ATCRBS Data from Atlanta, Georgia, Spring 1985

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16. Abstract

The Mobile Transponder Performance Analyzer (MTPA) was used to collect data on general aviation aircraft transponders in the Atlanta, Georgia, area. The data were collected at three different airports (Fulton County, Peachtree/DeKalb, and McCollum) in the Atlanta area. The data were collected at a distance of 250 to 400 feet from the taxiway being used by the aircraft. The pilots were asked to hold their position on the taxiway while the tests were conducted.

Data were collected which describe the interrogation decoding characteristics of the transponders as well as their reply characteristics. A total of 24 parameters were checked during the test which required approximately 1 minute per transponder. Altitude data reported by the transponders were also compared to that received from a calibrated altimeter which is a part of the MTPA.

The most frequently failed parameter was the requirement to reply at 90 percent rate during the side-lobe suppression (SLS) decoding accuracy test when the P2 pulse is outside the prescribed limits for suppression.

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EXECUTIVE SUMMARY

The Mobile Transponder Performance Analyzer (MTPA) was used to collect data on general aviation aircraft transponders in the Atlanta, Georgia, area. The data were collected at three different airports (Fulton County, Peachtree/DeKalb, and McCollum) in the Atlanta area. The data were collected on 154 transponders at a distance of 250 to 400 feet from the taxiway being used by the aircraft. The pilots were asked to hold their position on the taxiway while the tests were conducted.

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The most frequently failed parameter was the requirement to reply at 90 percent rate during the side-lobe suppression (SLS) decoding accuracy test when the P2 pulse is outside the prescribed limits for suppression. Only 41 percent of the transponders tested passed this test compared to 65 percent when these data were collected on general aviation transponders at Philadelphia in 1983.

Seven transponders out of the 154 tested passed all 24 parameters tested. Five additional transponders passed all parameters, but replied with "brackets only" to the Mode C interrogations and were failed by MTPA for that parameter. Thus, approximately 7 percent of the transponders passed all tests for which they were equipped. An additional 38 failed to reply at a 90 percent rate during the SLS decoding accuracy test and/or were "brackets only" as their only problem. Another 43 failed one other parameter (in addition to the previous ones), 24 failed two others, and 49 failed three or more additional parameters.

INTRODUCTION

OBJECTIVE.

The objective of this project was to collect data describing the performance of transponders of general aviation aircraft based in the Atlanta, Georgia, area. Of special interest were the side-lobe suppression (SLS) characteristics and the accuracy of the transponder reported altitude data.

BACKGROUND.

The Federal Aviation Administration (FAA) Technical Center was requested to provide support to the Headquarters FAA Air Traffic Control Radar Beacon System (ATCRBS) Analysis Team in the investigation of transponder related problems in the Atlanta, Georgia, area. The problems reported by the operational air traffic controller personnel were target dropout, excessive coasting, and erroneous altitude data.

The implementation and operation of the Traffic Collision Alert System (TCAS) is dependent on the accuracy, reliability, and integrity of the transponder reported altitude data from TCAS intruder aircraft. The air traffic control (ATC) ground-based system normally interrogates the aircraft for their 4096 code identity and Mode C altitude for use in the ATC system. The TCAS interrogates the transponders for Mode C altitude for use in the airborne TCAS logic to develop commands for evasive maneuvers. Importance of accurate, reliable altitude information cannot be overemphasized for the safe operation of the TCAS.

The Mobile Transponder Performance Analyzer (MTPA) was used to collect large volumes of data in a relatively short period of time in an operational environment.

The MTPA is a system designed and fabricated at the FAA Technical Center to analyze performance characteristics of all known types of aircraft surveillance transponders. The system is mounted in a bus which has its own engine generator for system power requirements. The system is fully software controlled. It includes a PDP-11/34 computer with peripherals, two low power programmable transmitters, and receiving and decoding hardware so that the format and protocol changes necessary can be implemented without hardware modifications. Digitally controlled phase shift keying (DPSK) modulators, pin diode modulators, and variable attenuators are used for control of the radio frequency (RF) interrogations. The maximum RF power for interrogation is approximately one watt. A parabolic dish antenna with approximately a 10-degree beamwidth is mounted to the side of the bus for ramp testing. The system will operate at any distance of up to 200 meters from the aircraft being tested.

The transponder parameters are comprised of two basic categories. One set contains the transponders waveform and signal characteristics such

as power, sensitivity, pulse amplitude, pulse width, pulse frequency, spacing, etc. The second set is message content and response to certain stimuli. These functions are primarily for Mode S transponders, but the suppression tests and the Mode C altitude data fall into this category for all transponders.

The MTPA software resides in both computer random access memory (RAM) and on disk. Required routines are overlayed in memory as necessary. Software control is broken down into sets and sequences of tests to provide maximum flexibility for operator control, interaction, and test time. On-line recording of data is done on disk; a real-time summary of test results is provided. A hard copy of this summary is provided if requested.

When not performing tests, the MTPA runs in an "idle" loop in which it continuously interrogates at a low pulse repetition frequency (PRF). When a candidate for testing arrives and is solidly responding to the idle loop interrogations (monitored by an A scope presentation), the tests can begin. Tests are nominally conducted at an interrogation signal of -47 decibels above 1 milliwatt (dBm) (at the approximate aircraft antenna position). If interference exists from other aircraft the interrogation signal power can be reduced from the keyboard in 1 decibel (dB) steps until the interference disappears prior to starting the test.

RELATED PROJECTS/DOCUMENTATION.

1. "ATCRBS Transponder Data from Dayton, Ohio Airshow - 1983," DOT/FAA/CT-TN83/53.
2. "Mobile Transponder Performance Analyzer Volume 1, System Description," DOT/FAA/CT-TN83/05.
3. "ATCRBS Transponder Data from Initial Field test of MTPA," DOT/FAA/CT-TN83/04.
4. "Summary of Transponder Data for Atlanta, Georgia, Area," FAA-CT-80-39.
5. "Summary of Transponder Data June 1977 through August 1978," FAA-RD-79-56.
6. "U.S. National Standard for the IFF Mark X (SIF)/Air Traffic Control Radar Beacon System Characteristics," FAA Order 1010.51A.

MTPA FIELD CALIBRATION.

The MTPA has previously been calibrated for the bench mode of operation. The only difference in ramp operation are the path losses (transmit and receive) and the time difference for the RF signal to travel to and from the transponder.

This translation is easily accomplished by a two-step process. A transponder is first connected to the calibrated laboratory cable and tested so that its power, sensitivity, and delay characteristics are known. This "calibrated" transponder is then placed in a vehicle with

an antenna mounted on its roof and driven down the taxiway to be used during the tests. Continuous power, sensitivity, and delay measurements are made on the transponder during this trip. As delay characteristics of most transponders vary with received signal strength, the interrogation signal is varied across the antenna pattern in order to maintain a -50 dBm signal at the vehicle antenna. (This is only possible since the transponder output characteristics are known; i.e., if the reply power is 60 dB down from that achieved on the calibrated cable, the path loss would be known and power of the next interrogation would be adjusted so that approximately -50 dBm would be seen at the transponder on the next interrogation.)

The MTPA antenna pattern also has a vertical component which must be considered. The RF coupling is significantly better at 5 feet (the approximate height of the roof of the car) than it is at 1 foot. The system contains a lookup table with offset values as a function of antenna height and distance. Prior to the test, the operator enters the approximate antenna height of the aircraft under test (i.e., 3 feet); the transmit power is automatically increased by the offset value so that a level of -47 dBm is achieved at the aircraft's antenna. (The measured sensitivity will also be offset by this value.) A power level of -47 dBm was used so that the majority of the tests would be conducted at a level of approximately -50 dBm. (The aircraft was normally stopped at a position where the power was down approximately 3 dBm from that at the nose of the beam.)

Measurement accuracy of power and sensitivity is normally about plus or minus 3 dB using the above techniques. At times, however, reflections and landing gear sheilding make this figure difficult to achieve.

DATA COLLECTION

Data were collected at three airports in the Atlanta, Georgia, area (Fulton County, Peachtree/DeKalb, and McCollum). The same test scenario was used at each of the airports.

As communications were available with the pilots of the aircraft under test, the planes were stopped during the conduction of the tests. The planes were taxied into position on a taxiway (approximately 400 feet away from the bus) so they were in a position approximately 3 to 6 dB down from the nose of the MTPA interrogation pattern. They were instructed to have their transponder and altimeter on as they taxied into position. The test scenario was then run while the pilot held this position. He was then instructed to taxi past a cone which designated the opposite edge of the interrogation beam. Continuous power, sensitivity (Modes A and C), and delay measurements were made as he taxied past. The maximum power and sensitivity values achieved and the minimum delay value achieved were saved as the true parameters for the transponder.

Each of the three sites presented its own data collection problem. Figure 1 shows the site plan of the Fulton County Airport with the MTPA bus position. Reflections from the Administration Building across the taxiway area were a minor problem, but this site was preferable to one further to the left where the taxiway dropped off to a level 3 to 4 feet below the bus. The taxiway used for data collection was approximately 250 feet from the MTPA bus.

Figure 2 shows the site plan of the Peachtree/DeKalb Airport with the selected site for data collection. The taxiway distance was about 400 feet from the bus. The problem here was interference from planes taking off and landing on the runway directly in our interrogation beam. Power reduction of interrogation signals was an effective means of minimizing the problem.

Figure 3 is the site plan of the McCollum Airport showing the site of the MTPA bus during data collection. Planes parked around the periphery of the taxiways caused reflection problems when parked parallel to the taxiway. The problem was solved by turning the bus so that the antenna pattern was centered at the intersection of the two taxiways shown. This caused a slight error in the delay data (only a few nanoseconds) if the tests were allowed to continue past the intersection.

TEST SCENARIO.

The test scenario selected for use required approximately 1 minute for completion. Since SLS amplitude and altitude data characteristics were of special interest, two separate tests for each parameter were included. Table 1 lists the tests in the order they were conducted.

The system was calibrated each morning prior to start of data collection. A run was also made each morning to verify the antenna pattern prior to the start of data collection. A set of data on our "standard" transponder was also collected at the start and finish of data collection each day in order to verify the stability of the system. A sample calibration run and antenna pattern run from Peachtree/DeKalb Airport is included in appendix A. Also included is the first run from the calibrated transponder after the calibration process.

