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SUMMARY OF TRANSPONDER DATA FOR ATLANTA, GEORGIA, AREA.(U)
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SUMMARY OF TRANSPONDER DATA FOR ATLANTA, GEORGIA, AREA

Max Greenberg

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FINAL REPORT

OCTOBER 1980

Prepared for
U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
TECHNICAL CENTER
Atlantic City Airport, New Jersey 08405

NOTICE

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16. Abstract

The Federal Aviation Administration (FAA) Technical Center was requested by the FAA Southern Region ~~in October 1979~~ to provide specialized support with the transponder performance analyzer (TPA) in their efforts to identify and localize Air Traffic Control Radar Beacon System (ATCRBS) coverage problems in the Atlanta, Georgia, Terminal. This support was to provide additional information and backup for other efforts in progress by the Southern Region. System performance tests, standard flight tests, and various other tests had been performed by technical and operational personnel. As a result of these tests, specific problems, localities, and aircraft types involved, beacon transponders became suspect as one source of difficulty. The requested TPA support was provided ~~in November 1979~~ and data included herein provides the subject information in the transponder area of concern.

This effort was accomplished under Project No. 031-241-820, ATCRBS field problem investigations.

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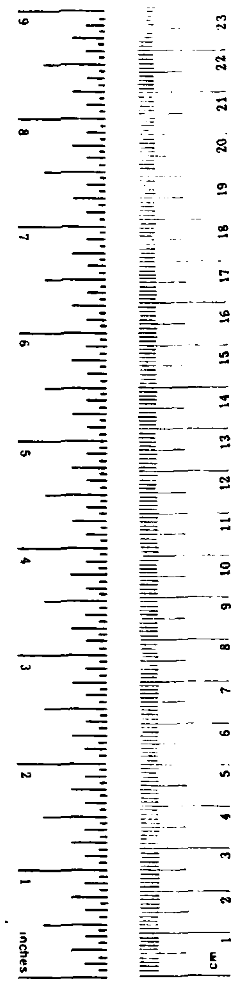
METRIC CONVERSION FACTORS

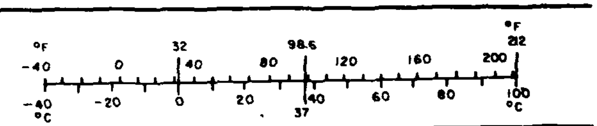
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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INTRODUCTION

PURPOSE AND BACKGROUND.

The Federal Aviation Administration (FAA) Technical Center was requested by the Southern Region, via letter dated October 23, 1979, to provide specialized support with the transponder performance analyzer (TPA) to help localize and identify Air Traffic Control Radar Beacon System (ATCRBS) problems in the Atlanta, Georgia, Terminal area. The problems reported by operational air traffic control (ATC) personnel were: target drop-out, excessive coasting, and lack of target reports in several locations. Based on ground system performance tests, the type aircraft involved, geographic localities, and other considerations, aircraft transponders became suspect. This resulted in the decision to conduct transponder checks with the TPA at DeKalb and Fulton County Airports and at Dobbins Air Force Base. The TPA data included in this report are to supplement and support controller logs and other data in the suspect areas of beacon coverage.

TRANSPONDER PERFORMANCE ANALYZER

GENERAL DESCRIPTION.

The TPA is a semiautomated mobile test system capable of testing up to 15 transponder parameters while the aircraft is momentarily stopped on a ramp or taxiway. The TPA is fully self-contained and housed in a bus for mobility. The basic equipment consists of a modified AN/UPX-14 beacon receiver, a directional horn antenna, voltage control PIN diodes, pulse mode generator (PMG), radiofrequency (RF) control unit, reply processor, digital clock, computer buffer, minicomputer with magnetic tape and disk storage, a display terminal with hard copy printer, and other elements for timing, control, analog-to-digital (A/D) conversions, etc. References 1 and 2 are comprehensive reports on the TPA and a summary of transponder data during 1977 and 1978, respectively.

TPA OPERATIONS AND PROCEDURES.

In normal operation the minicomputer issues commands to the pulse mode generator (PMG), which establishes the pulse rate and spacing between interrogation pulses (see figure 1). The PMG also triggers the transmitter, which generates a low level of RF power. Control of the pulse rate and spacing are utilized in measurement of transponder dead time, suppression time, decode accuracy, and other characteristics. Amplitude of the transmitted RF is controlled via PIN diode modulators which feed the PMG and horn antenna. The horn antenna transmits and receives all the RF pulses. The transponder reply is processed through the receiver intermediate frequency (IF) amplifiers and various circuits for measurments such as pulse amplitude, width, and spacing and then recorded on magnetic tape for data reduction and future analysis. A 100 megahertz (MHz) clock is used to measure the pulse width, spacing, and timing. A cathode ray tube (CRT) provides a visual output during the test; a thermal printer provides a hard copy printout for immediate assessment.

In the ramp test procedure the TPA bus is located alongside the taxiway, the aircraft under test is positioned over a reference mark, and the pilot requested to turn on the transponder and squawk a specified code. The test requires approximately 30 seconds. When the aircraft transponder's antenna is over the calibrated reference mark the free-space attenuation, horn antenna gain, and cable losses are accounted for in measurements of transponder power and sensitivity. The computer software automatically controls interrogation, spacing, and rate of the onboard equipment as 15 transponder characteristics are measured and recorded. These are also shown on the computer printout (figure 2).

The information from references 3, 4, and 5 were used in the TPA design to determine equipment characteristics and test standards.

DATA COLLECTION.

The transponder data recorded were from three areas: Peachtree-DeKalb Airport, Fulton County Airport, and Dobbins Air Force Base. The data to be analyzed and discussed in this report includes the DeKalb and Fulton County Airports. Dobbins Air Force Base data (approximately 20 military planes) are omitted for reasons to be discussed later.

More than 100 aircraft were interrogated by the TPA at both the DeKalb and Fulton County Airports. The parameters measured are listed in table 1; the parameter values are compared with the established standards and are defined in reference 1.

TEST PROCEDURES.

A very high frequency (VHF) communication frequency was assigned by frequency management prior to TPA arrival at the subject airports. This information, along with other general information about the TPA, was utilized in Notices to Airmen (NOTAM's), Automatic Terminal Information Service (ATIS), brochures, and handouts for advance publicity. In addition, signs directed the aircraft toward the TPA test area. Once communications were established, the pilot was guided by a member of the TPA team to a calibrated mark on the taxiway and advised to operate his transponder on the specified discrete code. When the TPA detected reply signals from the transponder, operating personnel entered the identification and frequency data via the CRT keyboard.

A standard gain directional antenna (horn) was used to couple the signal between the aircraft transponder antenna and the TPA bus. The horn is a Scientific Atlanta model 12-0.9. Calibration and dimensions for the horn are taken from Naval Research Laboratory (NRL) Report No. 4433. The nominal gain at 1.0 gigahertz (GHz) is 13.7 decibel (dB). The E-plane and H-plane nominal bandwidths are 40 and 35 degrees, respectively. The average height from ground to the general aviation transponder antenna is approximately 30 inches; the horn is set at that height. A coupling factor, due to height variation, is taken into consideration as part of the measurement tolerance (reference 6, pages 48 and 49). The distance of 50 feet between horn and aircraft transponder antenna is used for separation and clearance purposes and is taken into account during calibration. Calibration of the TPA electronics utilizes state-of-the-art test equipment and a reference transponder. The reference transponder is measured for 15 parameters directly by the TPA equipment (bench test), and the parameter values are recorded.

The reference transponder antenna is then placed over the calibrated reference mark. When the transponder is interrogated, the TPA equipment is then adjusted by offset voltages to produce the same readings as previously recorded from the bench test. This calibrates the TPA parameters such as: free-space attenuation, cable losses, power level settings, and gain of the horn. If a different distance is required, new offset voltages are required to produce the same readings.

RESULTS

Measurement of the 15 parameters from 108 samples (46 from DeKalb and 62 from Fulton County) were compared to the standards. Table 2 indicates the 15

TABLE 1. TEST PARAMETERS

Characteristics	Specification	Measurement Tolerance	Remarks
1. Dead Time	No greater than 125 μs		
2. Suppression Time	35 ±10 μs		
3. Reply Power	At least 48.5 dBm not more than 57 dBm	±3 dB*	For aircraft operating below 15,000 feet.
4. Frequency	1090 ±3 MHz		
5. F_1 Pulse Width	450 ±100 ns	±20 ns	
6. F_2 Pulse Width	450 ±100 ns	±20 ns	
7. Sensitivity	69 -77 dBm	±3 dB*	
8. Delay Time Diff.	Not to exceed 200 ns	±50 ns	Delay variations between modes (e.g., A, C)
9. Reply Jitter	Not to exceed 100 ns	±10 ns	
10. Mode A Delay	3 ±0.5 μs		
11. Mode C Delay	3 ±0.5 μs		
12. F_1 - F_2 Spacing	20.3 ±0.1 μs	±20 ns	
13. SLS Decode Accur.	2.0 ±0.15 μs		Interval between P_1 P_2
14. Mode A Decode Accur.	8.0 ±0.2 μs		Interval between P_1 P_3
15. Mode C Decode Accur.	21.0 ±0.2 μs		Interval between P_1 P_3

*Measurement error and/or antenna coupling factor includes variations due to antenna height, lobing, reflections, etc.

TABLE 2. PERCENTAGE OF TRANSPONDERS MEETING STANDARDS

Characteristics	DeKalb, Ga. (46) Meas.* Toler. Percent	DeKalb, Ga. (46) Spec. Percent	Fulton, Ga. (62) Meas.* Toler. Percent	Fulton, Ga. (62) Spec. Percent	Composite (Atlanta) (108) Meas.* Toler. Percent	Composite (Atlanta) (108) Spec. Percent	No. A/C
1. Dead Time		100.00		98.39		99.07	107
2. Suppression Time		95.65		93.55		94.44	102
3. Reply Power	43.48	89.13	27.42	91.42	34.26	90.74	98
4. Frequency		89.13		93.55		91.67	99
5. F_1 Pulse Width	0.0	95.65	4.84	93.55	2.78	94.44	102
6. F_2 Pulse Width	2.17	97.83	9.68	91.94	6.48	94.44	102
7. Sensitivity	23.91	86.96	19.35	87.10	21.30	87.04	94
8. Delay Time Diff.	0.0	89.13	3.23	90.32	1.85	89.81	97
9. Reply Jitter	4.34	95.65	4.84	96.77	4.63	96.30	104
10. Mode A Delay		95.65		95.16		95.37	103
11. Mode C Delay		91.30		95.16		93.52	101
12. F_1 - F_2 Spacing	0.0	91.30	3.23	890.32	1.85	90.74	98
13. SLS Decode Accur.		93.48		90.32		91.67	99
14. Mode A Decode Accur.		93.48		93.55		93.52	101
15. Mode C Decode Accur.		91.30		85.48		87.96	95

*Measurement tolerance provides for measurement error and/or antenna coupling factor including variations due to antenna height, lobing, shielding, reflections, etc.

parameters at each airport as well as the composite data for both. Columns in tables 1 and 2 under the heading of "Measurement Tolerance Percent" are also included and defined in the Comparative Analysis portion of this report.

Table 3 shows the percentages of transponders which met some number "N" of the standards, where the parameter "N" varies from 1 to 15. It can be seen from table 3 that 60 out of 108 transponders met all 15 parameters measured, which is approximately 55.56 percent; 73.15 percent of the transponders tested met 14 out of 15 parameters; 84.21 percent of the transponders tested met 13 out of 15 parameters; and 88.89 percent met 12 out of 15 parameters.

Table 2 shows parameters with the lowest percentage meeting the specifications: reply power, 90.74 percent; frequency, 91.67 percent; sensitivity, 87.04 percent; delay time difference 89.81 percent; F_1-F_2 spacing, 90.74 percent; and mode C decode accuracy, 87.96 percent.

It should also be noted that there were two aircraft owners who were aware that their transponders were inoperative and our test verified that was correct. That data were not included in our count.

COMPARATIVE ANALYSIS.

