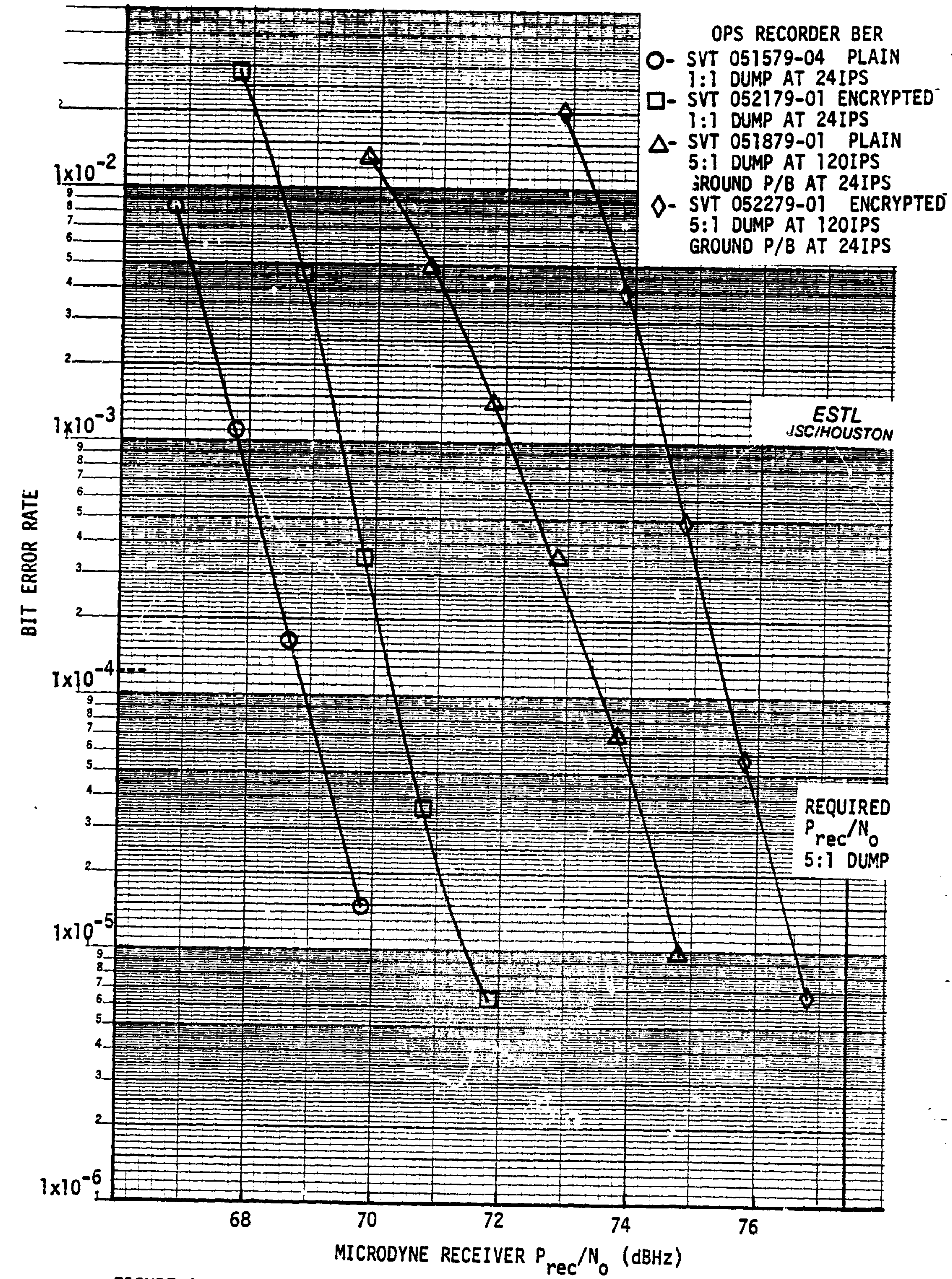

FIGURE A-5 OPS RECORDER TDM BER (COMPARISON OF ENCRYPTED AND PLAIN DATA) AS A FUNCTION OF P_{rec}/N_o

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TABLE A-5 FM DOWNLINK CIRCUIT MARGIN SUMMARY

INFORMATION (ENCRYPTED)	EXPECTED P_{rec}/N_o*	MEASURED P_{rec}/N_o FOR 1x10^{-5} BER		CIRCUIT MARGIN DB	
		MICRODYNE	ASGLS	MICRODYNE	ASGLS
PAYLOAD DIGITAL DATA - 256 KBPS BI-Ø-L	92 DBHz	72.5	76.9	19.5	15.1
PLAYBACK TDM DATA (1:1)	92 DBHz	71.4	76.0	20.6	16.0
PLAYBACK TDM DATA (5:1)	92 DBHz	76.7	81.1	15.3	10.9