3-18-85 ATLANTA - CHARLIE BROWN (FULTON COUNTY AIRPORT

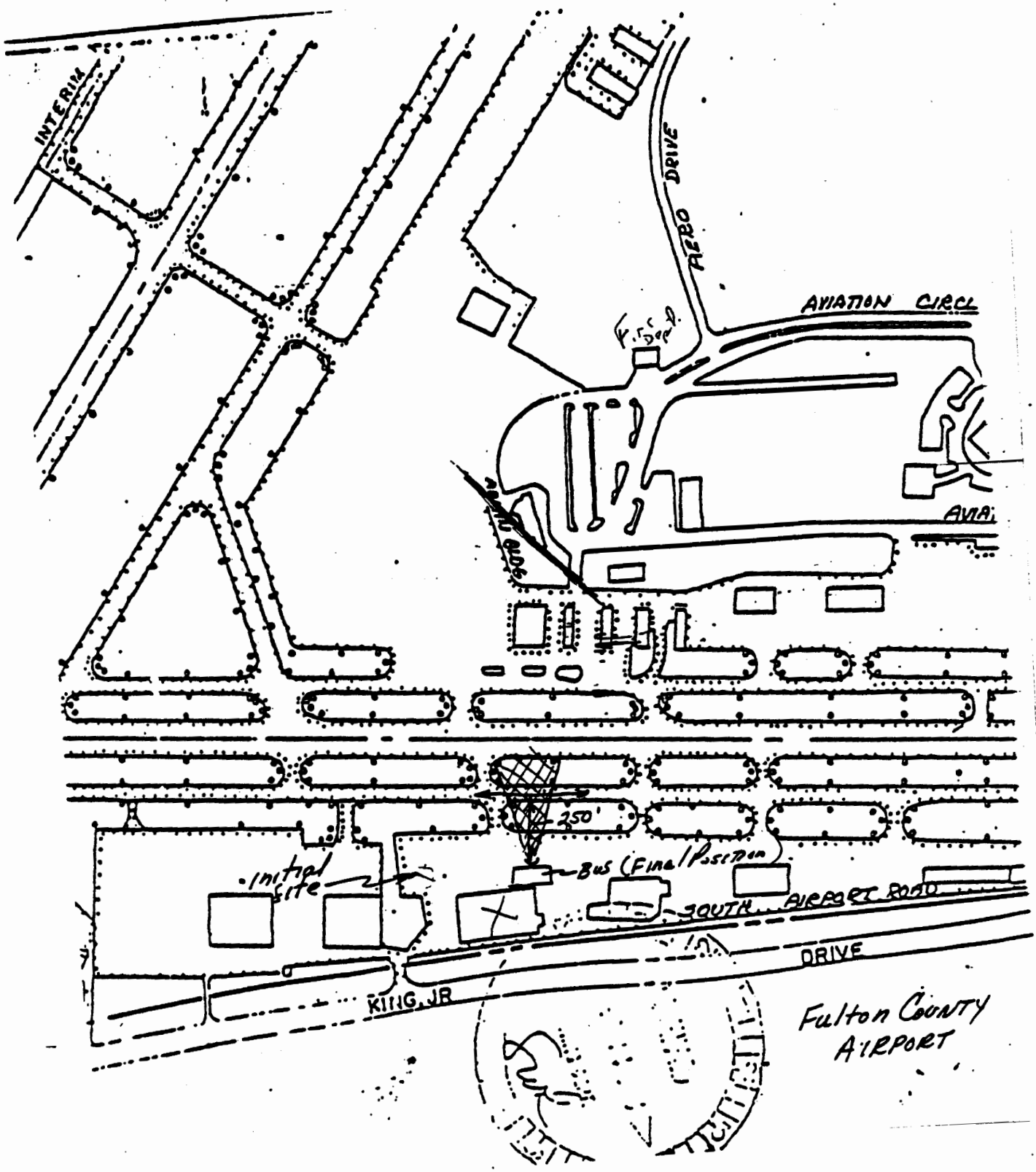


FIGURE 1. DATA COLLECTION SITE PLAN - FULTON COUNTY AIRPORT

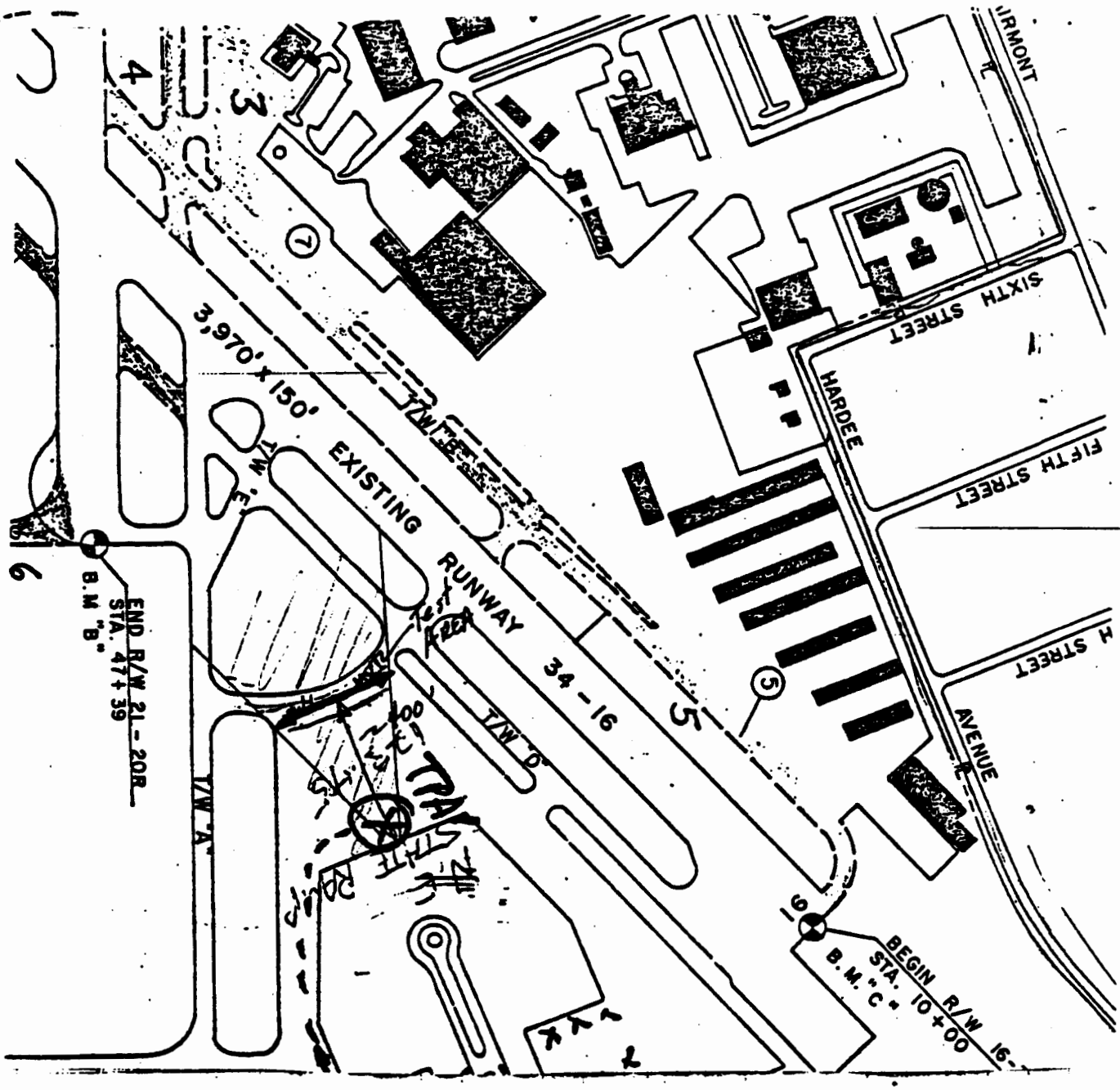


FIGURE 2. DATA COLLECTION SITE PLAN - PEACHTREE/DEKALB AIRPORT

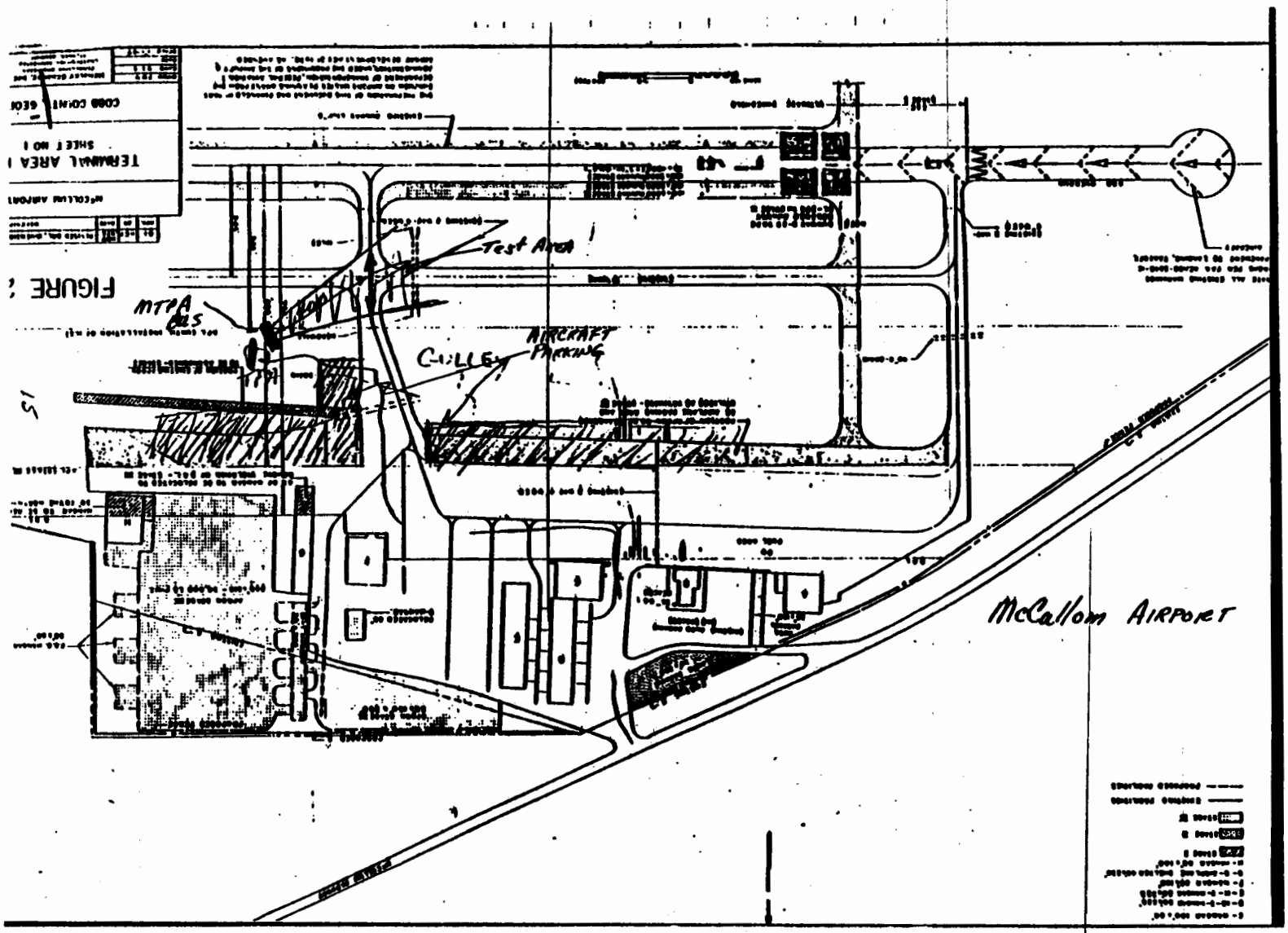


FIGURE 3. DATA COLLECTION SITE PLAN - MCCOLLUM AIRPORT

TABLE 1. TEST SEQUENCE FOR THE ATLANTA TESTS (ATL1)

Test Sequence No.	MTPA Test No.	MTPA Test Description	Test Duration (sec)
1	2	Reply Characteristics	0.5
2	3	Mode Acceptance--Spacing	4.0
3	4	Mode Acceptance--Pulse Width	2.0
4	99	Altitude Comparison	0.5
5	15	SLS AMP Characteristics -50,-60 dBm	3.0
6	6	Dead Time	1.5
7	7	Supression Time	1.0
8	8	Reply Rate Limiting	4.0
9	12	SLS Mode Acceptance -- Spacing	10.0
10	13	SLS Mode Acceptance -- Pulse Width	10.0
11	14	Mode A and Mode C Sensitivity	1.0
12	5	SLS AMP Char. ~-40 to -75 dBm (3 dB steps)	16.0
13	99	Altitude Comparison	0.5
14 to ??	14	Mode A and Mode C Sensitivity	1.0

TEST RESULTS.

Tests were conducted on a total of 154 different aircraft transponders. Some were tested more than once, but the results were included only once in these data. There were cases when all tests were not successfully completed (the transponder may have been turned off by the pilot prior to completion or interference from another plane invalidated the data from a particular test). In these cases the data are not included in the summaries. The results of each particular test are summarized below as a group.

REPLY CHARACTERISTICS. This test, which is MTPA test No. 2, makes 100 interrogations and measures the characteristics of the replies. This test produced data on the following parameters for 154 transponders:

1. Reply Frequency. Figure 4 shows the distribution of the reply frequencies from the 154 samples. The frequencies range from approximately 1086 to 1096 megahertz (MHz) with approximately 9 percent outside the limits of 1087-1093 MHz.

2. Bracket Spacing. Figure 5 shows the distribution of F1-F2 bracket spacing for the 154 samples. The times varied from 20.12 to 20.55 microseconds (μs) with six transponders or approximately 3 percent outside the allowed range of 20.2 to 20.4 μs.

3. Pulse Width. Figure 6 shows the pulse width distribution from the 154 transponders. Variations from 0.35 to 0.625 μs were found with 5 percent outside the limits of 0.35 to 0.55 μs.

4. Code Pulse Offset. Figure 7 shows the code pulse offset variations from the 840 code pulse samples from the 154 transponders. Figure 8 shows the maximum code pulse offset (the deviation from the nominal position of the code pulse which is the furthest from its prescribed position). The specified tolerance is plus or minus 100 nanoseconds (ns) with eight transponders or approximately 5 percent falling outside this limit.

5. Reply Jitter. Figure 9 shows the distribution of reply jitter for the Atlanta sample. No planes fell outside the prescribed limits of plus or minus 100 ns.