The data collected at the DeKalb and Fulton County Airports indicate approximately 56 percent of the transponders tested met FAA standards for all 15 parameters tested, which is significantly better than results from other data collected at various air shows (56 percent compared to 36 percent) and reported in reference 2. This difference is attributed to the much larger number of training and executive/business type aircraft included in the Atlanta data; air show data are almost exclusively the private owner pleasure-type aircraft. Maintenance and inspection schedules for the training and business aircraft are believed to be relatively good; the private owner would be much more prone to slippage or neglect, particularly as compared to aircraft subject to more rigid inspection such as training aircraft. Maintenance fees for training/business aircraft can be deducted as a business expense; the private owner cannot deduct these expenses.

Comparison of Atlanta data with reference 3 shows that 73.15 percent met 14 of the 15 parameters compared to 61 percent; 84.26 percent met 13 of the 15 compared to 79 percent, and 88.89 percent met 12 of the 15 parameters compared to 88 percent. Table 4 depicts this comparison. As stated, the Atlanta data indicates transponders in this geographic area are generally better than those recorded in reference 2.

Table 5 shows the comparison of the individual characteristics of the 1979 Atlanta data with the 1977/1978 data in reference 2. The most frequent out-of-specification parameters in reference 2 were reply power and sensitivity; in the Atlanta data, it was primarily sensitivity. The rest were almost equal to, and in most cases better than, those in reference 2. The most difficult parameters to measure are power and sensitivity. This is due to many variables such as ground effect, antenna coupling/orientation, lobing, reflections, shielding, and height. Therefore, an additional ± 3 dB was allowed to the original specification requirement. This 3 dB gray area is indicated in tables 1 and 2 under the column "Measurement Tolerance Percent" (this also takes into consideration test equipment and other inherent errors). In table 2, approximately 34.26 percent of the reply power measurement falls into this category. Those measurements actually meeting the specification would then be 90.74 less 34.26, or 56.48 percent. Again, for sensitivity, 21.3 percent fell in the gray area. The other measurement tolerance percent for F_1 and F_2 pulse width, delay time

TABLE 3. PERCENTAGE OF TRANSPONDERS MEETING "N" OF THE 15 STANDARDS

"N" Standards Out of 15	DeKalb (46)		Fulton (62)		Composite Atlanta (108)	
	No. A/C	Percent	No. A/C	Percent	No. A/C	Percent
15	29	63.04	31	50.00	60	55.56
14	34	73.91	45	72.58	79	73.15
13	39	84.78	52	83.87	91	84.26
12	41	89.13	55	88.71	96	88.89
11	43	93.48	59	95.16	102	94.44
10	44	95.65	61	98.39	105	97.22
9	45	97.83	61	98.39	106	98.15
8	45	97.83	62	100.00	107	99.07
7	46	100.00	62	100.00	108	100.00
6	46	100.00	62	100.00	108	100.00
5	46	100.00	62	100.00	108	100.00
4	46	100.00	62	100.00	108	100.00
3	46	100.00	62	100.00	108	100.00
2	46	100.00	62	100.00	108	100.00
1	46	100.00	62	100.00	108	100.00
0	46	100.00	62	100.00	108	100.00

TABLE 4. PERCENTAGE OF TRANSPONDERS MEETING "N" OF THE 15 STANDARDS COMPARED WITH 1977/1978 DATA

"N" Standards Out of 15	1977 and 1978 (965 samples) No.	Percent	1979 Atlanta (108 samples) No.	Percent
15	348	36.10	60	55.56
14	590	61.20	79	73.15
13	760	78.80	91	84.26
12	852	88.30	96	88.89
11	910	94.30	102	94.44
10	935	96.90	105	97.22
9	944	97.80	106	98.15
8	954	98.90	107	99.07
7	958	99.30	108	100.00
6	960	99.50	108	100.00
5	962	99.70	108	100.00
4	963	99.80	108	100.00
3	964	99.90	108	100.00
2	965	100.00	108	100.00
1	965	100.00	108	100.00

TABLE 5. COMPARISON OF 1977/1978 DATA WITH 1979 ATLANTA DATA

	1977 and 1978 (965 samples)		1979 Atlanta (108 samples)	
Characteristics	No.	Percent	No.	Percent
1. Dead Time	942	97.6	107	99.07
2. Suppression Time	889	92.1	102	94.44
3. Reply Power	802	83.1	98	90.74
4. Frequency	893	92.5	99	91.67
5. F_1 Pulse Width	862	89.3	102	94.44
6. F_2 Pulse Width	844	87.5	102	94.44
7. Sensitivity	754	78.1	94	87.04
8. Delay Time Difference	896	92.8	97	89.81
9. Reply Jitter	904	93.7	104	96.30
10. Mode A Delay	926	96.0	103	95.37
11. Mode C Delay	924	95.8	101	93.52
12. F_1-F_2 Spacing	857	88.8	98	90.74
13. SLS Decode Accuracy	869	90.1	99	91.67
14. Mode A Decode Accuracy	861	89.2	101	93.52
15. Mode C Decode Accuracy	794	82.3	95	87.96

difference, reply jitter, and F_1-F_2 spacing were relatively small and are negligible. Figures 3 through 17 are bar graphs depicting the individual characteristics for the 108 samples tested in the Atlanta area.

The data from Dobbins Air Force Base are not included due to anomalies in the data and lack of knowledge by the test personnel on the transponder types and specific antenna installations. Since the Dobbins test, it has been learned that several types of military aircraft have dual antenna systems that are automatically switched at a nonsychronized frequency 38 hertz (Hz). This resulted in signal amplitude variations in the Dobbins test and could not be properly interpreted by the TPA in the standard test. Further, certain TPA test conditions triggered other transponder reply modes, which resulted in erroneous data. Additional tests, conducted after the Dobbins test, indicates antenna placement onboard the aircraft has a serious effect on target detection of the aircraft. For example: an F-105 flying an inbound radial toward an ATCRBS site, at an altitude of 5,000 feet, has extremely poor detection with the bottom aft antenna. An F-105 inbound toward the TFAST facility at the Technical Center, at an altitude of 5,000 feet, did not respond with a single reply over the 50-mile distance from Waterloo, Maryland, to Atlantic City. This poor response has a serious effect on target declaration and tracking in the ARTS system, and is considered to be a major factor in tracking the F-105 aircraft on arrivals/departures at Dobbins Air Force Base from the Atlanta Terminal (i.e., at low altitude and on an approximate radial from the Atlanta site).

It has also been determined that specific requirements do not exist for test and certification of military transponders. They are only removed and checked on a complaint basis. Additional information on military aircraft is contained in Report No. FAA-CT-80-37, "Operation of Military Aircraft in an ATCRBS Environment."

RESULTS/DISCUSSION

It is evident that a significant number (48) of the transponders tested (108) failed to meet the required standards. The most notable of these is receiver sensitivity, where approximately 13 percent failed. Mode C decode accuracy, delay time difference, and reply power are next, in that order. In general, the impact of the tested parameters being out of spec would be reduced range and marginal target detection, particularly at low altitudes and areas shielded by man-made or natural terrain. Low power, poor sensitivity, and off frequency would result in short range of detection. Poor decode accuracy, bad pulse width, and bad spacing would result in poor or intermittent target detection. These problems were detected in 7 to 13 percent of the aircraft tested. Other parameters, such as "dead time" and suppression time, probably would not cause any significant problem in the Atlanta area since the interrogation density is believed to be relatively low compared to other areas with high density ATCRBS interrogators.

CONCLUSIONS

It is concluded that:

1. A significant percentage of transponders tested failed to meet the required standards. Most notable is receiver sensitivity where approximately 13 percent failed.

2. Poor transponder performance is one factor contributing to the problem of poor tracking and lost targets, particularly in the fringe area of coverge.

RECOMMENDATIONS

It is recommended that:

1. Logs and reports of aircraft tail numbers reported as lost targets or poor tracking be maintained and submitted.

2. Followup action be initiated to check on repeated offenders.

3. Avionics test data along with transponder serial number and aircraft tail number be submitted to the Federal Aviation Administration (FAA) each time the transponder is certified or repaired.

REFERENCES

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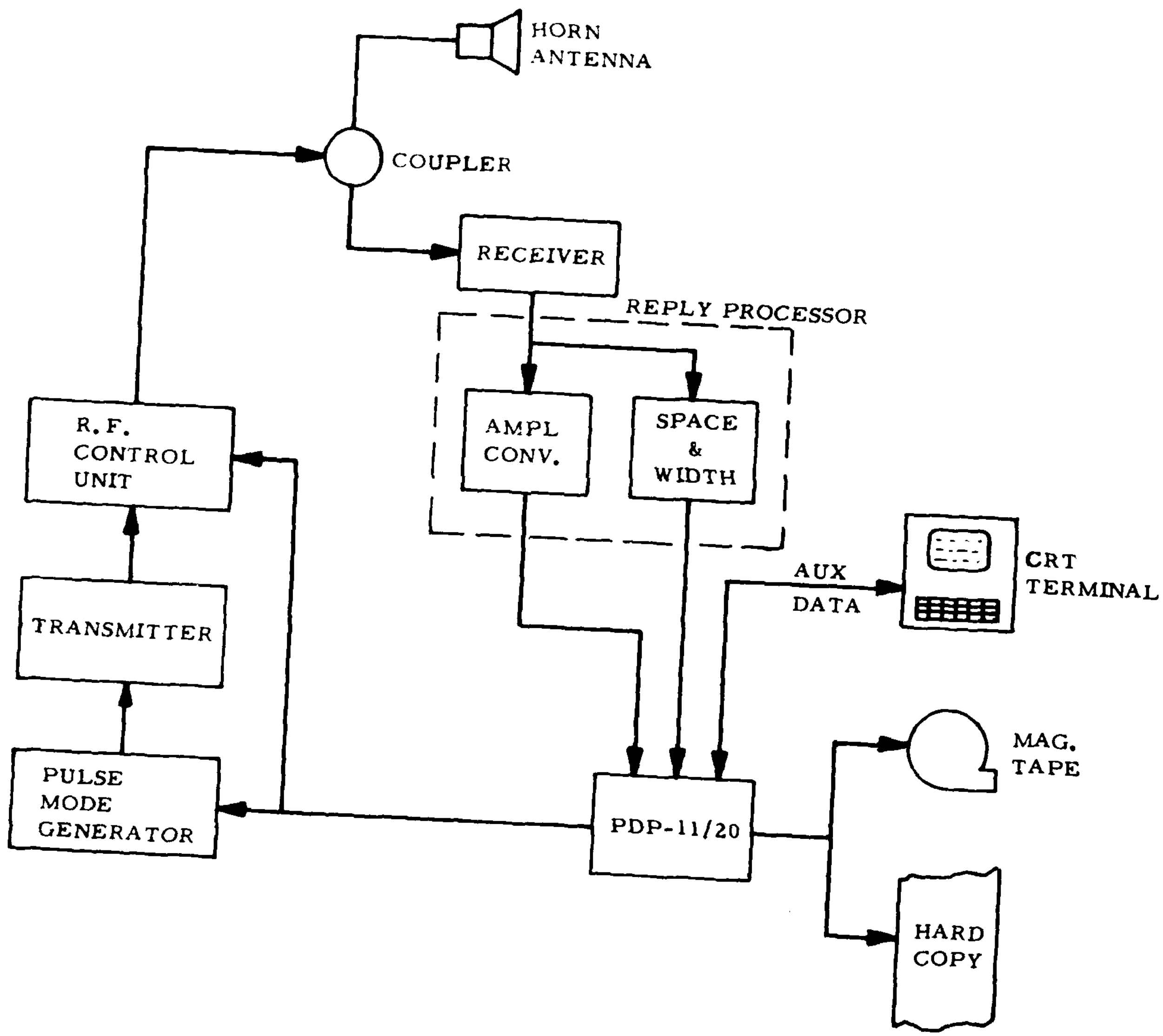