* Orbiter Transmit Power = 10 DBW; Orbiter Antenna Gain = +1 dB; Slant Range = 966 nmi (Slant Range for 5° Elev. and 225 nmi Orbit); AFSCF/RTS Receive Antenna Gain = 47.5 dB

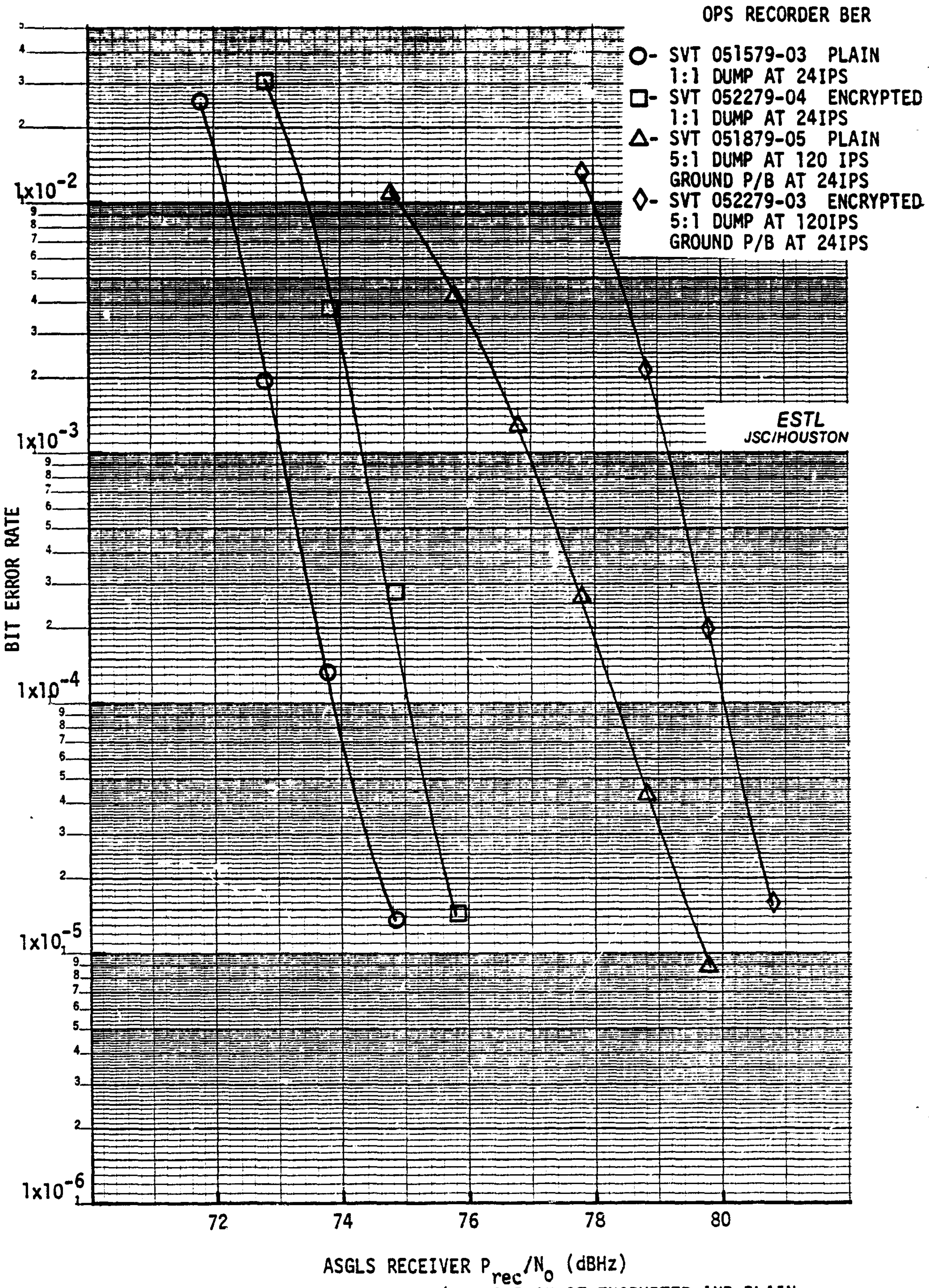

FIGURE A-6 OPS RECORDER TDM BER (COMPARISON OF ENCRYPTED AND PLAIN DATA) AS A FUNCTION OF P_{rec}/N_o

TABLE A-6 PLAYBACK VOICE QUALITY TEST RESULTS

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VOICE QUALITY RATING	MICRODYNE RECEIVER				ASGLS RECEIVER			
	1:1 PLAYBACK		5:1 PLAYBACK		1:1 PLAYBACK		5:1 PLAYBACK	
	P_{rec}/N_o	BER	P_{rec}/N_o	BER	P_{rec}/N_o	BER	P_{rec}/N_o	BER
GOOD	71.8	6.6×10^{-6}	75.8	5.6×10^{-5}	76.8	-	80.8	1.6×10^{-5}
FAIR	68.8	4.5×10^{-3}	72.8	2×10^{-2}	73.8	3.7×10^{-3}	77.8	1.3×10^{-2}
POOR	67.8	2.9×10^{-2}	71.8	7.3×10^{-2}	72.8	3.2×10^{-2}	76.8	5.4×10^{-2}
USABLE	66.8	1.2×10^{-1}	70.8	2.0×10^{-1}	71.8	1.6×10^{-1}	75.8	1.6×10^{-1}
UNUSABLE	65.8	3.1×10^{-1}	69.8	3.6×10^{-1}	70.8	4×10^{-1}	74.8	3.3×10^{-1}