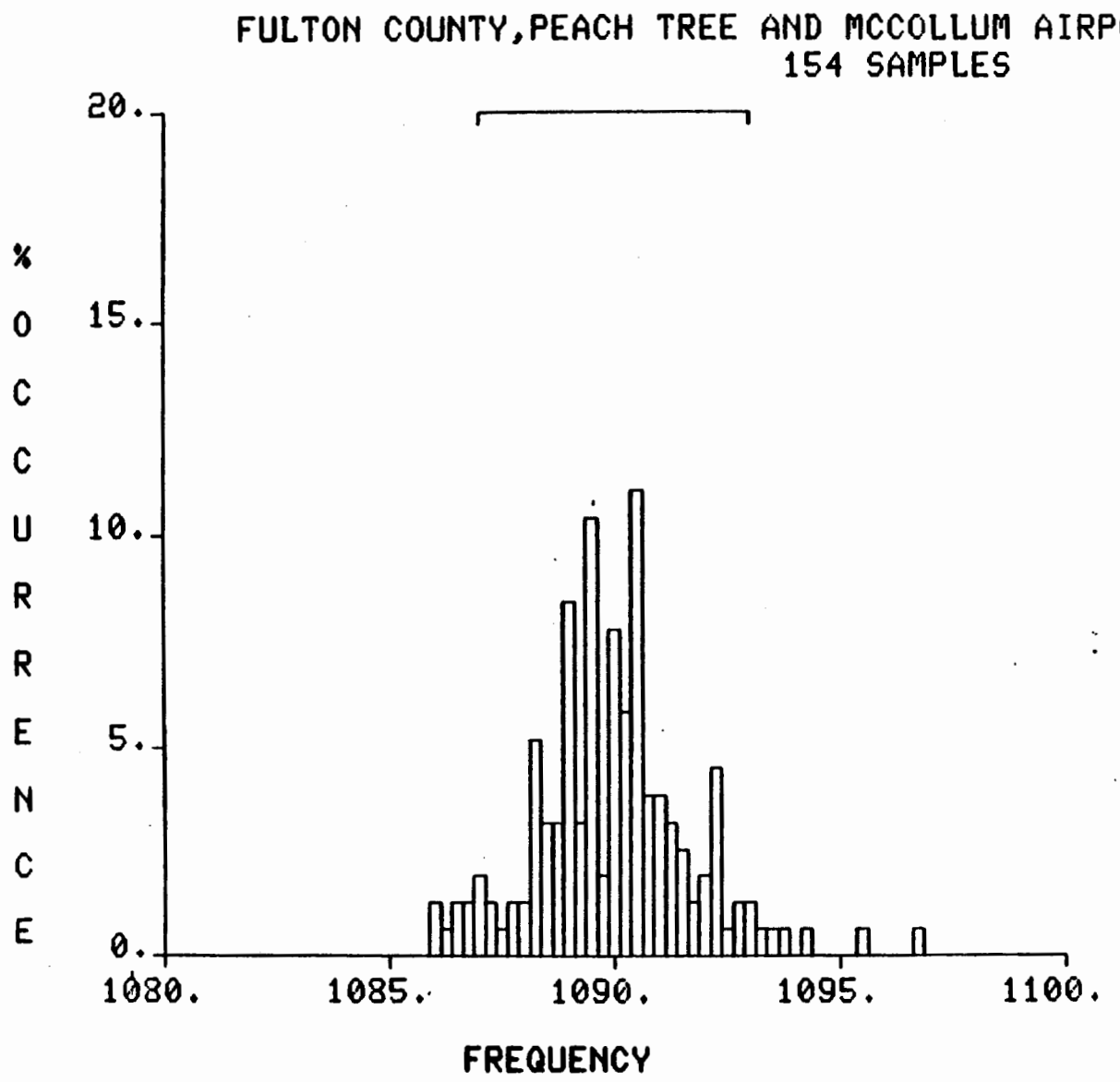


FIGURE 4. FREQUENCY DISTRIBUTION - ATLANTA SAMPLE

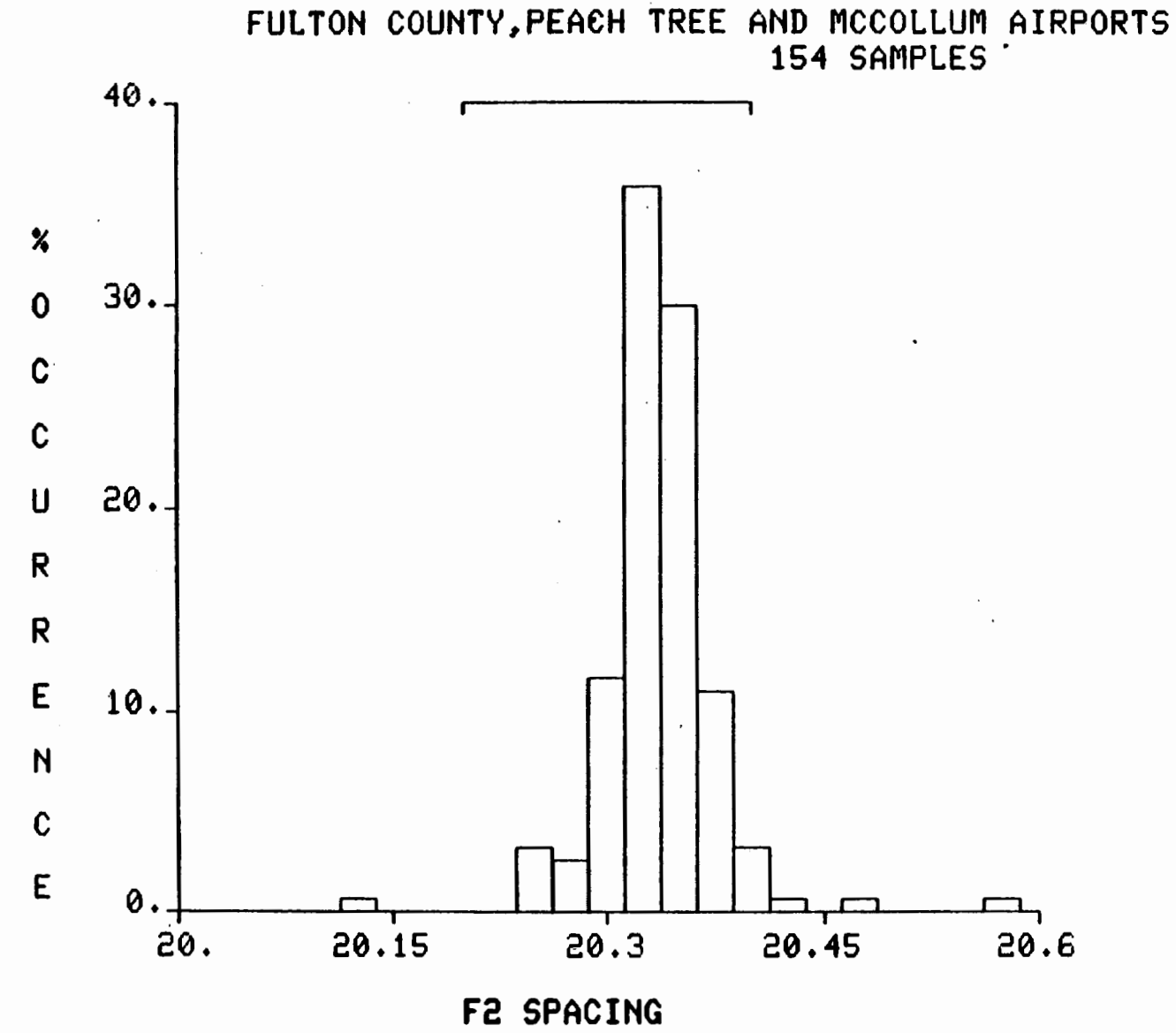


FIGURE 5. BRACKET SPACING DISTRIBUTION - ATLANTA SAMPLE

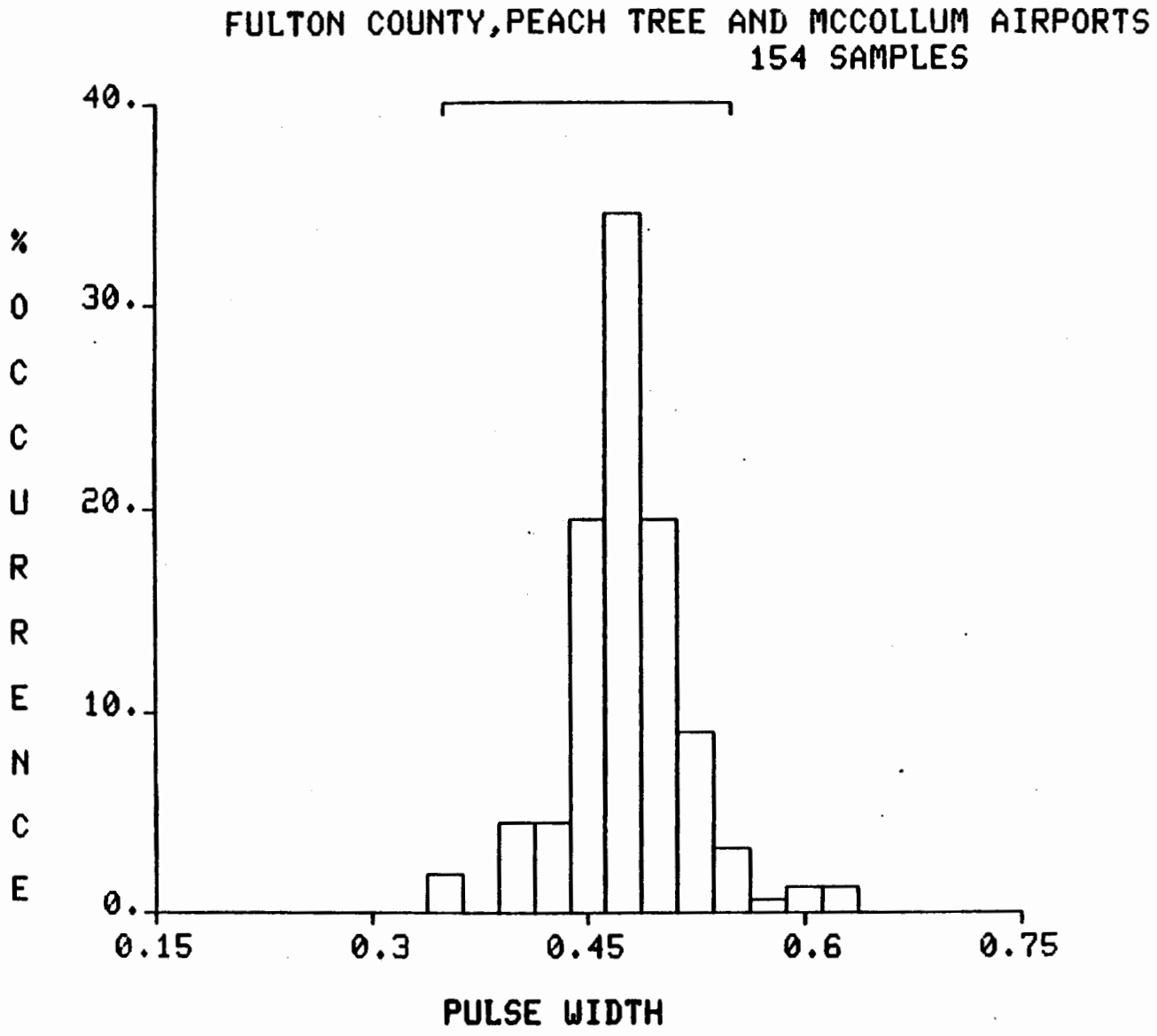


FIGURE 6. PULSE WIDTH DISTRIBUTION - ATLANTA SAMPLE

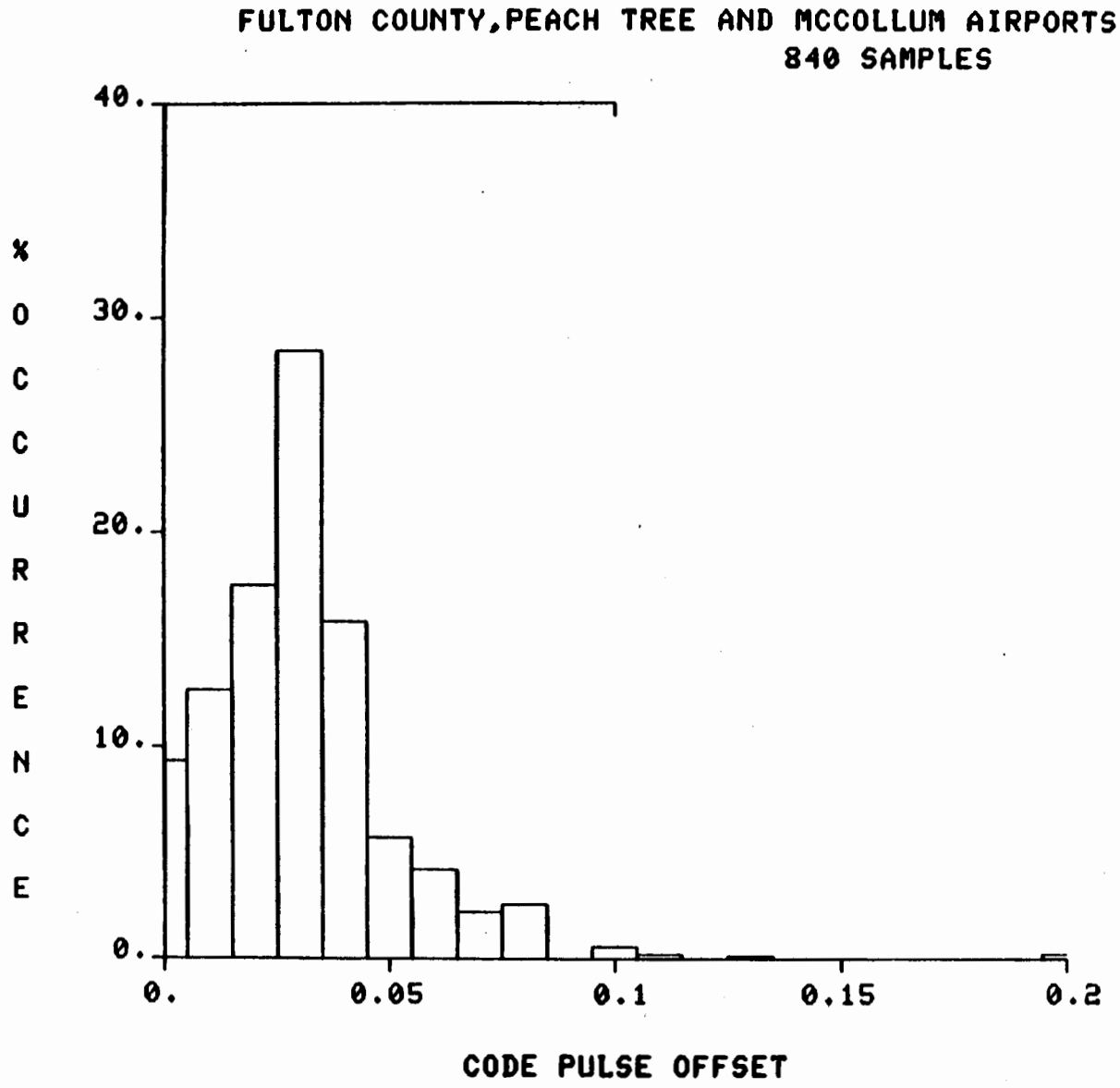


FIGURE 7. CODE PULSE OFFSET DISTRIBUTION - ATLANTA SAMPLE

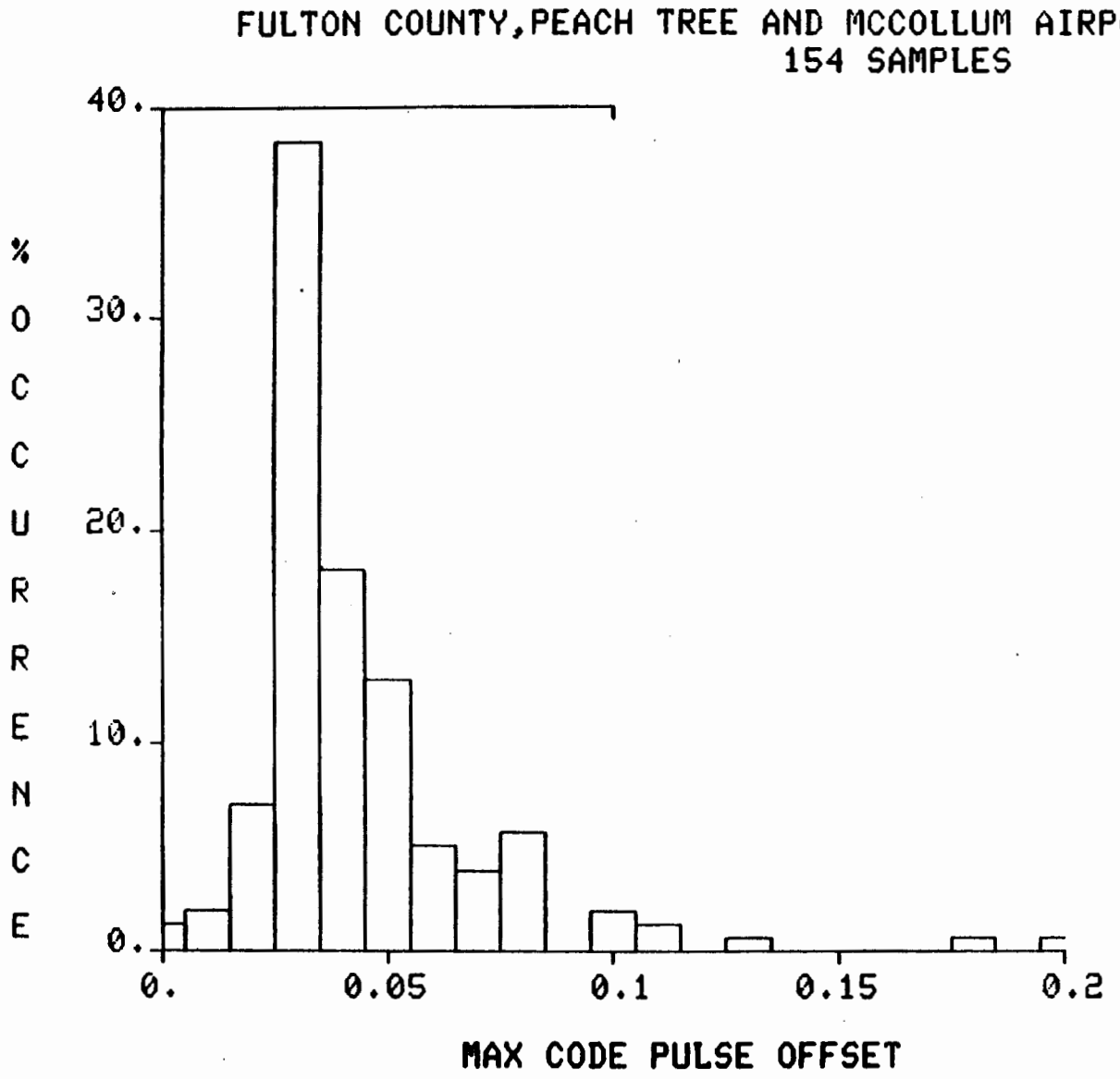


FIGURE 8. MAXIMUM CODE PULSE OFFSET DISTRIBUTION - ATLANTA SAMPLE

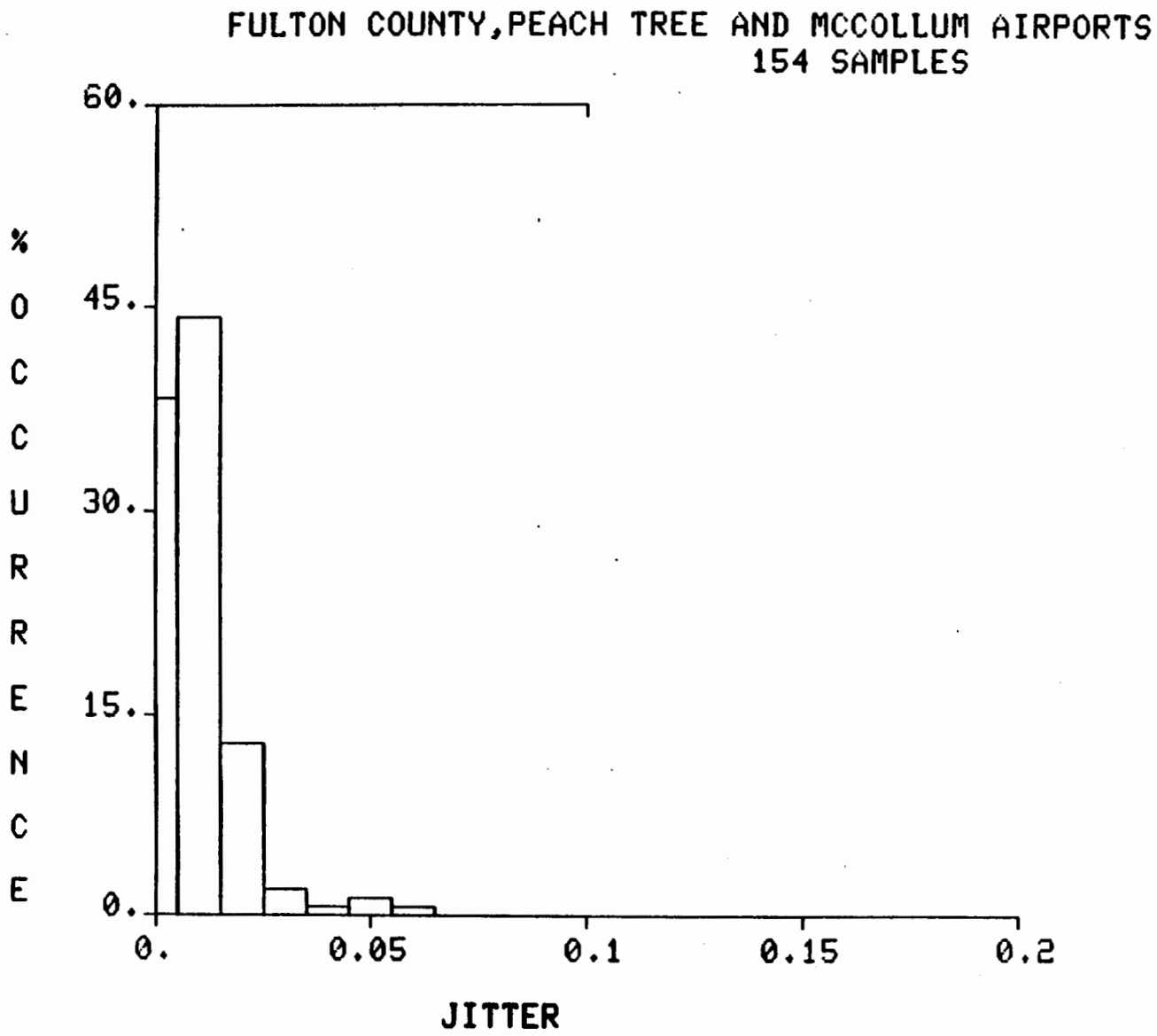


FIGURE 9. JITTER DISTRIBUTION - ATLANTA SAMPLE

MODE ACCEPTANCE -- PULSE SPACING. This test varies the spacing between P1 and P3 of the mode interrogation pulses to ascertain the acceptance/rejection characteristics of the transponder. Twenty interrogations are made in 50 ns increments from the nominal Mode A and Mode C spacings minus 800 ns to nominal plus 800 ns. The reply rates for the group of interrogations at each point are saved. Figure 10 shows an analysis of the 154 samples from