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FIGURE 1. TPA BLOCK DIAGRAM

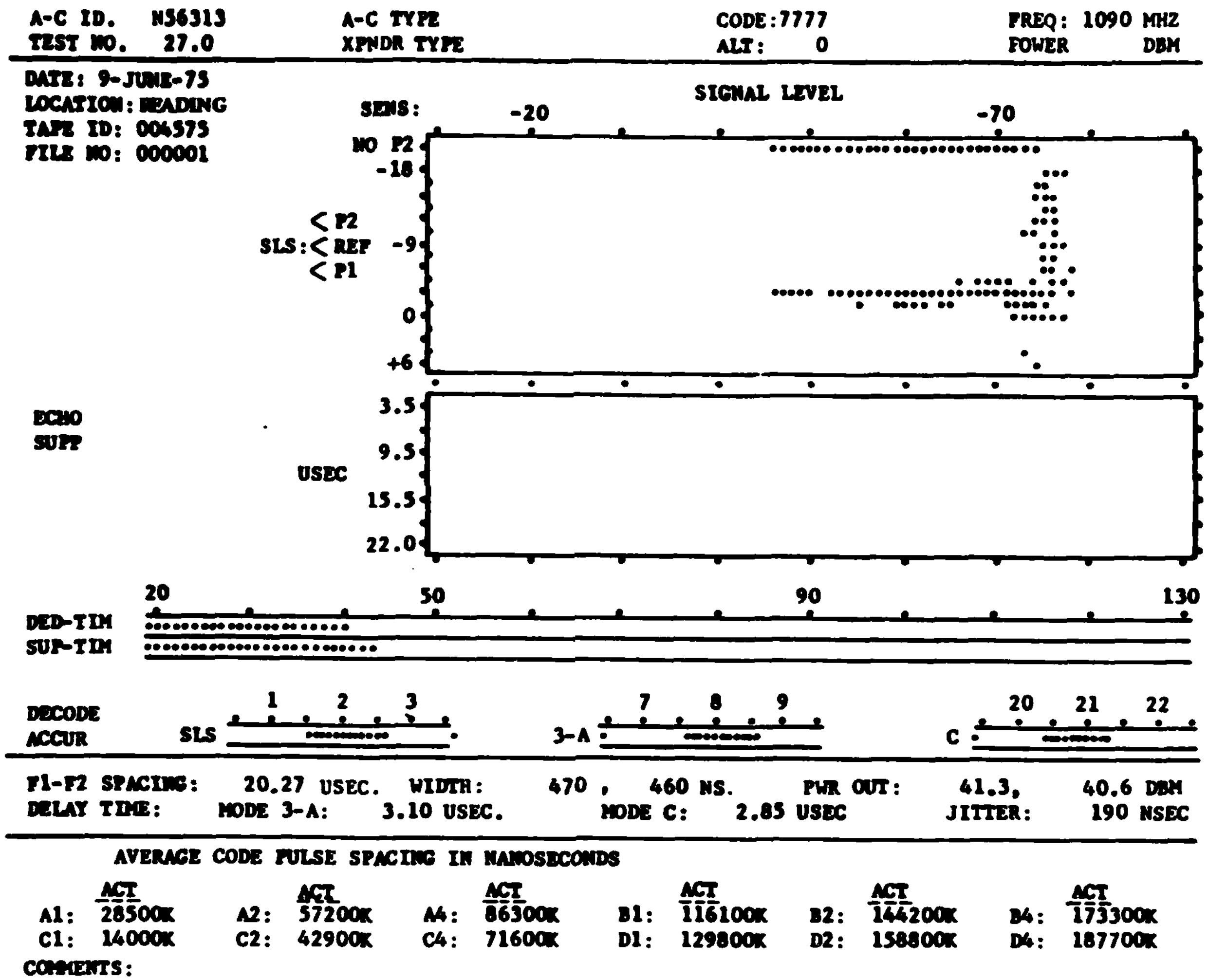

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FIGURE 2. COMPUTER PRINTOUT SAMPLE