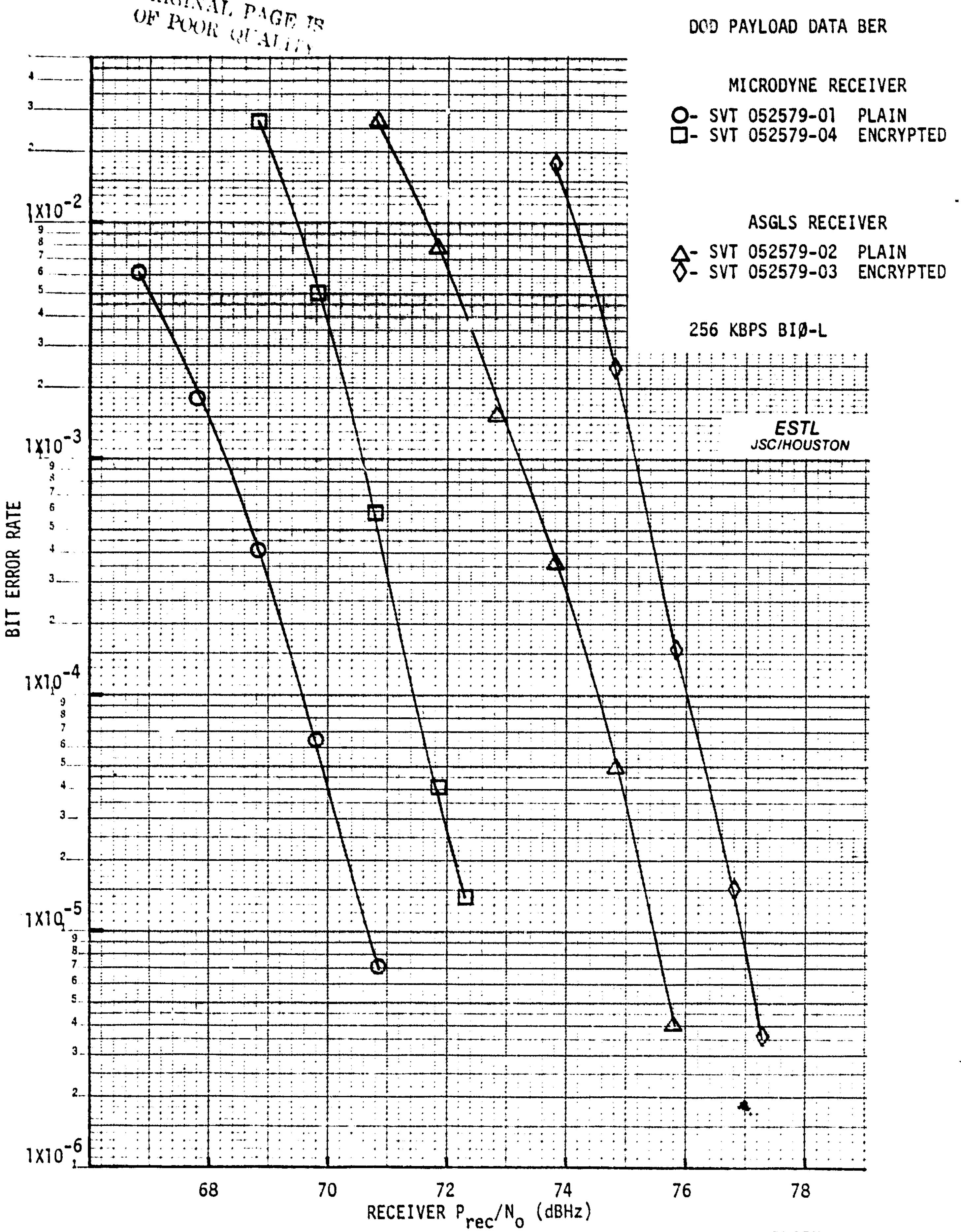

FIGURE A-7 DOD PAYLOAD BIT ERROR RATE (COMPARISON OF ENCRYPTION AND PLAIN DATA) AS A FUNCTION OF P_{rec}/N_o

Microdyne receiver was 19.5 dB. Measured circuit margins for the ASGLS receiver was 15.1 dB. The measured circuit margins are presented in Table A-5.