Atlanta. The shaded in portion of the figure shows the defined area of the specification. Samples falling in this area are out of tolerance. For example, the interrogations spaced at 7 µs resulted in 153 transponders not replying at all and one which replied at a 90 percent rate. Eight transponders or approximately 5 percent failed to meet the specified tolerances.

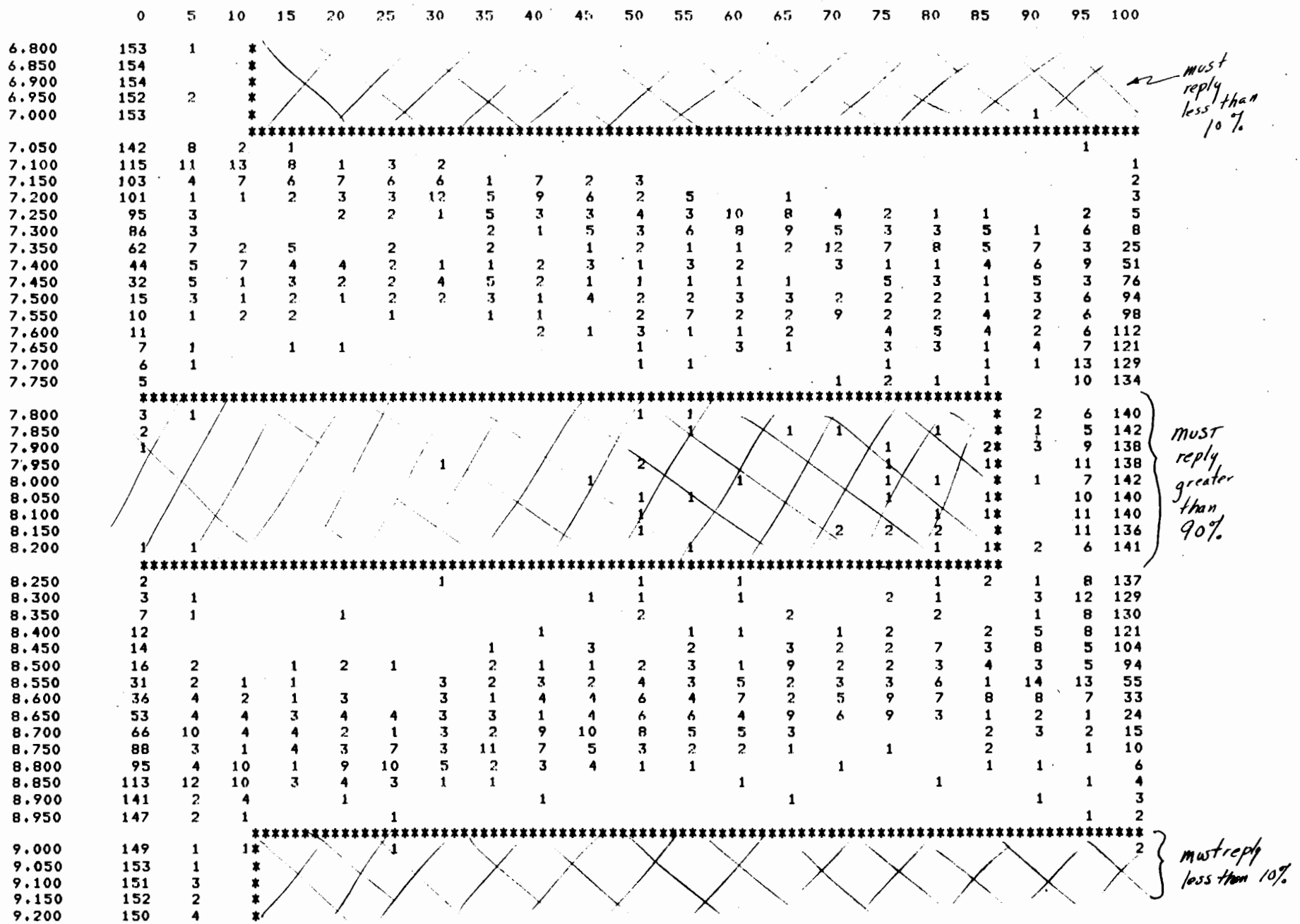
Figure 11 shows the data from the Mode C acceptance pulse spacing portion of the test. Thirteen transponders or approximately 8 percent fell outside the allowable area. The data from all those transponders that failed were examined further to see why they had failed. In almost all cases, the acceptance zone was merely skewed from the nominal spacing. Figure 12 shows an example of the detailed data from one of the samples that failed. The acceptance zones appear to be centered at approximately 8.4 and 21.5 µs rather than the nominal of 8.0 and 21.0 µs. Seven were skewed so badly that they did not respond at the nominal spacing.