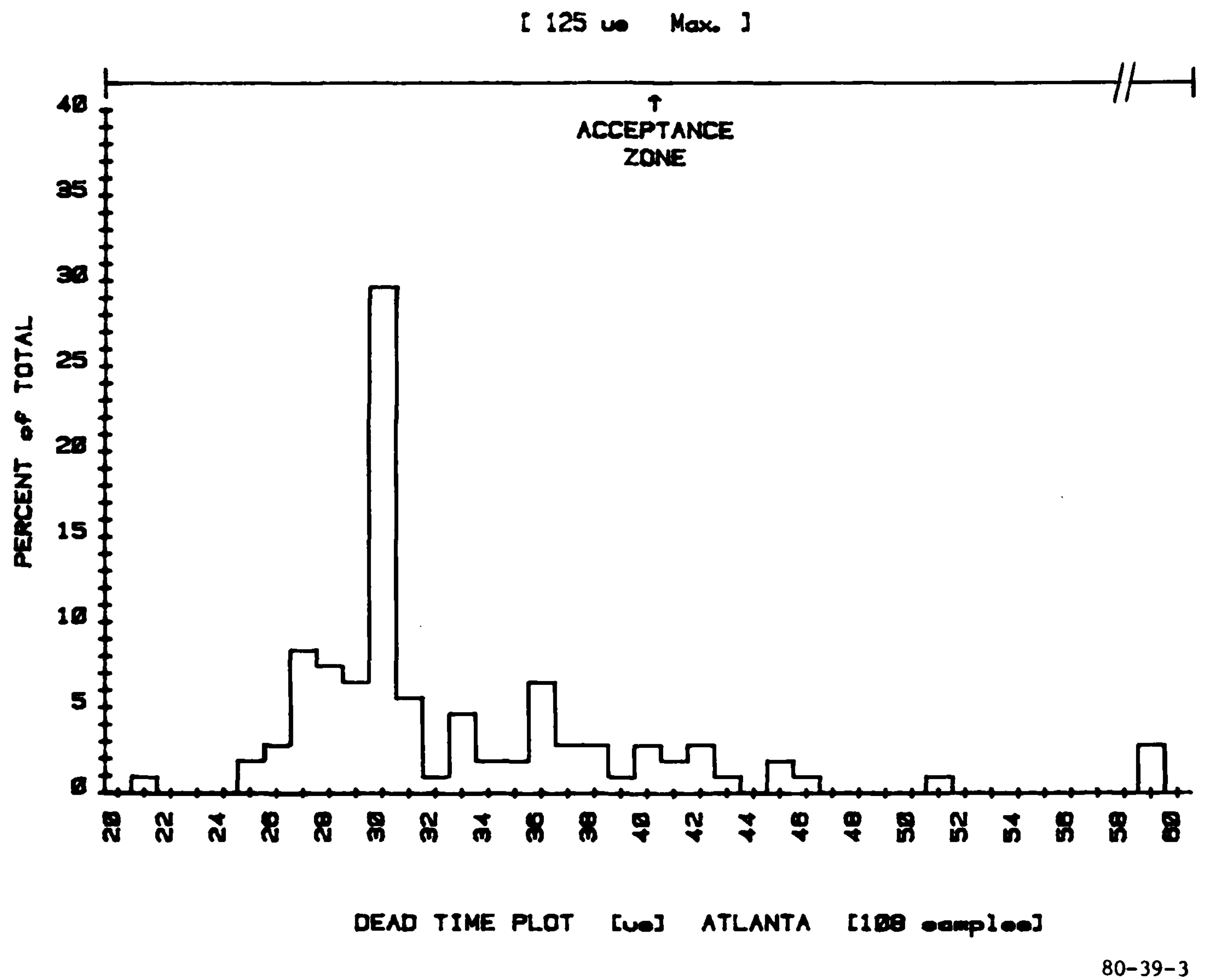

FIGURE 3. BAR GRAPH, DEAD TIME PLOT

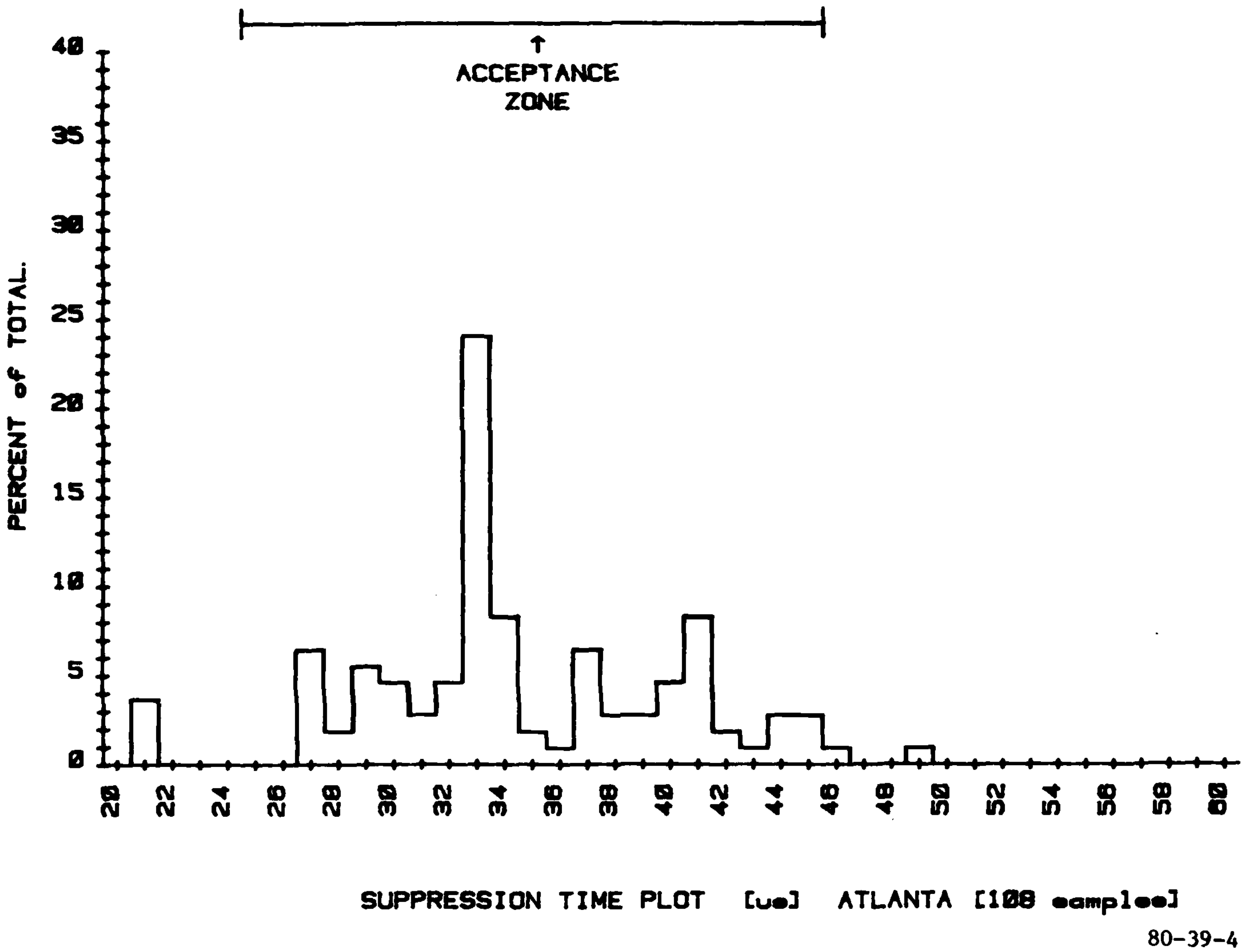

FIGURE 4. BAR GRAPH, SUPPRESSION TIME

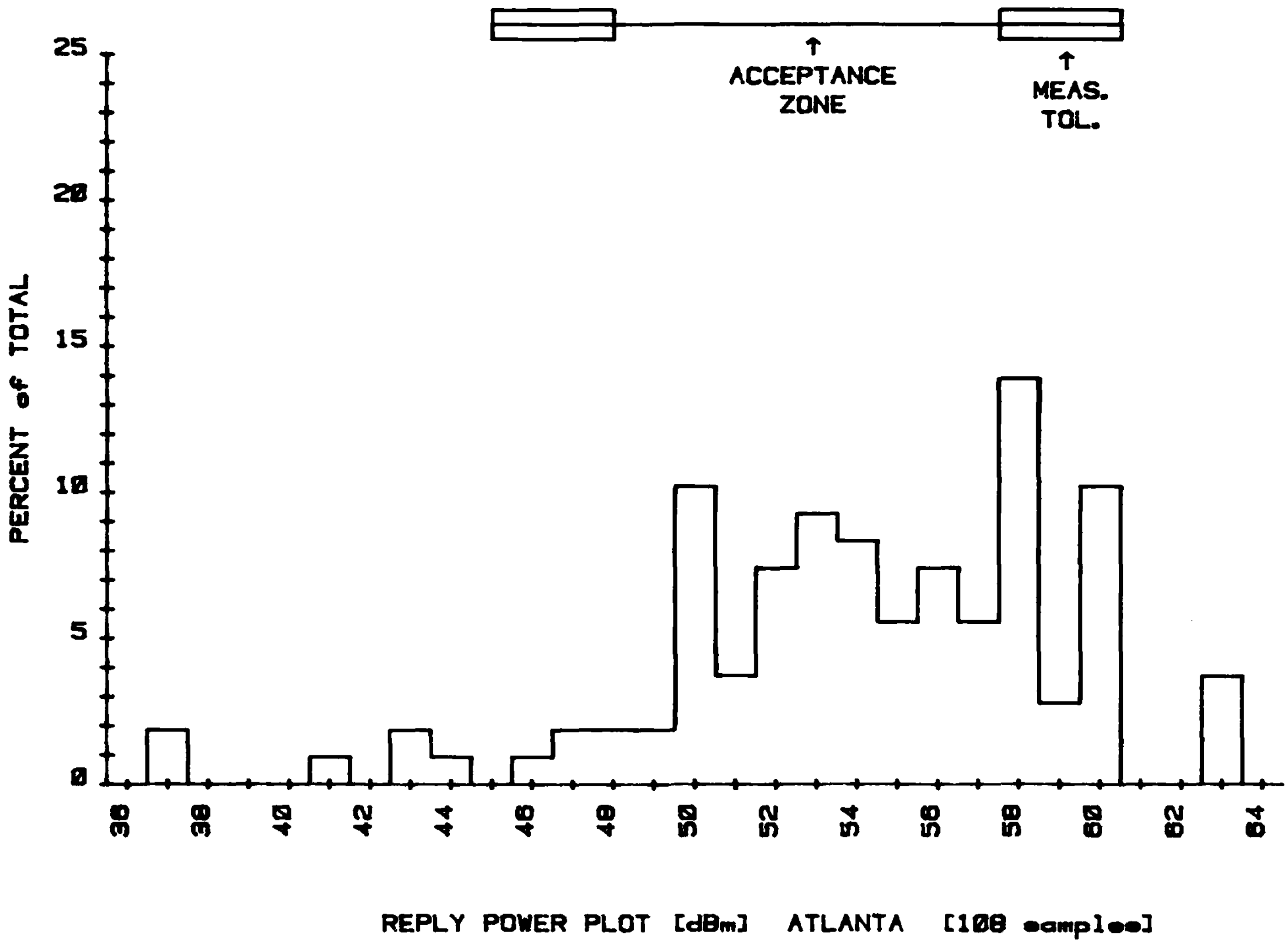

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FIGURE 5. BAR GRAPH, REPLY POWER PLOT

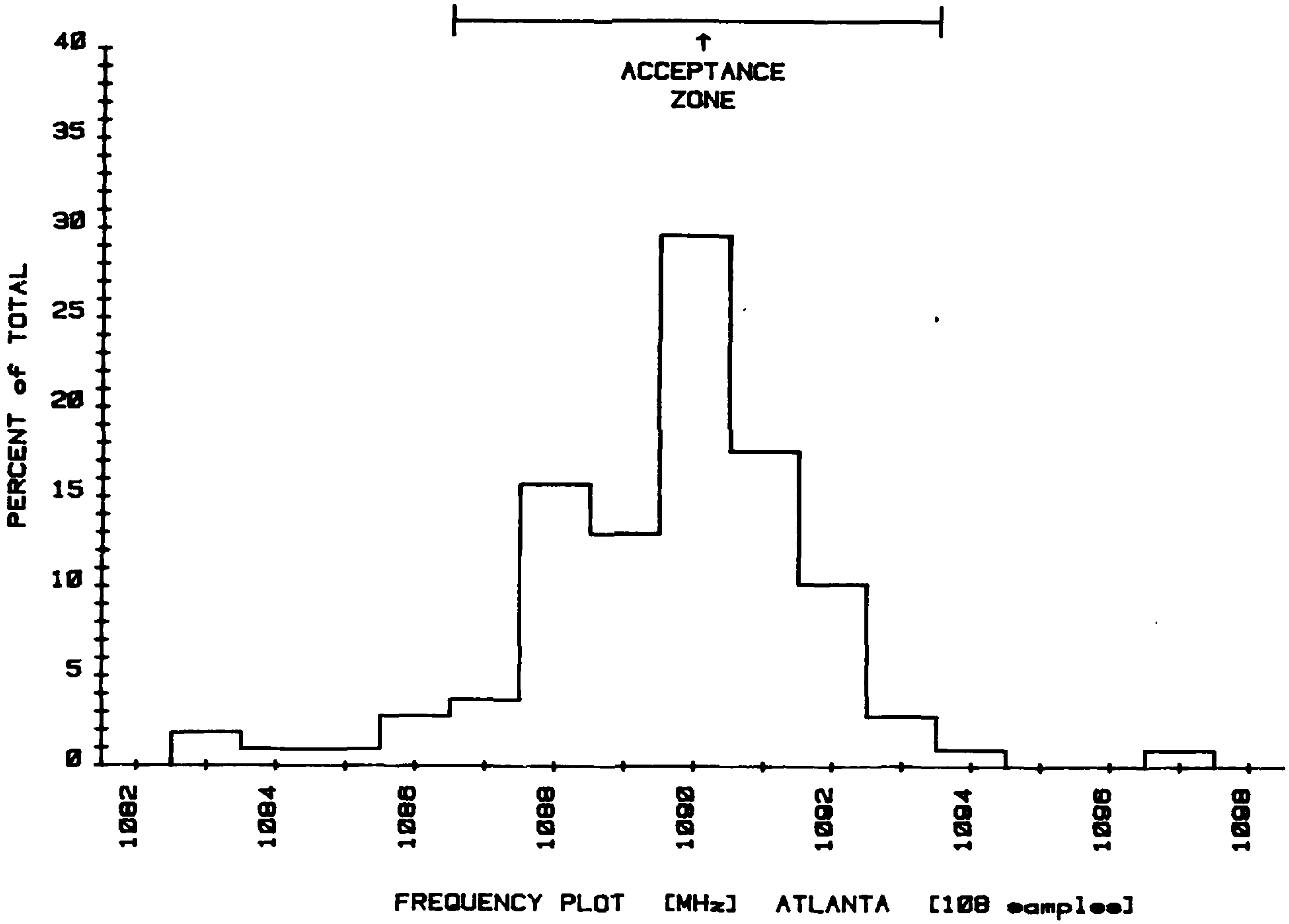

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FIGURE 6. BAR GRAPH, FREQUENCY PLOT