The reply delay difference data was also gathered from the mode acceptance (pulse spacing) test. The allowable delay difference is 200 ns. Figure 13 shows the distribution of differences in delay for the Atlanta data. Seven planes or about 5 percent failed to meet this criteria. Only 147 samples are included because the remainder did not respond to Mode C at the nominal interrogation characteristics.

MODE ACCEPTANCE -- PULSE WIDTH. Figure 14 shows the reply rates of the Atlanta sample as a function of pulse width. All samples which fell into the shaded area were investigated further by examining the individual tests. In general, the cause was a single data point in the shaded (out of tolerance) area of the data plot. The nominal (0.8 µs) point was compared to the results of the pulse position test which used the same interrogation parameters. After this analysis two transponders or approximately 1 percent were out of specified limits.

FULTON COUNTY,PEACH TREE AND MCCOLLUM AIRPORTS

154 POINTS - REPLY RATE (%) VS PULSE SPACING (USEC) MODE A



	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
6.800	153	1	*																		
6.850	154		*																		
6.900	154		*																		
6.950	152	2	*																		
7.000	153		*																1		
			**********																		
7.050	142	8	2	1																1	
7.100	115	11	13	8	1	3	2														1
7.150	103	4	7	6	7	6	6	1	7	2	3										2
7.200	101	1	1	2	3	3	12	5	9	6	2	5		1							3
7.250	95	3			2	2	1	5	3	3	4	3	10	8	4	2	1	1		2	5
7.300	86	3						2	1	5	3	6	8	9	5	3	3	5	1	6	8
7.350	62	7	2	5		2		2		1	2	1	1	2	12	7	8	5	7	3	25
7.400	44	5	7	4	4	2	1	1	2	3	1	3	2		3	1	1	4	6	9	51
7.450	32	5	1	3	2	2	4	5	2	1	1	1	1	1		5	3	1	5	3	76
7.500	15	3	1	2	1	2	2	3	1	4	2	2	3	3	2	2	2	1	3	6	94
7.550	10	1	2	2		1		1	1		2	7	2	2	9	2	2	4	2	6	98
7.600	11								2	1	3	1	1	2		4	5	4	2	6	112
7.650	7	1		1	1						1		3	1		3	3	1	4	7	121
7.700	6	1									1	1				1		1	1	13	129
7.750	5														1	2	1	1		10	134
7.800	3	1									1	1						*	2	6	140
7.850	2											1		1	1		1	*	1	5	142
7.900	1															1		2*	3	9	138
7.950							1				2					1		1*		11	138
8.000										1			1			1	1	*	1	7	142
8.050											1	1				1		1*		10	140
8.100											1						1	1*		11	140
8.150											1				2	2	2	*		11	136
8.200	1	1										1					1	1*	2	6	141
8.250	2						1				1		1				1	2	1	8	137
8.300	3	1								1	1		1			2	1		3	12	129
8.350	7	1			1						2			2			2		1	8	130
8.400	12								1			1	1		1	2		2	5	8	121
8.450	14							1		3		2		3	2	2	7	3	8	5	104
8.500	16	2		1	2	1		2	1	1	2	3	1	9	2	2	3	4	3	5	94
8.550	31	2	1	1			3	2	3	2	4	3	5	2	3	3	6	1	14	13	55
8.600	36	4	2	1	3		3	1	4	4	6	4	7	2	5	9	7	8	8	7	33
8.650	53	4	4	3	4	4	3	3	1	4	6	6	4	9	6	9	3	1	2	1	24
8.700	66	10	4	4	2	1	3	2	9	10	8	5	5	3				2	3	2	15
8.750	88	3	1	4	3	7	3	11	7	5	3	2	2	1		1		2		1	10
8.800	95	4	10	1	9	10	5	2	3	4	1	1			1			1	1		6
8.850	113	12	10	3	4	3	1	1					1				1			1	4
8.900	141	2	4		1				1					1					1		3
8.950	147	2	1			1														1	2
9.000	149	1	1*			1															2
9.050	153	1	*																		
9.100	151	3	*																		
9.150	152	2	*																		
9.200	150	4	*																		

FIGURE 10. MODE ACCEPTANCE (PULSE SPACING) DISTRIBUTION, MODE A - ATLANTA SAMPLE

FULTON COUNTY,PEACH TREE AND MCCOLLUM AIRPORTS

154 POINTS - REPLY RATE (%) VS PULSE SPACING (USEC) MODE C

	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
19.800	152	1	*																		1
19.850	150	1	1*					1													1
19.900	151	1	*	1																	1
19.950	150	1	*			1															2
20.000	149	2	*							1										1	1
			**********																		
20.050	146	2	1		1																4
20.100	128	11	6	3			1						1					1		1	2
20.150	105	8	7	8	9	4	5		1								1				6
20.200	92	6	8	3	5	10	9	6		2	5									1	7
20.250	92	4	2	1	1	4	5	3	4	7	6	7	4	3	2						9
20.300	90	3	1		1	1	2	4	2	6	6	7	11	2	5	1	2		1		9
20.350	66	5	3	5	2		1	1		4	3	3	9	5	8	5	6	3	3	6	16
20.400	48	4	10	2	1	4	1		2	1	1	3	1	1	5	8	7	13	6	6	30
20.450	42	3	1	1	5		2	3	4	2	1	2	2	2		3	1	3	8	14	55
20.500	27	2	2	1	1	2	2	3	4	3	3	2	3	4	1	1	2	3	2	11	75
20.550	20	1	1	2	1	1		1	4	1	2	3	4	1	5	2	1	3	4	8	89
20.600	13				1				1	3		1	2	4	2	2	2	4	6	7	106
20.650	11									2			1	3	1	2	4		3	15	112
20.700	9			1											1	1	1	3	3	8	127
20.750	9				1								1		1			2	1	9	130
					**********																
20.800	9								1		1		1	1				*	2	9	130
20.850	5							1		1	1	1			1	1		1*	1	13	129
20.900	6										2	1			1			1*		6	137
20.950	6										2		1				1	1*	1	6	136
21.000	6										1					1		*	1	13	132
21.050	5	1									1	1			1		1	*	2	13	129
21.100	6										1					1	1	*	1	10	134
21.150	6										1				1			1*		9	136
21.200	7										1	1			2			*	2	11	130
					**********																
21.250	6		1									1		1	1		2		2	12	128
21.300	8												1	1					2	10	132
21.350	8		1		1						2				1		1		7	12	121
21.400	14			1			1					2				1	4			14	117
21.450	18			1	1						3	1	1	2	1	3	5	6	4	8	100
21.500	21	2			1	1		1			5		3	4	6	2	1	3	2	12	90
21.550	29	2		1			1	2	1	2	4	3	4	6	4	3	1	1	2	9	79
21.600	39	2	2	1	1		5	4	3	4	4	4	2	2			4	11	5	11	50
21.650	47	3	3	4	7	3	5	1	1	2	1	3	2	6	4	7	6	5	7	3	34
21.700	56	9	1	3	2	5	2	2		2	10	5	6	10	2	5	4	3	1	2	24
21.750	78	5	2	1	2	1	1	5	7	8	3	5	8	4	1	1		1		1	20
21.800	81	7	2	3	4	8	10	3	2	6	4	2	2		3				1		16
21.850	91	9	6	5	10	5	8	3	2	2									1	2	10
21.900	108	11	12	5			4		1			1						1	1		10
21.950	132	6	4	1	1			1										1			8
			**********																		
22.000	146		1*													1					6
22.050	145	2	*	1															1		5
22.100	146	2	1*																	1	4
22.150	147	2	*																	1	4
22.200	148		1*														1				4

must reply less than 10%.

must reply greater than 90%.

must reply less than 10%.