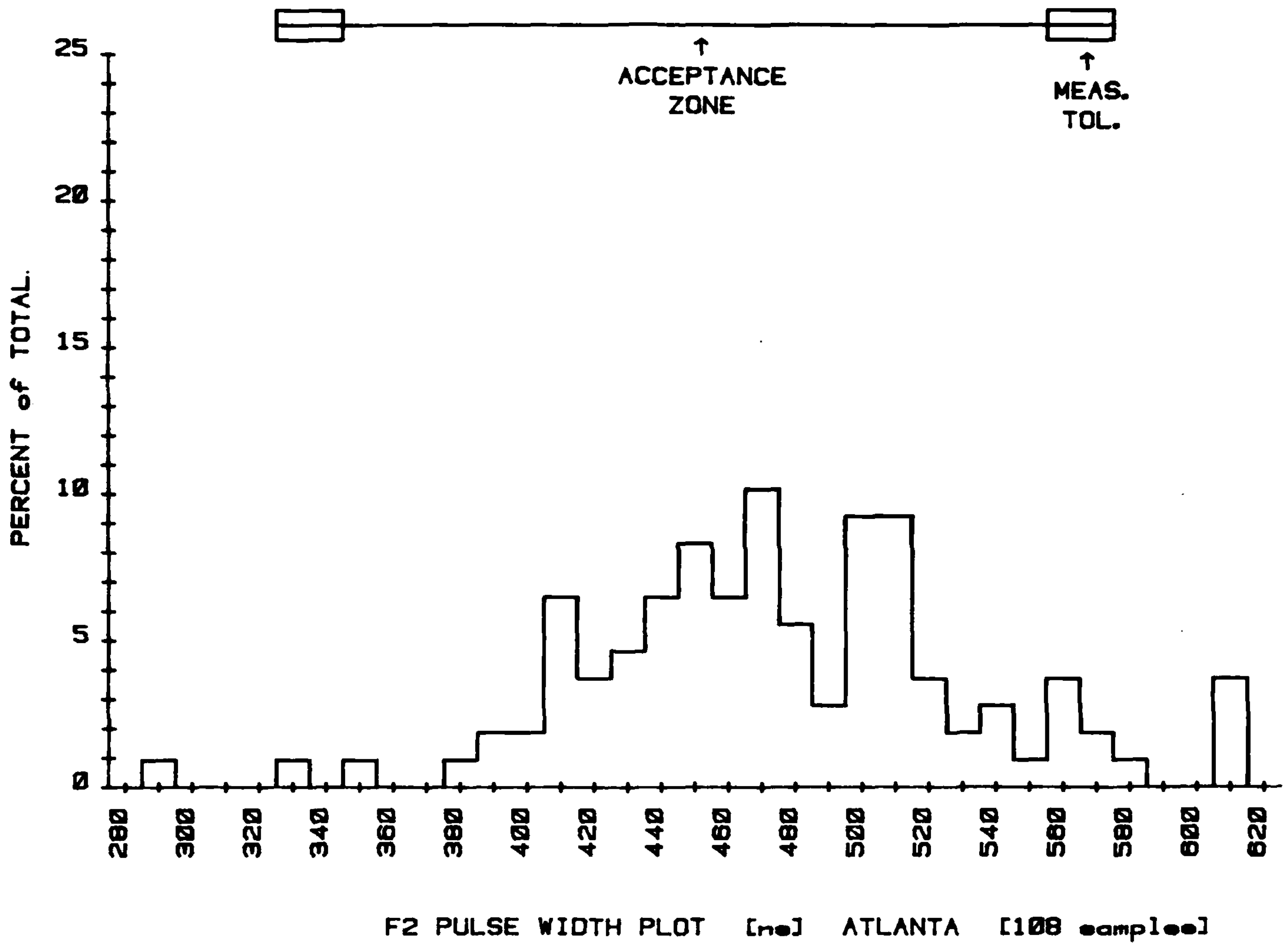

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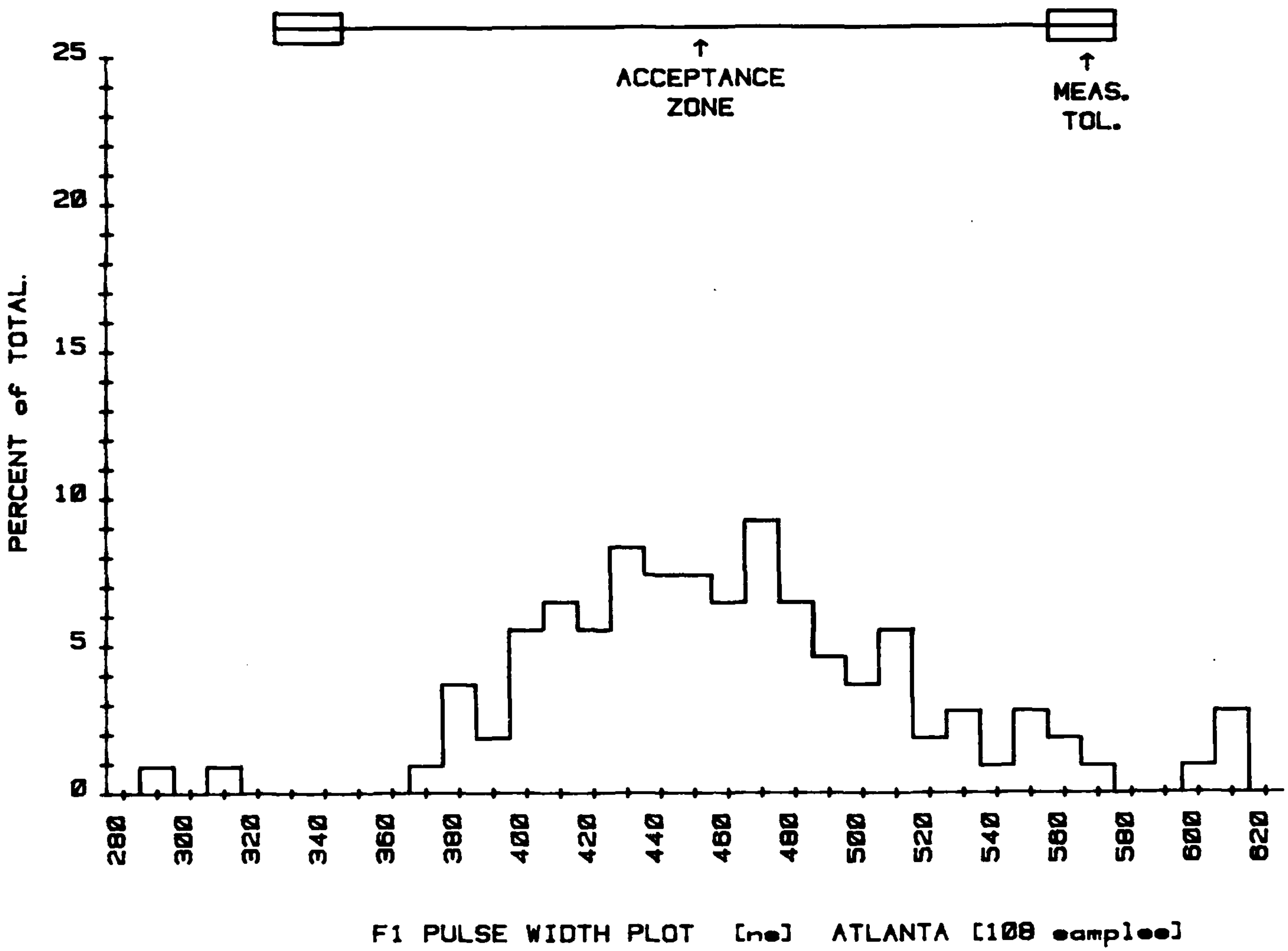
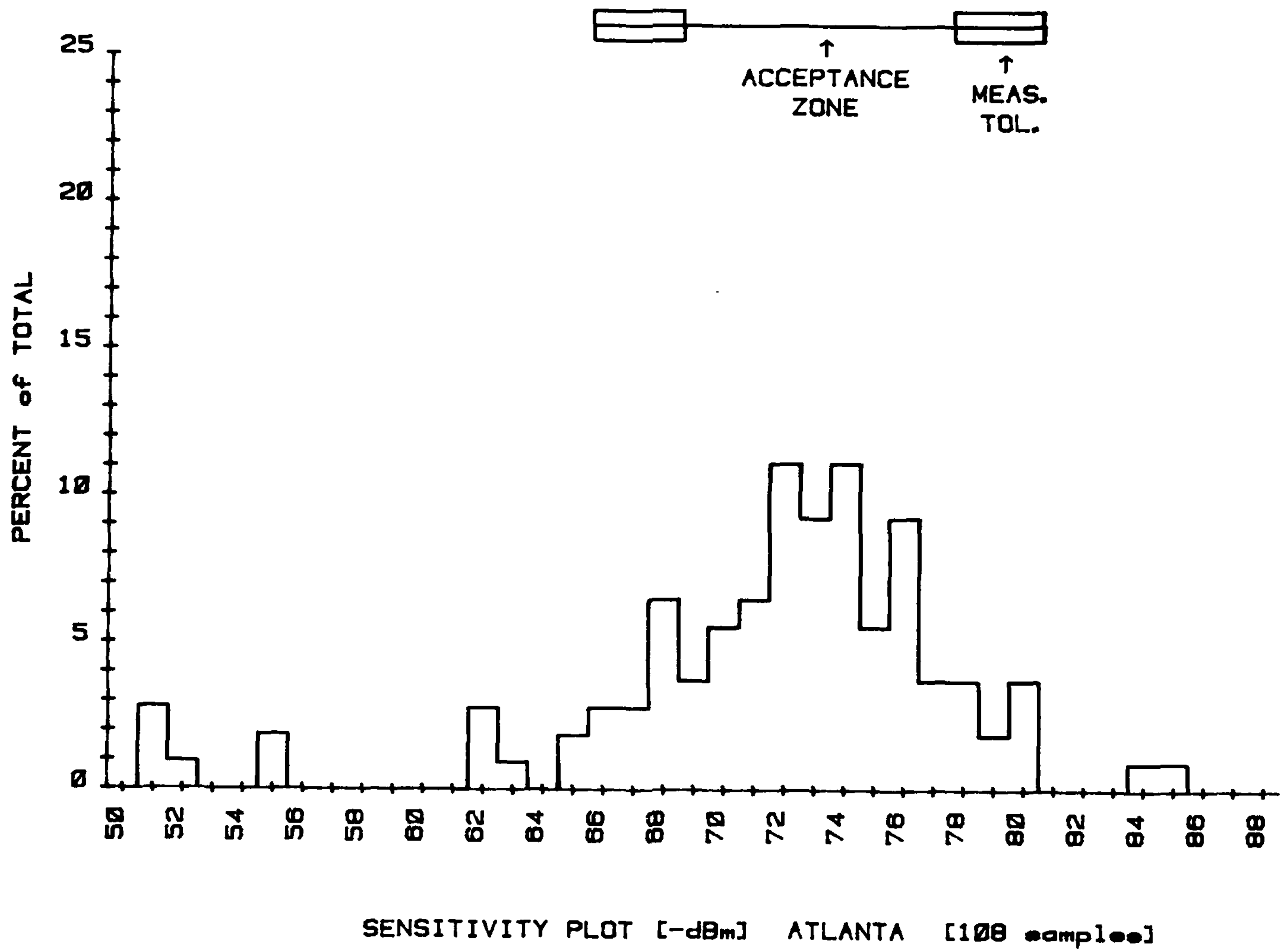
FIGURE 7. BAR GRAPH, F_1 PULSE WIDTH PLOT



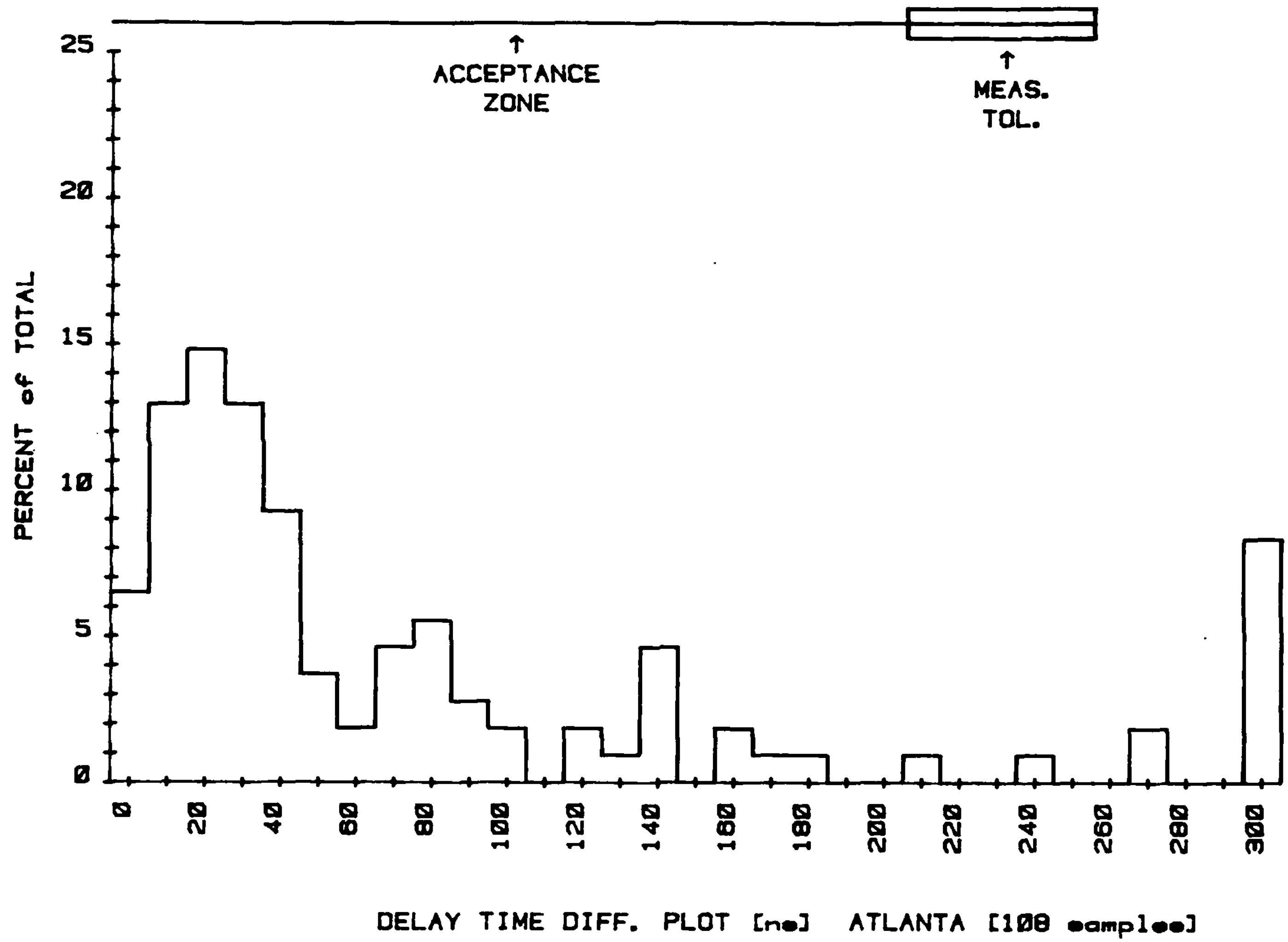
80-39-8

FIGURE 8. BAR GRAPH, F_2 PULSE WIDTH PLOT



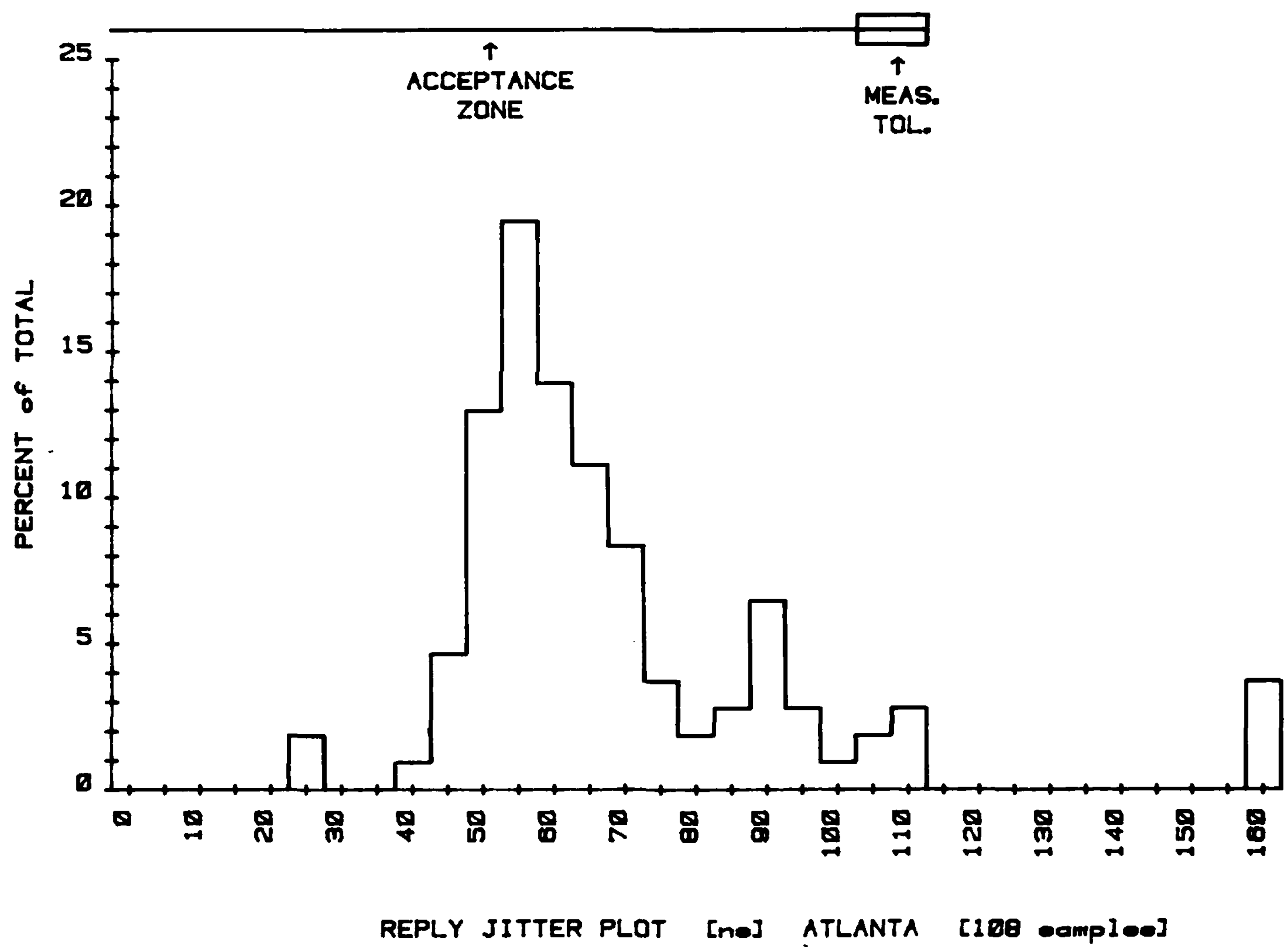
80-39-9

FIGURE 9. BAR GRAPH, SENSITIVITY PLOT



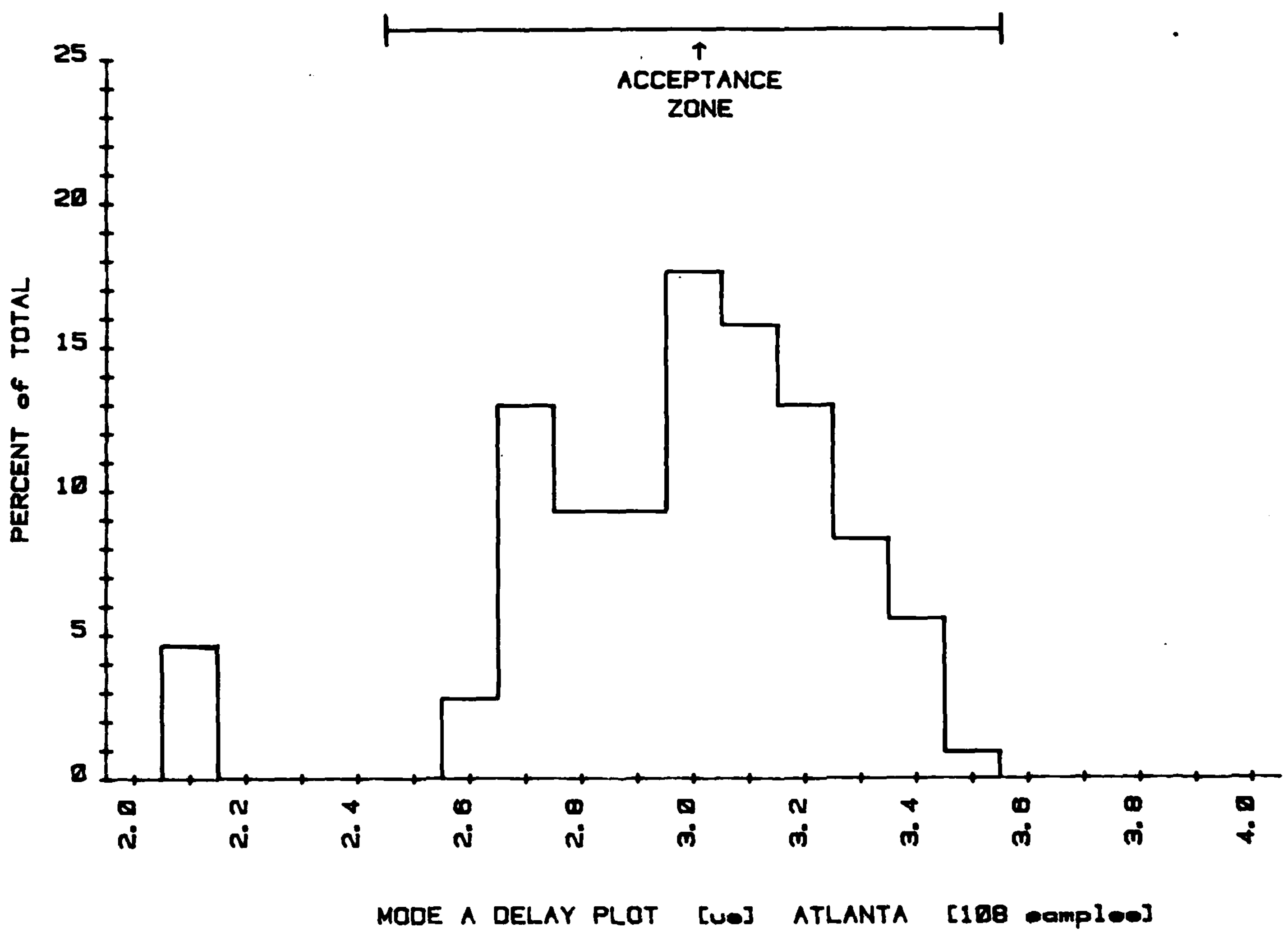
80-39-10

FIGURE 10. BAR GRAPH, DELAY TIME DIFFERENCE PLOT



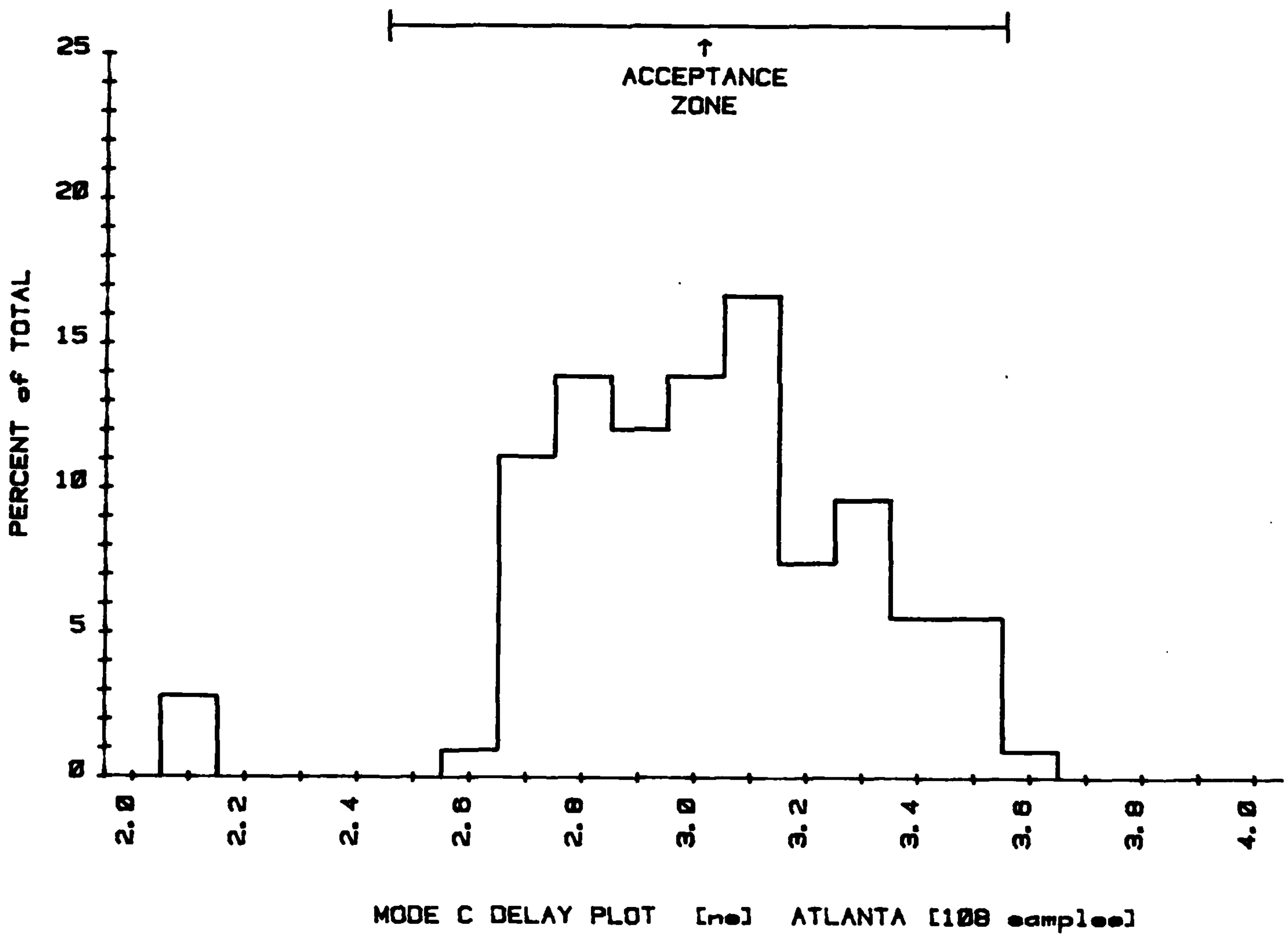
80-39-11

FIGURE 11. BAR GRAPH, REPLY JITTER