FIGURE 11. MODE ACCEPTANCE (PULSE SPACING) DISTRIBUTION, MODE C - ATLANTA SAMPLE

C

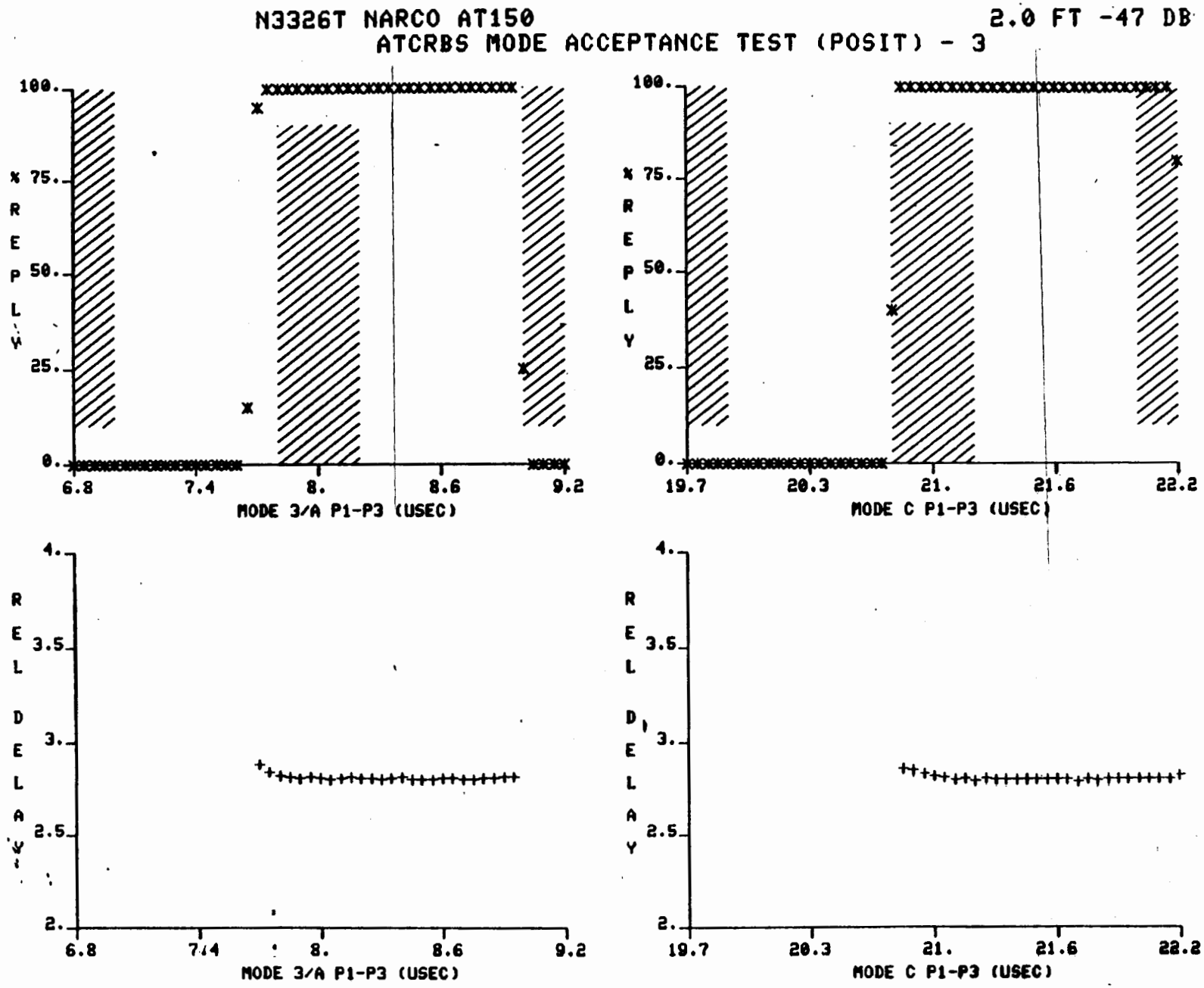


FIGURE 12. INDIVIDUAL SAMPLE - MODE ACCEPTANCE - ATLANTA SAMPLE

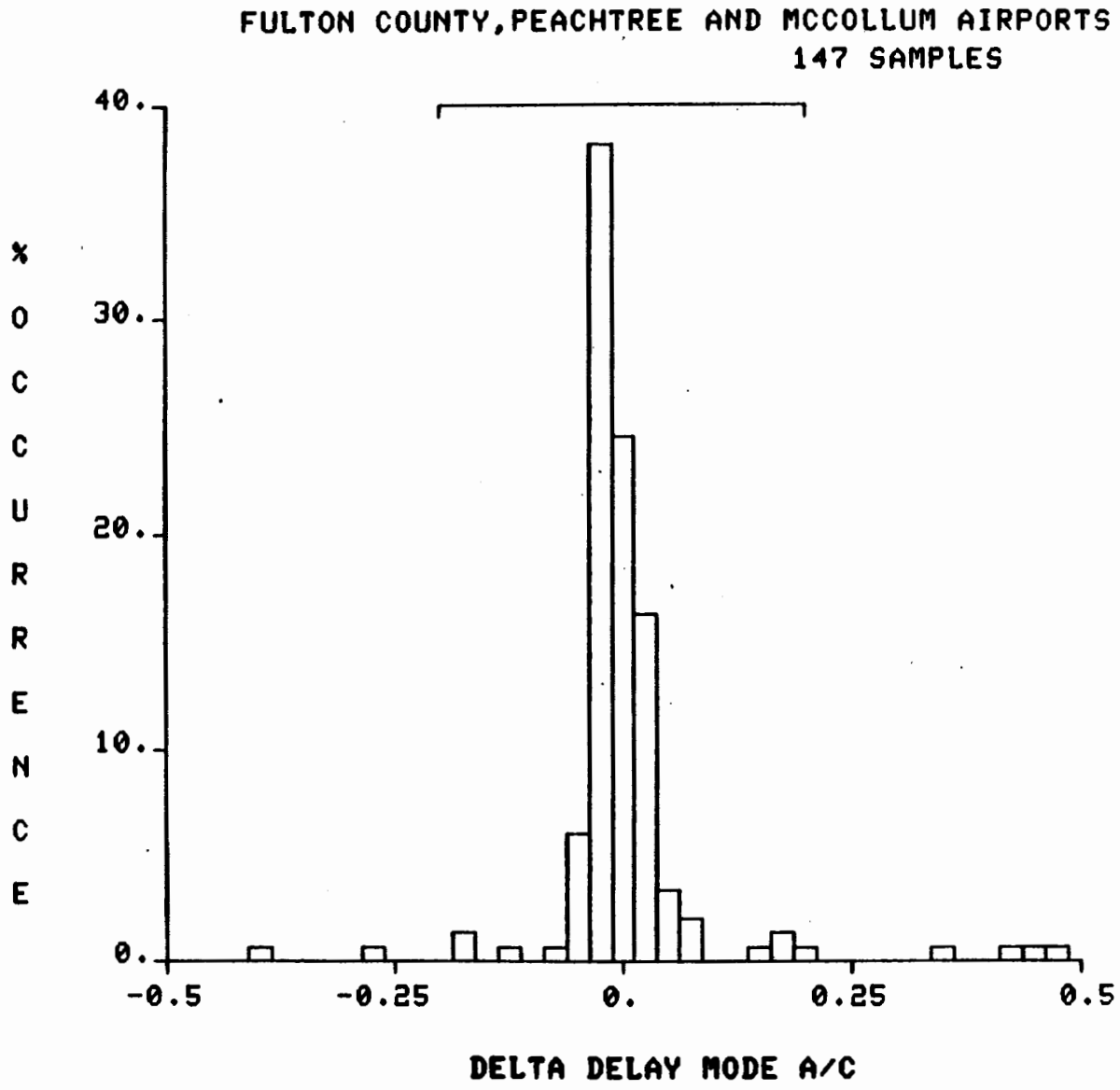


FIGURE 13. REPLY DELAY DIFFERENCE (MODE A TO MODE C) - ATLANTA SAMPLE

FULTON COUNTY,PEACH TREE AND MCCOLLUM AIRPORTS

154 POINTS - REPLY RATE (%) VS PULSE WIDTH (USEC) MODE A

	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
0.300	24	1			1			1			1	2		1					1	6	116
0.325	22		1				1	1		2		1		1	1				1	6	117
0.350	22										1			2			1		2	15	111
0.375	20		1					1			1		1					1	2	4	123
0.400	15	2		1					1			1		1		1			1	3	128
0.425	9		1	1	1			1				1	1		1					4	134
0.450	6	2							1		1	2			1		1		1	7	132
0.475	6				1				1	1	1	1		1			2	1		9	130
0.500	5				1						2		1	1		1	1	2		10	130
0.525	4	1		1								1	1				2	1	1	12	130
0.550	2			1				1		1			1	1			2		1	9	135
0.575	2							1			1	1		1		1		1		7	139
0.600	1							1			2	2		1		1		1	2	5	138
0.625											1	1		1		1	1			11	138
0.650													1	1		1	1	1	1	7	141
0.675												1	1	1				1		5	145
	**********																				
0.700												2	1	1				1*	1	6	142
0.725								1				1					2	*		4	146
0.750											1		1			1		1*	1	9	140
0.775										1					2	1	1	*		7	142
0.800										1	2						2	*		5	142
0.825														1	1		1	1*	1	7	142
0.850							1										1	2*	1	6	143
0.875										1							1	1*	1	8	142
0.900												1			1	1		*	3	9	139
	**********																				
0.925									1					1	1			1		9	141
0.950											1		1					1	1	6	144
0.975							1											2		5	146
1.000												1				1	1		1	7	143
1.025							1				1						2	1		8	141
1.050								1			1						1		3	8	140
1.075												1	1	1		1		2		5	143
1.100					1			1			1							1	2	5	143
1.125						1				1				1		1			3	6	141
1.150		1							1						1			1	2	8	140
1.175	1										1		1				2	1	2	3	143
1.200	1										2	1	1	2					1	7	139
1.225	1									1					1				1	10	140
1.250	1								1							1		2	1	8	140
1.275	1									1			1			1			2	8	140
1.300	2				1						1							2	1	5	142
1.325	3									1	2	1	1					1	1	9	135
1.350	4									1	3	1	1					1		5	138
1.375	4		1								1								2	10	136
1.400	7									1	1	1		1			1	1		6	135
1.425	7										1	1		1					1	7	136
1.450	7										2	1	1					2		7	134
1.475	7										1		1	1	1	1		1		7	134
1.500	7										1				1	1		1	1	6	136

must reply >90%

FIGURE 14. MODE ACCEPTANCE (PULSE WIDTH) DISTRIBUTION - ATLANTA SAMPLE

DEAD TIME. This test determines how long a transponder is "dead" after responding to an ATCRBS interrogation. An interrogation is made to solicit an ATCRBS reply. A second interrogation is then moved in time from 20 to 140 μs after the first. The reply rate to the second interrogation is used to determine dead time parameter of the transponder. It must reply at a 90 percent rate no later than 125 μs following the end of the first reply. Eighteen transponders originally appeared to fail this criteria. They were investigated individually to get a better idea of their characteristics. It was found that the dead time data was affected by two other circumstances: (1) triggering of the reply rate mechanism of the transponder, and (2) RF coupling between MTPA and the transponder which could not maintain the 90 percent threshold. Most transponders raise their receiver threshold in order to reduce the amount of interrogations they see when the reply rate exceeds a certain amount. When the dead time test was conducted, two interrogations were made on the same interrogation sequence which is repeated at a 500 hertz (Hz) rate, giving an effective rate of 1000 interrogations per second. If this triggered the reply rate limiting circuitry, the receiver threshold was increased. If the coupling was marginal (for whatever the reason, i.e., shielding, poor sensitivity, etc.), it may no longer be possible to retain the 90 percent reply rate for the duration of the test. In the real ATC environment, the transponder does not receive more than about 50 interrogations from the same interrogator in a burst. Thus, the situation created with the dead time test was not a realistic one in which to measure dead time (it measured the effect of two parameters at once). Figure 15 is a plot of the dead time characteristics of a single sample showing the effect of the reply rate limiting on the output of this test. The reply rate limiting test of all samples which exhibited this characteristic were examined. If the reply rate was less than 100 percent during this test and if it were 100 percent during the preceding test, it was assumed to be in reply rate limiting. It was then assumed the dead time to be the point at which the transponder first replied at a 90 percent rate. Applying this criteria, only one plane failed to respond within the limits of the dead time specification. The distribution of the data is shown in figure 16. Reply delay data were not used from this test as the reply rate limiting action of the transponders also affected the reply delay.

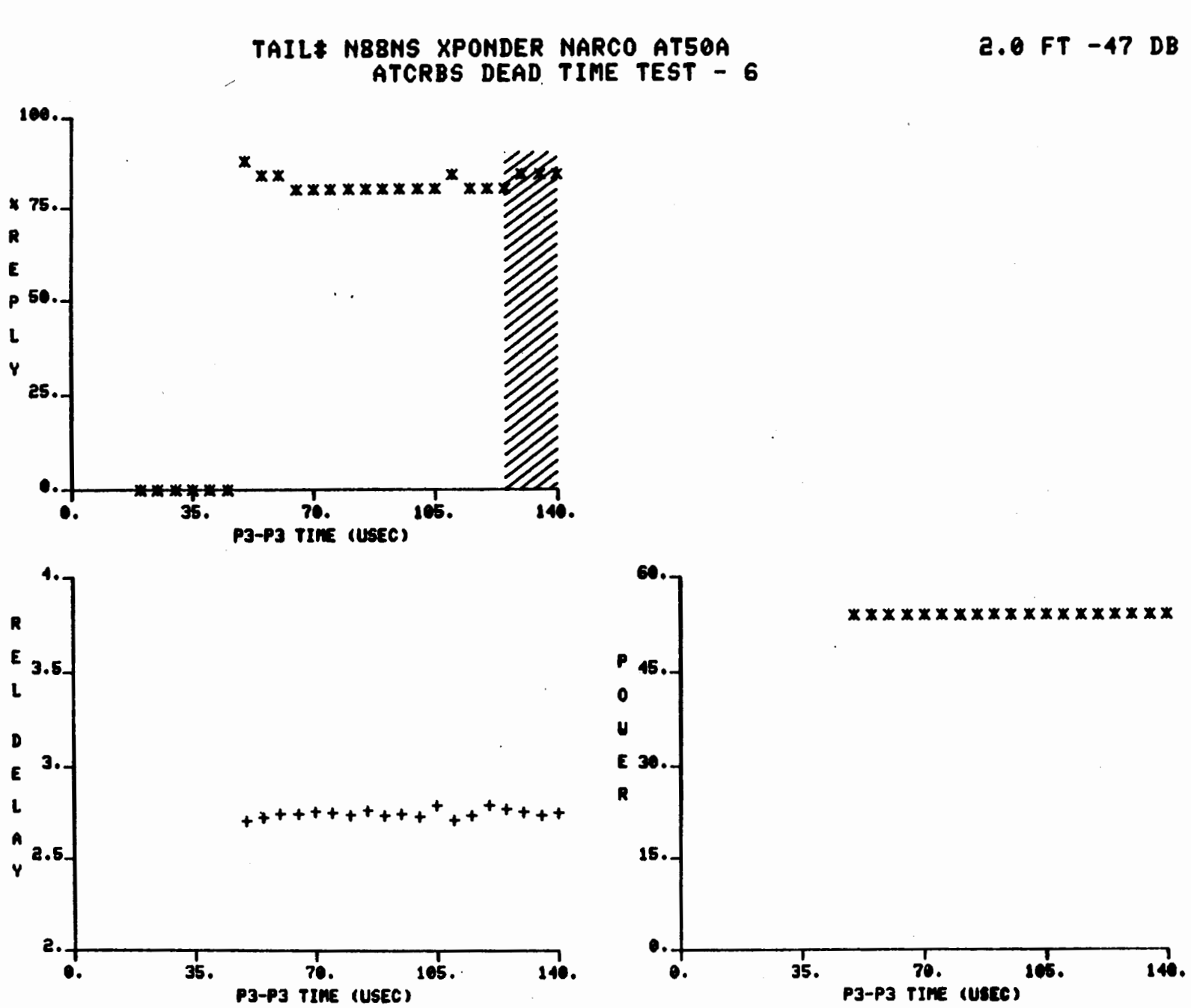


FIGURE 15. INDIVIDUAL SAMPLE - DEAD TIME TEST

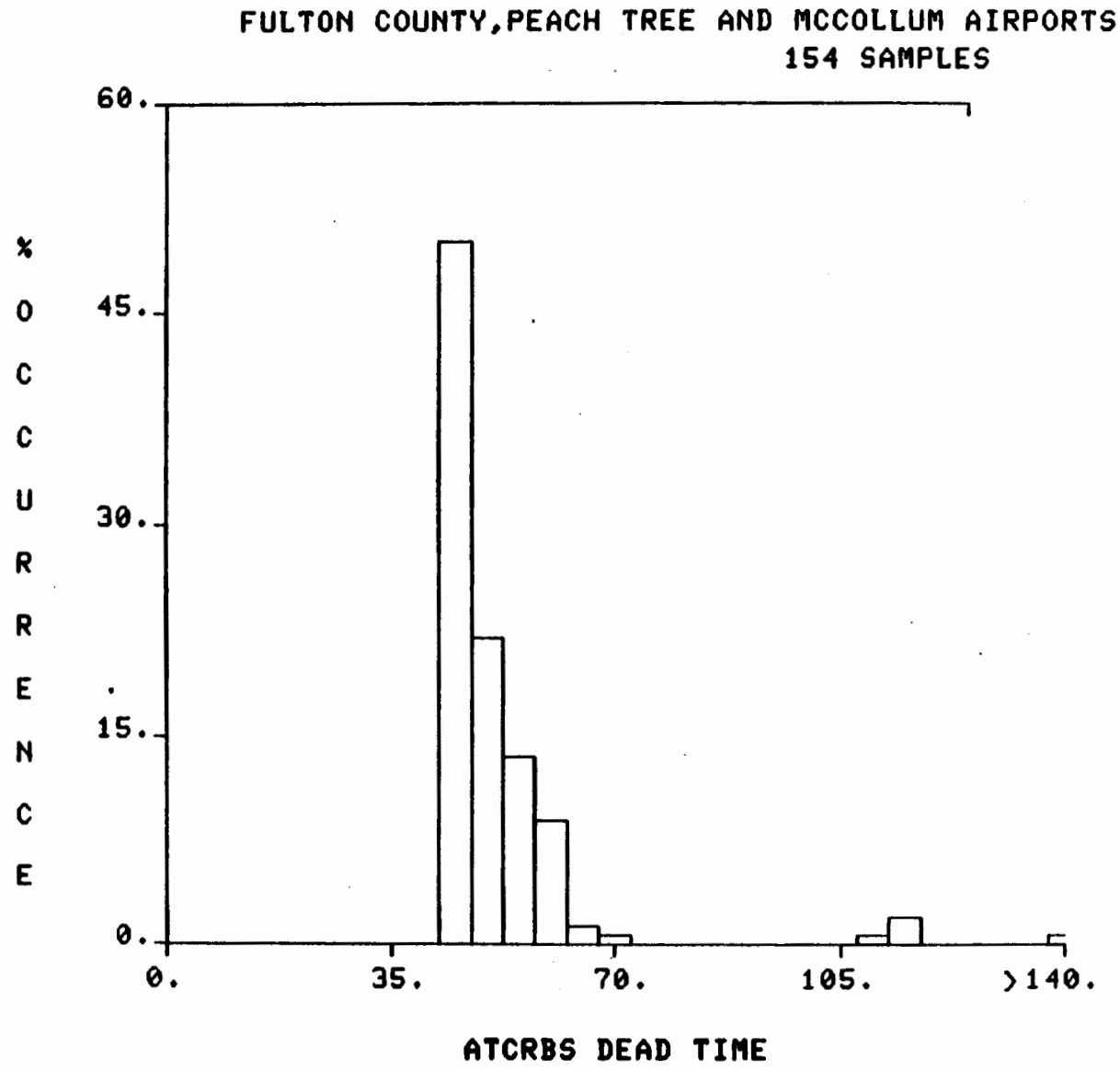


FIGURE 16. DEAD TIME DISTRIBUTION - ATLANTA SAMPLE

ATCRBS SUPPRESSION TIME. The suppression time test is essentially the same as the dead time test except the first interrogation consists only of a suppression pair (P1 and P2) and, thus, requires no reply. The second interrogation is moved away from the first to see how long the suppression period (initiated by the first interrogation) lasts. The reply rate to the second interrogation is used to determine the suppression time. Figure 17 shows the distribution of suppression times. Twenty-two transponders, or approximately 14 percent, fell outside the limits of 25 to 45 µs.

SLS CHARACTERISTICS--PULSE SPACING. This test makes 100 interrogations at each point. A Mode A interrogation is used with a P2 pulse 3 dB higher than P1 and P3. The spacing between P1 and P2 is then varied in 50 ns increments from 1.2 to 2.8 µs. This was the most frequently failed test in the sample from Atlanta. The results are broken into two areas: (1) the area where the transponder should reply less than 1 percent (the suppression area--1.8 to 2.2 µs), and (2) the area where it should reply at greater than a 90 percent rate (see figure 18). Eighteen (approximately 11 percent) failed the first category while 91 (approximately 59 percent) failed the second. Detailed investigation of the test results showed that one SLS acceptance region was too wide or skewed from nominal in almost all cases. Figure 19 is a sample showing the response of one sample to the variation in the SLS.

SLS CHARACTERISTICS--PULSE WIDTH. This test makes 100 interrogations at each point in order to check the pulse width acceptance characteristics of the transponder. Nominal pulse positions and widths are used for all pulses of the interrogations with the exception of the P2 pulse (its position is nominal but the width is variable). The P2 pulse is set to be 3 dB greater than P1 and P3. Widths from 300 ns to 1.5 µs are used. Figure 20 shows the results of this test. A total of five transponders (approximately 3 percent) failed to suppress as a function of width, although four of these failed to suppress altogether.

SLS AMPLITUDE/DYNAMIC RANGE CHARACTERISTICS. Two versions of this test were conducted during each run as these parameters were of special interest. One test was run at only a power level of -50 and -60 dBm (MTPA test 15) while varying the P1/P2 power ratio. The other (MTPA test 5) was run throughout the entire dynamic range capability attainable at the transponder (normally the range was from -75 to approximately -39 dBm).

Test 5 was performed in the following sequence: the power level of P1 and P3 were set to -75 dBm. Sets of interrogations (100 per point) were then made where the ratio of P1 (and P3) to P2 was 15, 12, and 9 dB (P1 and P3 are greater than P2), to which the transponder should reply at least 90 percent. Interrogations were then made at ratios of 6 and 3 dB, where the performance is unspecified, and at ratios of 0, -3, and -6 dB where the transponder must reply less than 1 percent

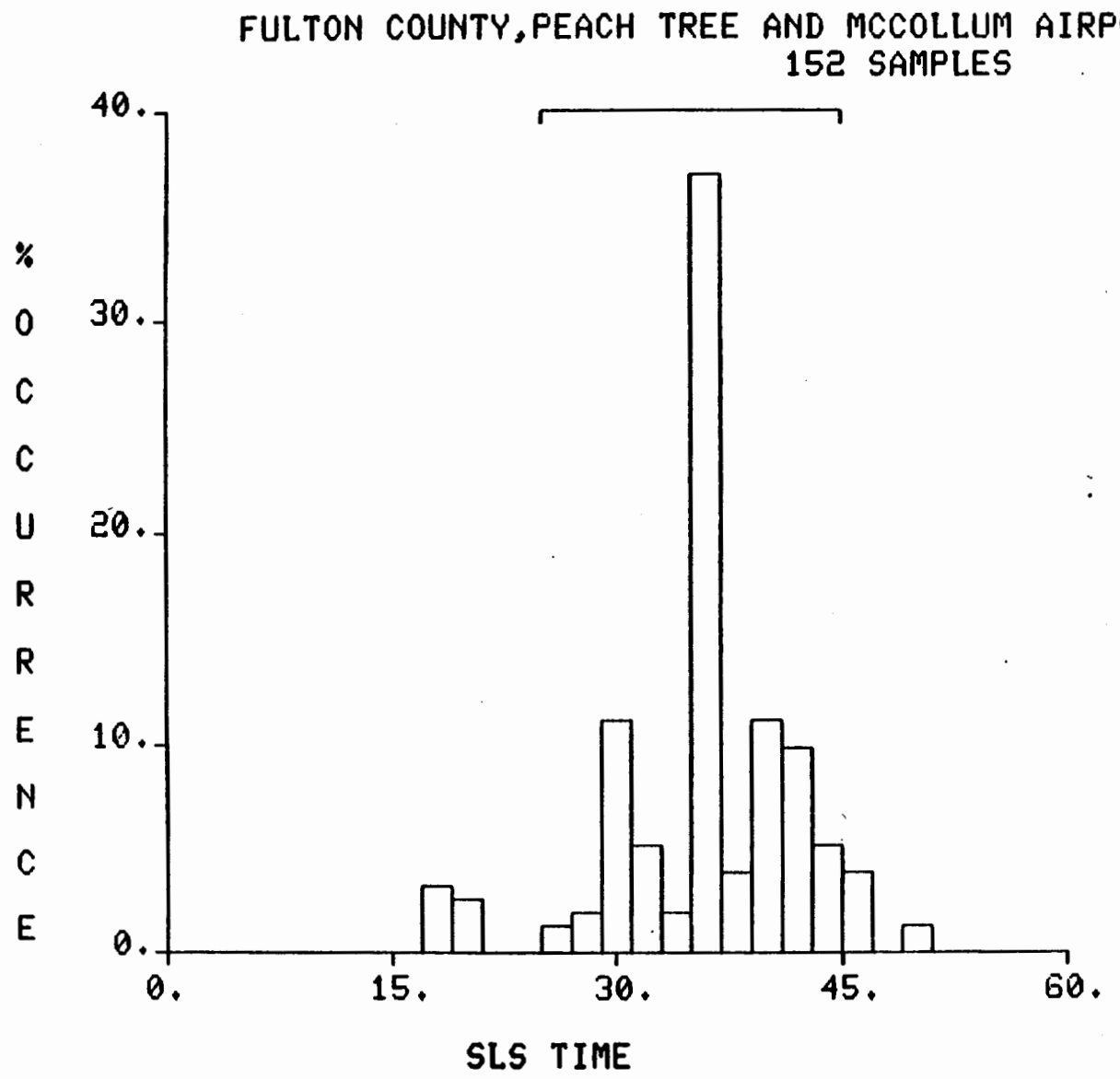


FIGURE 17. SLS SUPPRESSION TIME DISTRIBUTION - ATLANTA SAMPLE

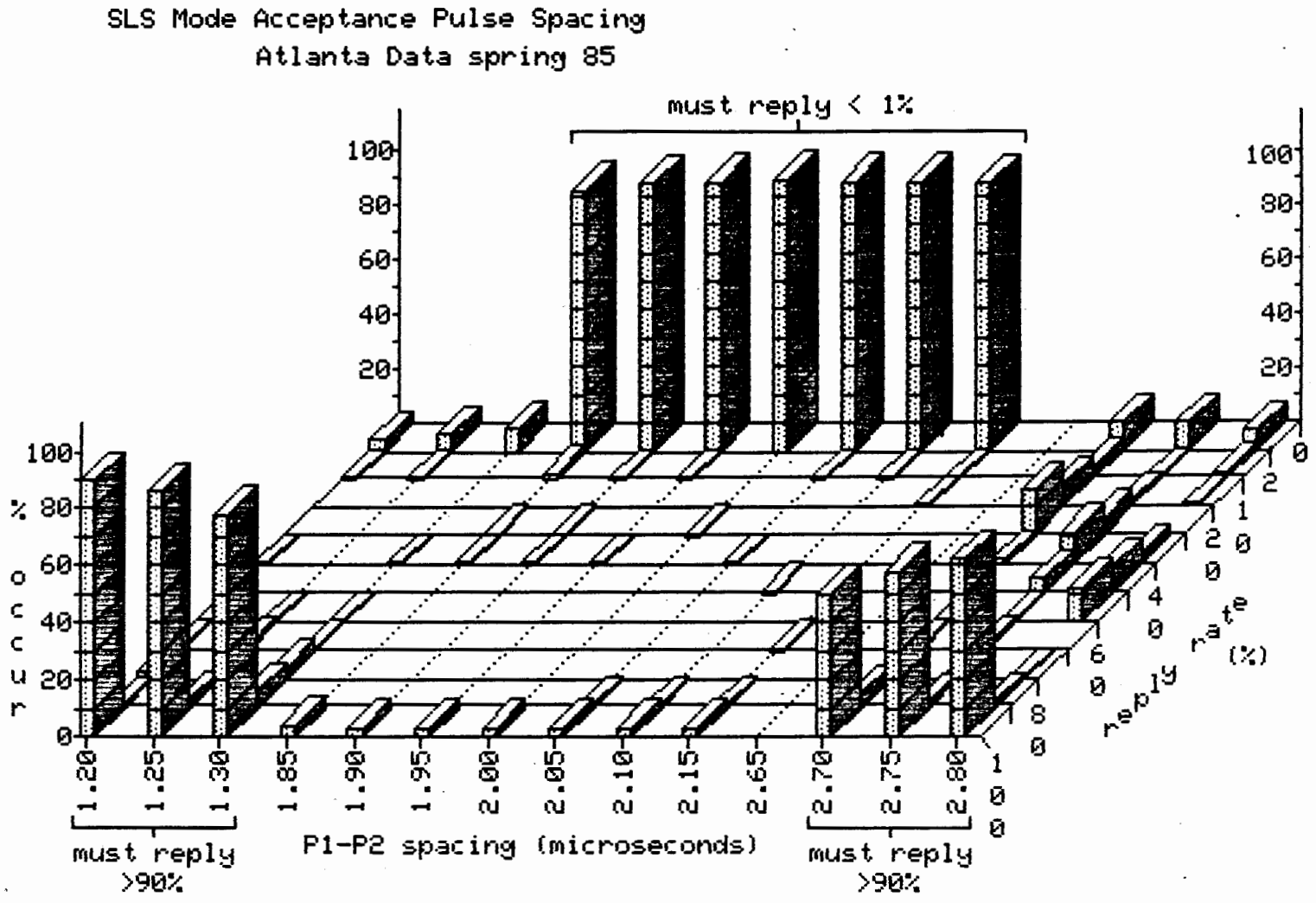


FIGURE 18. SLS MODE ACCEPTANCE (PULSE POSITION) DISTRIBUTION - ATLANTA SAMPLE

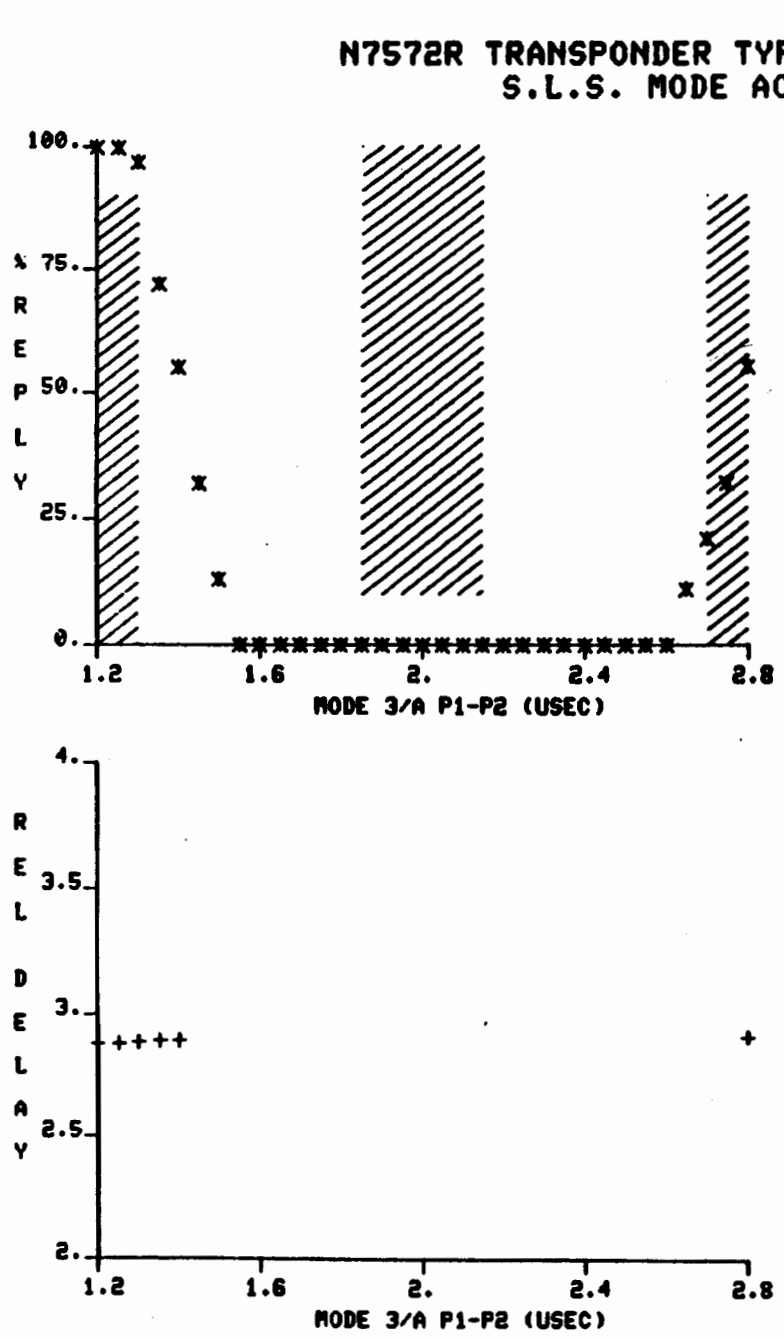


FIGURE 19. INDIVIDUAL SAMPLE - SLS MODE ACCEPTANCE (PULSE POSITION)