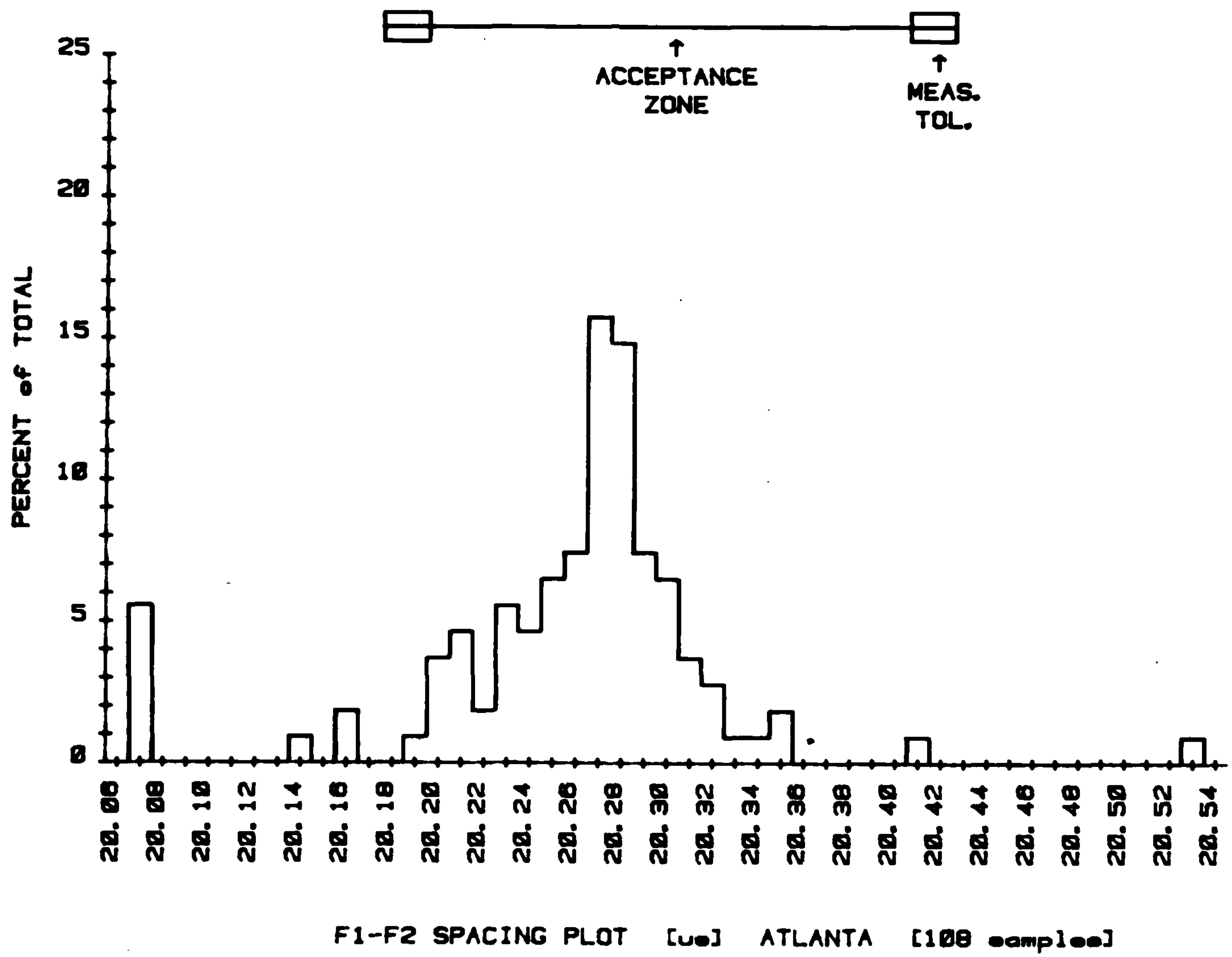
80-39-12

FIGURE 12. BAR GRAPH, MODE A DELAY TIME PLOT



80-39-13

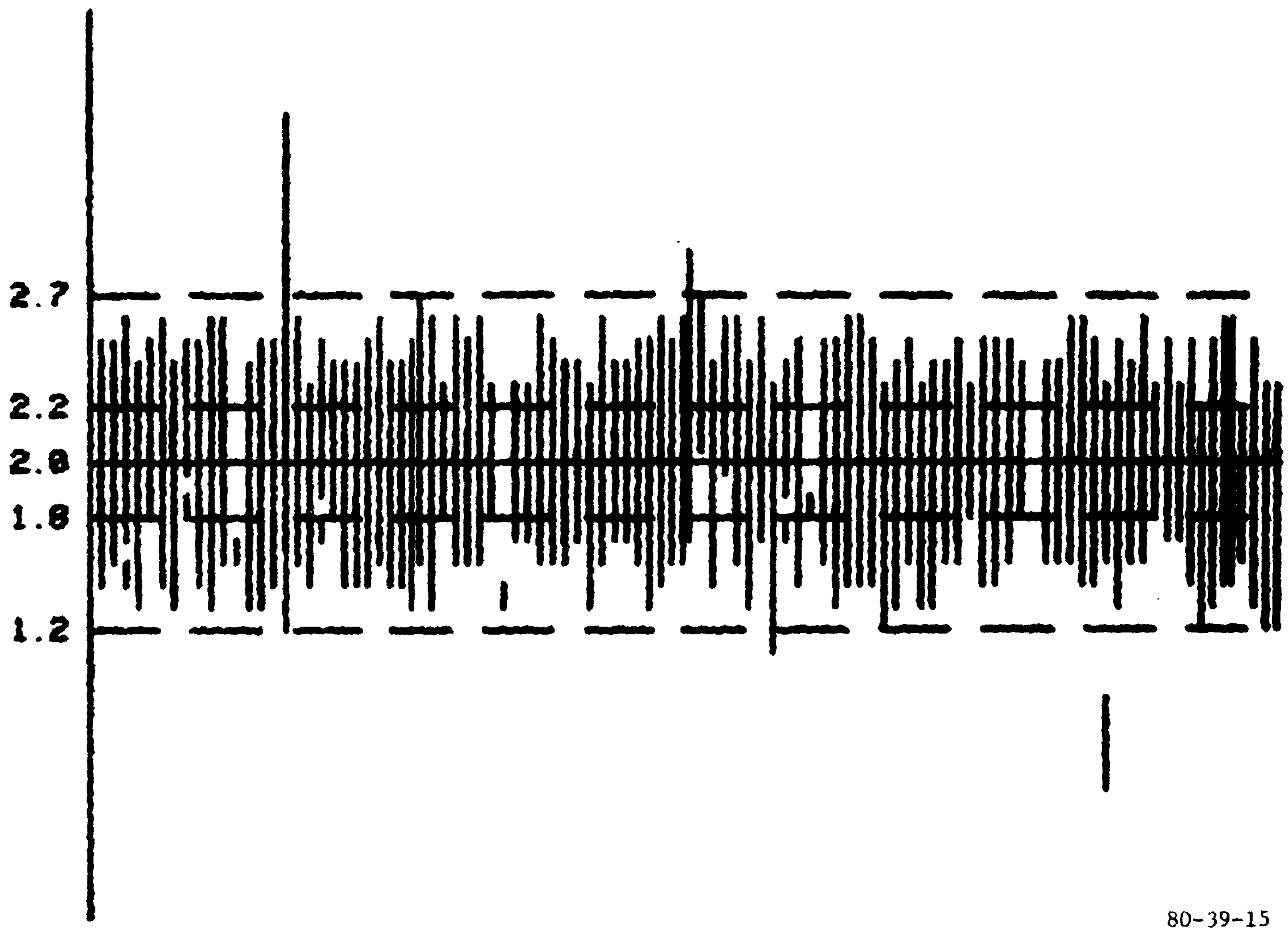
FIGURE 13. BAR GRAPH, MODE C DELAY TIME PLOT



80-39-14

FIGURE 14. BAR GRAPH, F_1 - F_2 SPACING PLOT

SLS DECODE ACCURACY



80-39-15

FIGURE 15. SLS DECODE ACCURACY (Sheet 1 of 2)

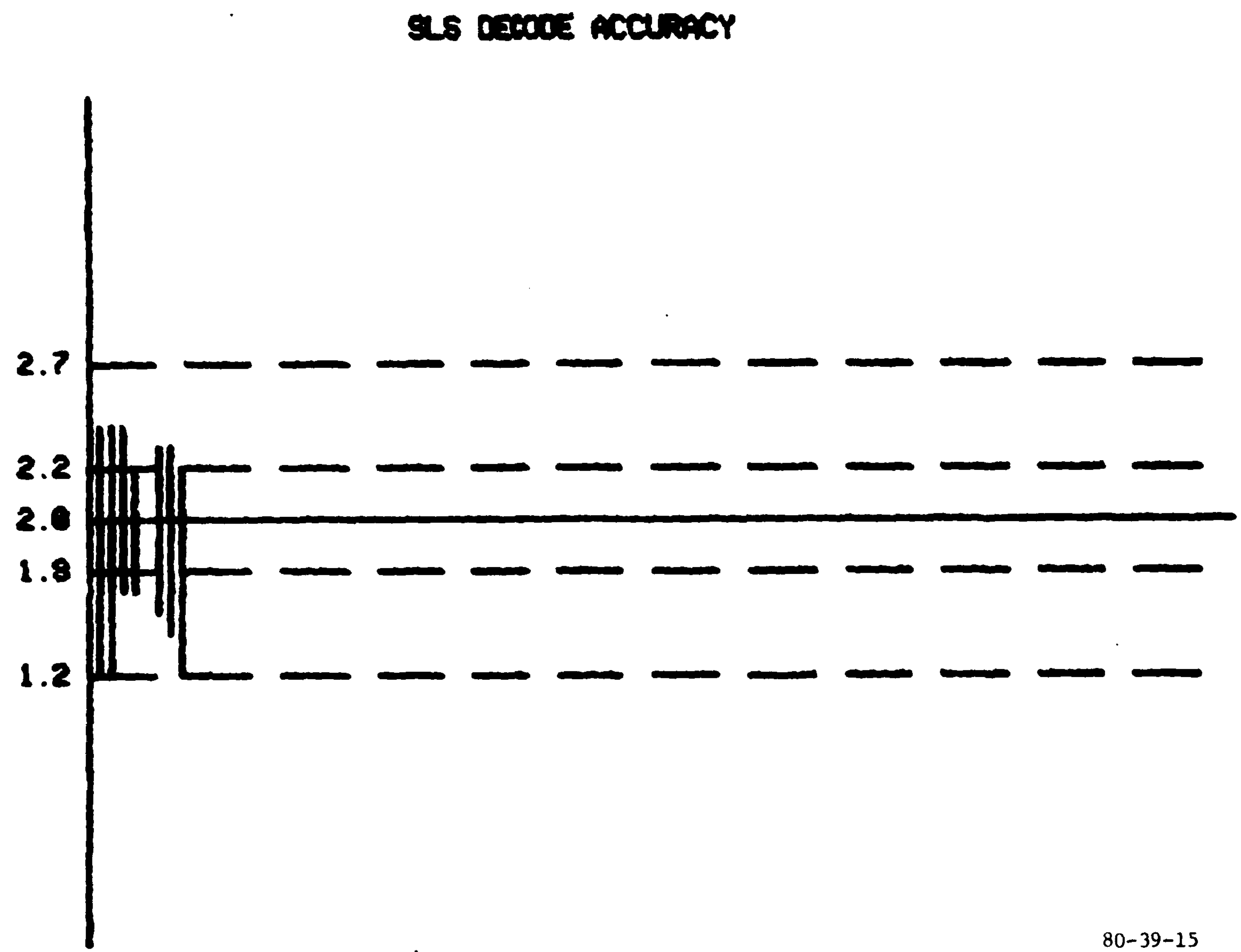
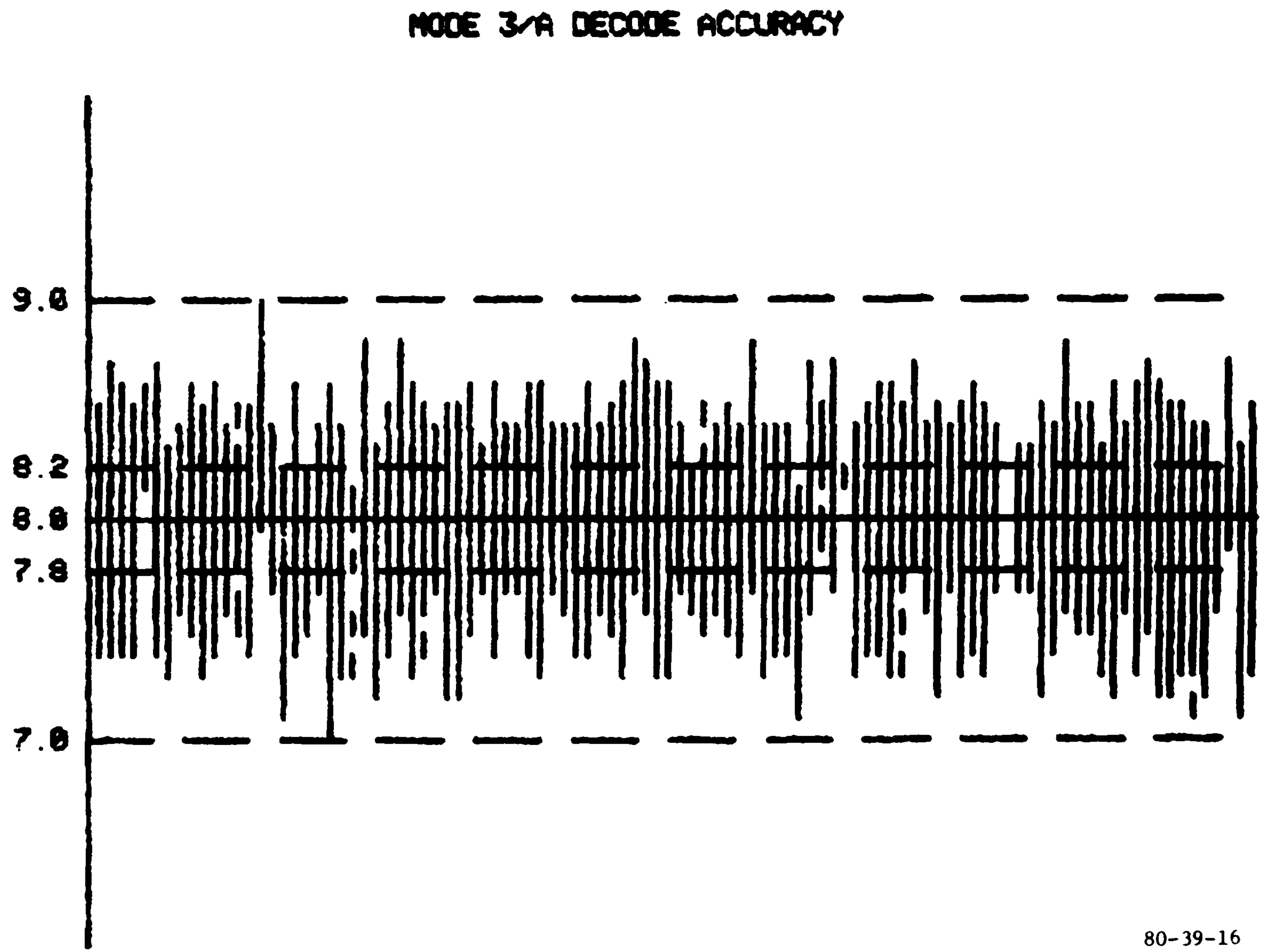


FIGURE 15. SLS DECODE ACCURACY (Sheet 2 of 2)



80-39-16

FIGURE 16. MODE 3/A DECODE ACCURACY (Sheet 1 of 2)

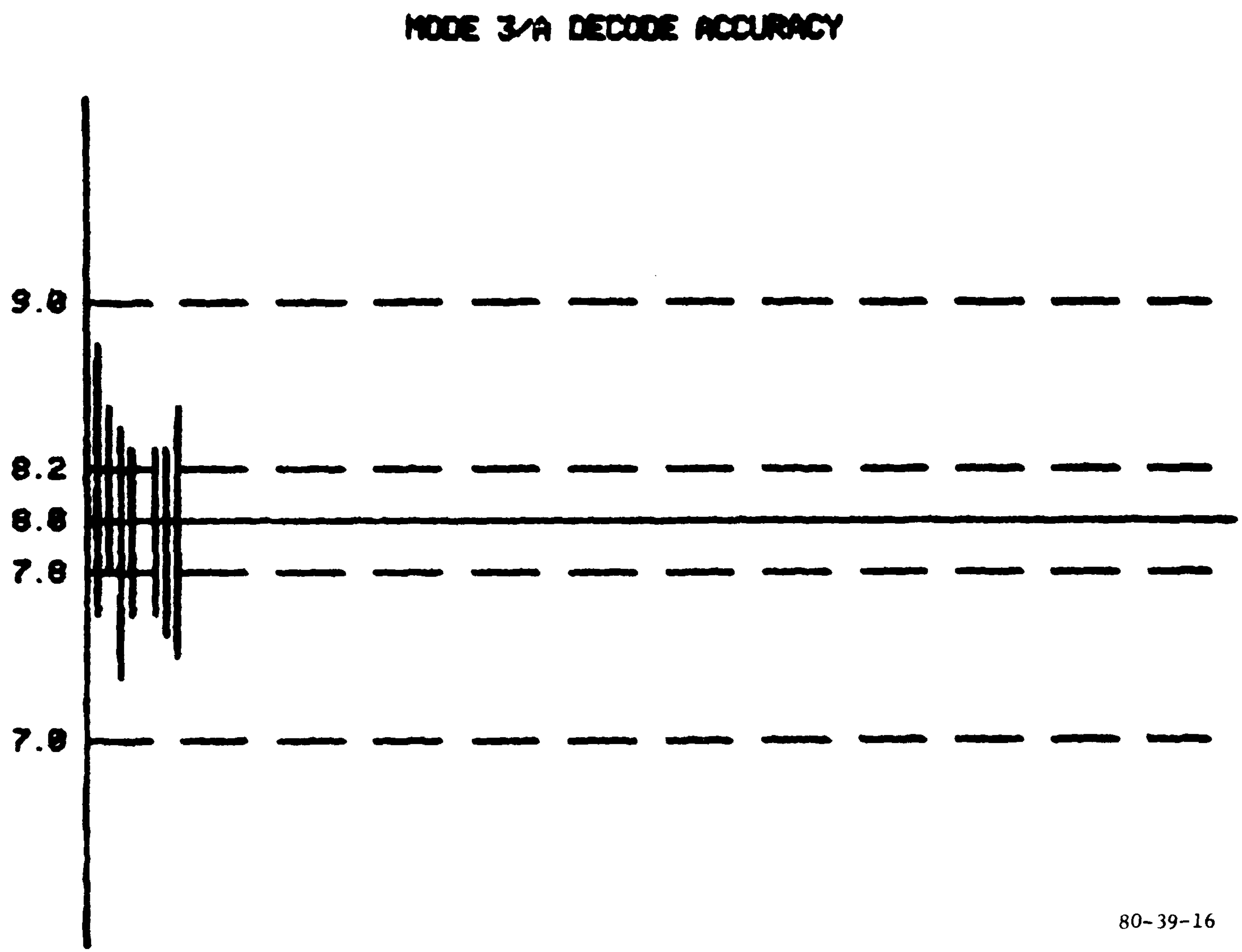
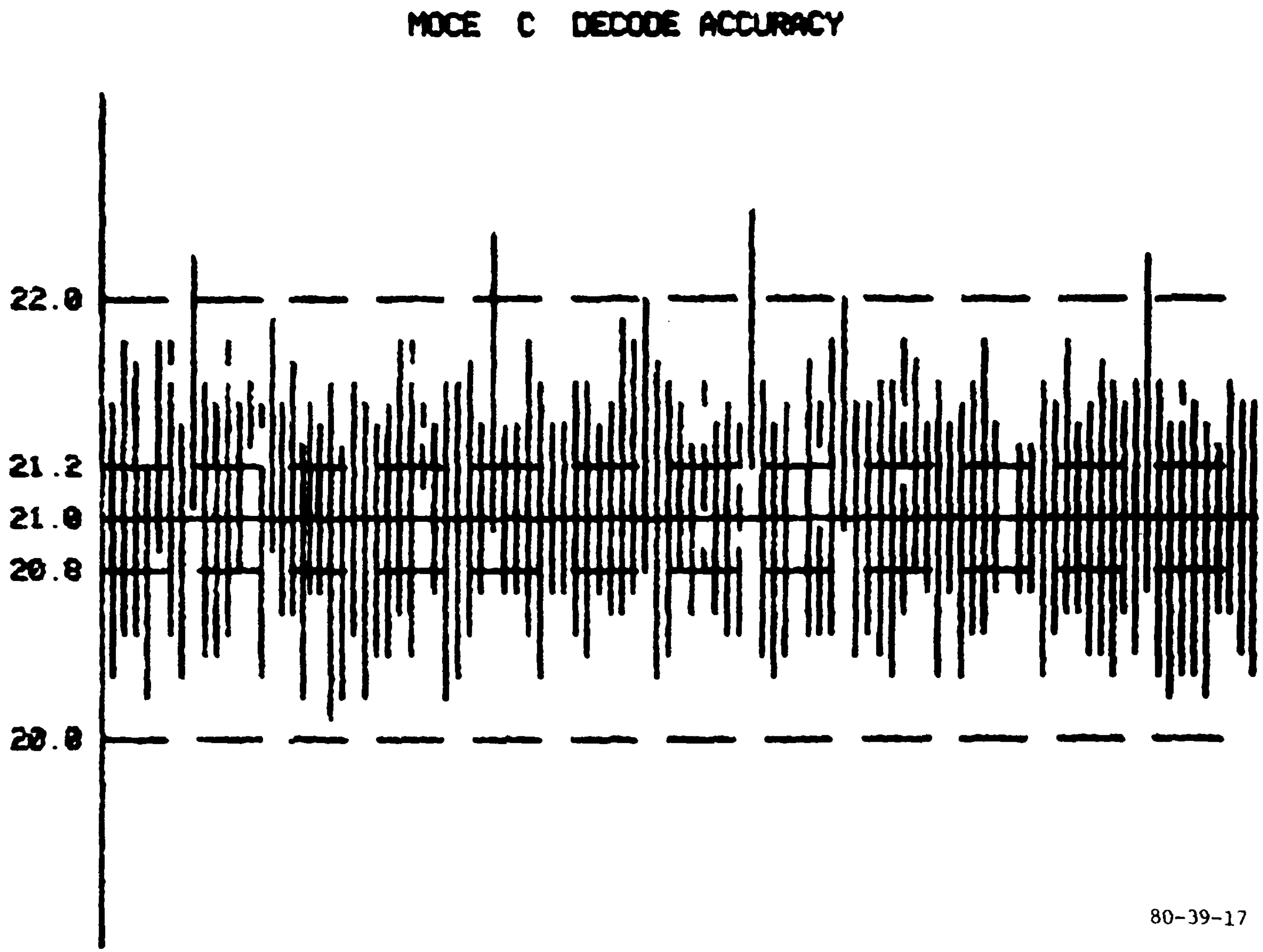
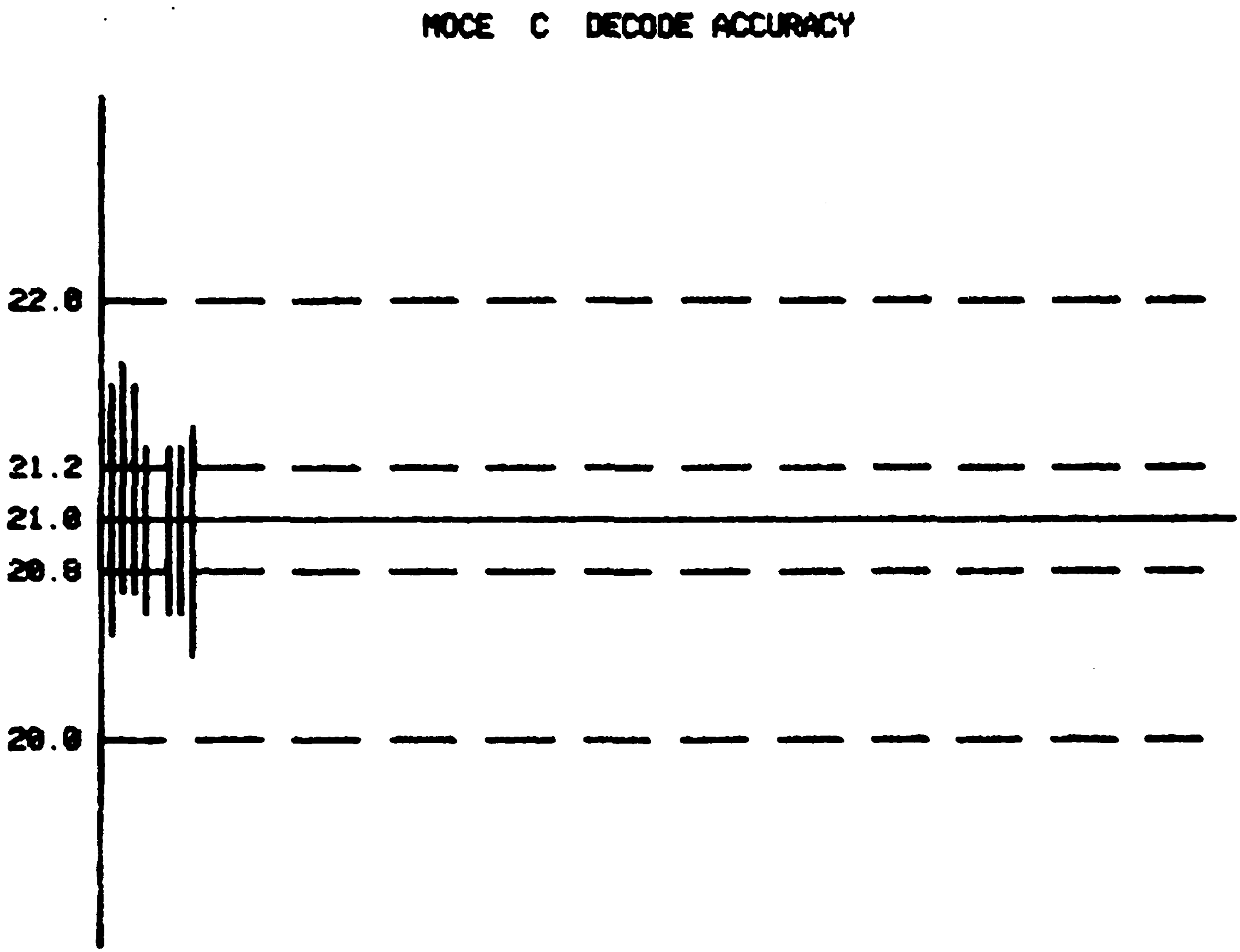


FIGURE 16. MODE 3/A DECODE ACCURACY (Sheet 2 of 2)



80-39-17

FIGURE 17. MODE C DECODE ACCURACY (Sheet 1 of 2)



80-39-17

FIGURE 17. MODE C DECODE ACCURACY (Sheet 2 of 2)