FULTON COUNTY,PEACH TREE AND MCCOLLUM AIRPORTS

154 POINTS - REPLY RATE (%) VS PULSE WIDTH (USEC) SLS - MODE A

	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
0.300	21	1	2	3	2	1		2		2	1	1	1			4	1	4	4	7	97
0.325	36	5	1	1	3		1	3	1		1	2	4	4	2	2	3	5	3	12	65
0.350	67	4	1	1	2	2		2	1	1	1	2	2	1		4	1	1	1	7	53
0.375	82	8	2	1	1	1			1			3		1	1	2	2	3	1	5	40
0.400	99	4	1	1	1	3	2	1	2		1		1	1	2	3			1	3	28
0.425	117	3	2	2	2	2		1					1			2			1		21
0.450	131	2			1	1		2										1			16
0.475	137	1					1						1		1			1	1	1	10
0.500	140	3	1	1												1	1		1		6
0.525	144	2					1										1				6
0.550	147											1								1	5
0.575	146	1							1											1	5
0.600	147								1												6
0.625	146	1				1										1				1	4
0.650	146	2			1											1					4
0.675	146	2						1										1			4
	**********																				
0.700	146*	2								1									1		4
0.725	148*								1												5
0.750	147*	1							1											1	4
0.775	148*		1																1		4
0.800	148*					1													1		4
0.825	146*	2			1															1	4
0.850	146*	2					1										1				4
0.875	148*					1											1				4
0.900	147*	1		1											1						4
	**********																				
0.925	146		1	1	1									1							4
0.950	147	1						1							1						4
0.975	148						1							1							4
1.000	147	1				1									1						4
1.025	147	1									1						1				4
1.050	147		1		1										1						4
1.075	146	1		1		1									1						4
1.100	147	1					1						1								4
1.125	148								1					1							4
1.150	148									1						1					4
1.175	146	2							1								1				4
1.200	147		1								1					1					4
1.225	143	3		1		1	1									1					4
1.250	144	1	1			1				1					1		1				4
1.275	145	1		1										1			1				5
1.300	144	1				1	1				1										6
1.325	144	1			1							1				1					6
1.350	143	1				1				1											8
1.375	144					1						1								1	7
1.400	143					1	1						1								8
1.425	136	6					1		1												10
1.450	142							1					1							1	9
1.475	142							1					1								10
1.500	142						1					1									10

FIGURE 20. SLS MODE ACCEPTANCE (PULSE WIDTH) DISTRIBUTION - ATLANTA SAMPLE

(suppress). The reply ratio at each point is saved. The power of the group is then increased by 3 dB (-72 dBm) and the process repeated. This is done at 3 dB increments until the maximum power output capability of MTPA is reached.

Test 15 performed the groups of interrogations only at -50 and -60 dBm. Figure 21 is a summary of the data from test 15. It shows that at an interrogation level of -60 dBm, only 116 transponders responded at a rate greater than 90 percent, while at -50 dBm, 149 reached this level. Since the transponders had not reached minimum triggering threshold (MTL) which is defined as the signal level which produces a 90 percent reply rate, the specification cannot be applied. It was used, however, in conjunction with test 5 where MTL can be determined.

The transponder producing the data for figure 22 (the results of an individual test 5) shows definite SLS problems. At a P1-P2 ratio of +9 dB the reply probability drops, as confirmed by test 15 (see figure 23) which was run at -50 and -60 dBm. The analysis program searches the "must reply" area (see figure 22) of each individual test 5 for a reply rate of at least 90 percent. This defines the MTL level for this transponder (-54 dBm for this case). Data from this column (MTL), -51, -48, -45, and -42 dBm (MTL + 9 dB), are then saved for the test 5 data base. This procedure is used on each transponder sample until the data for all the transponders has been standardized to these four levels referenced to MTL. Figures 24, 25, 26, and 27 are plots of the SLS amplitude characteristics from the Atlanta sample at MTL, MTL + 3, MTL + 6, and MTL + 9 dB, respectively. The "reply rate" axis is not completely linear on these plots. The first row contains reply rates of 0 and 1 percent (in order to separately show the suppression area of the specification). The remaining rows are 2 to 10, 11 to 20, 21 to 30 percent, etc. Thus, at a P1-P2 ratio of -6 dB, 91 percent of the transponders replied at a rate of 1 percent or less, 3 percent replied at a rate of 2 to 10 percent, 1 percent replied 10 to 20 percent, 1 percent replied 30 to 40 percent, 1 percent at 80 to 90 percent, and 3 percent replied at 90 to 100 percent.

The "must suppress" characteristics apply at all signal levels at MTL +3 dB and above. Failures of the specification are indicated by an "x" on figures 25, 26, and 27. A total of 10 transponders failed this specification with 4 of those failing to suppress at all.

Figure 27 is a plot of the data from all the SLS amplitude characteristic tests at a level of MTL + 9 dB for each transponder. Only 141 samples passed the threshold of MTL + 9 dB (poor sensitivity or shielding of the antenna caused a reduction of dynamic range of the MTPA interrogations). The maximum signal capability (at the antenna of the aircraft under test) varied from site to site, but was normally in the area of -39 dBm.

FULTON COUNTY,PEACH TREE AND MCCOLLUM AIRPORTS

154 POINTS - REPLY RATE (%) VS P1 - P2 AMPLITUDE S.L.S. P1 @ -60 DBM

	0	> 1	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	
15	16	2	1	1			1	1		2	1	1	4	1	2	2	3	1	5	8	102	must reply ≥90%
12	17	2		1		1		1		1	2	1		1	3	3	3	2	4	9	103	
9	17	2	1			1		1			3	1	2	1	2	1	3	3	4	9	103	
6	19	4	2	1		2		1		5		4	6	2	5	3	6	4	6	13	71	
3	79	14	6	4	3	3	3	4	4	3	4	3	5	3	2	2	3	2	2	1	4	
0	134	11	1	2	1			1												1	3	must reply less than 1%
-3	145	3	2																1		3	
-6	145	5																	1		3	

154 POINTS - REPLY RATE (%) VS P1 - P2 AMPLITUDE S.L.S. P1 @ -50 DBM

	0	> 1	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	
15											1	1		2	1	2		2		13	132	Must reply ≥90%
12		1										2			1		1		1	7	141	
9	2							1			1		1		1	1	2	1	1	7	136	
6	11	3	2			2			2	3		4		3	2	4	4	1	3	12	98	
3	78	20	5	5	6	3	1	1	2		3	3	2	1	1	1	2	1	2	4	13	
0	145	2	1	1						1											4	Must reply less than 1%
-3	149											1									4	
-6	150	1									1										2	

FIGURE 21. MTPA TEST 15 DISTRIBUTION - ATLANTA SAMPLE

N15101 KING KT78
SIDE LOBE SUPPRESSION TEST - 5

2.0 FT -47 DB

P1 LEVEL (-DBM)

P1-P2	75	72	69	66	63	60	57	54	51	48	45	42	39	36	33	30	27	24
15	0	0	0	0	0	81	88	91	94	100	100	100	0	0	0	0	0	0
12	0	0	0	0	0	80	87	91	94	100	100	98	0	0	0	0	0	0
9	0	0	0	0	0	79	87	91	82	92	60	47	0	0	0	0	0	0
6	0	0	0	0	0	81	88	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	79	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-3	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0
-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

must reply at least 90%

MTL

FIGURE 22. INDIVIDUAL SAMPLE (MTPA TEST 5) - N15101

N15101 KING KT78
SIDE LOBE SUPPRESSION TEST - 15

2.0 FT -47 DB

P1-P2	P1 LEVEL (-DBM) 60	50
15	78	96
12	81	98
9	78	37
6	81	0
3	78	0
0	0	0
-3	0	0
-6	0	0

FIGURE 23. INDIVIDUAL SAMPLE (MTPA TEST 15) - N15101

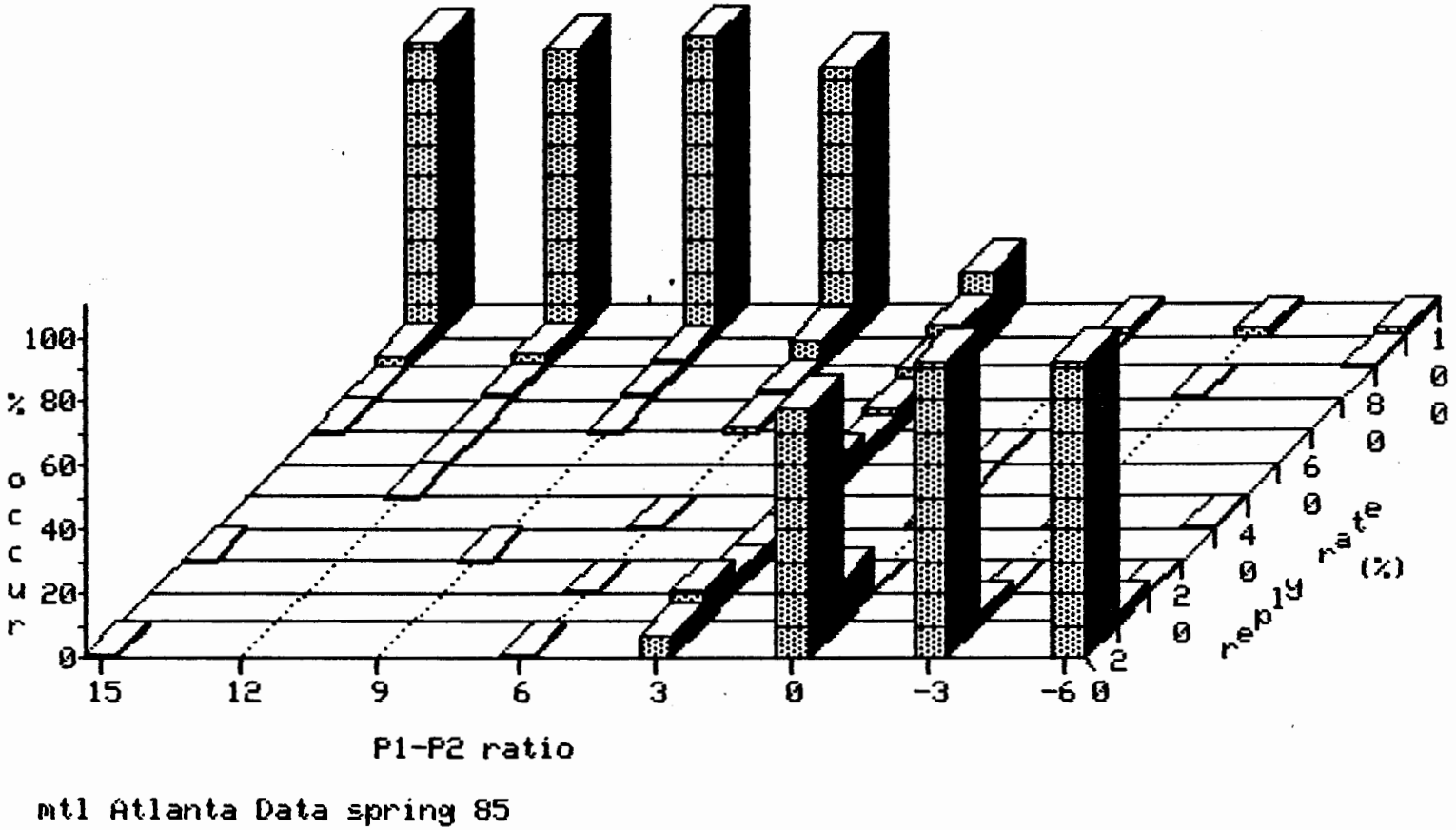


FIGURE 24. SLA AMPLITUDE CHARACTERISTICS DISTRIBUTION (MTL) - ATLANTA SAMPLE

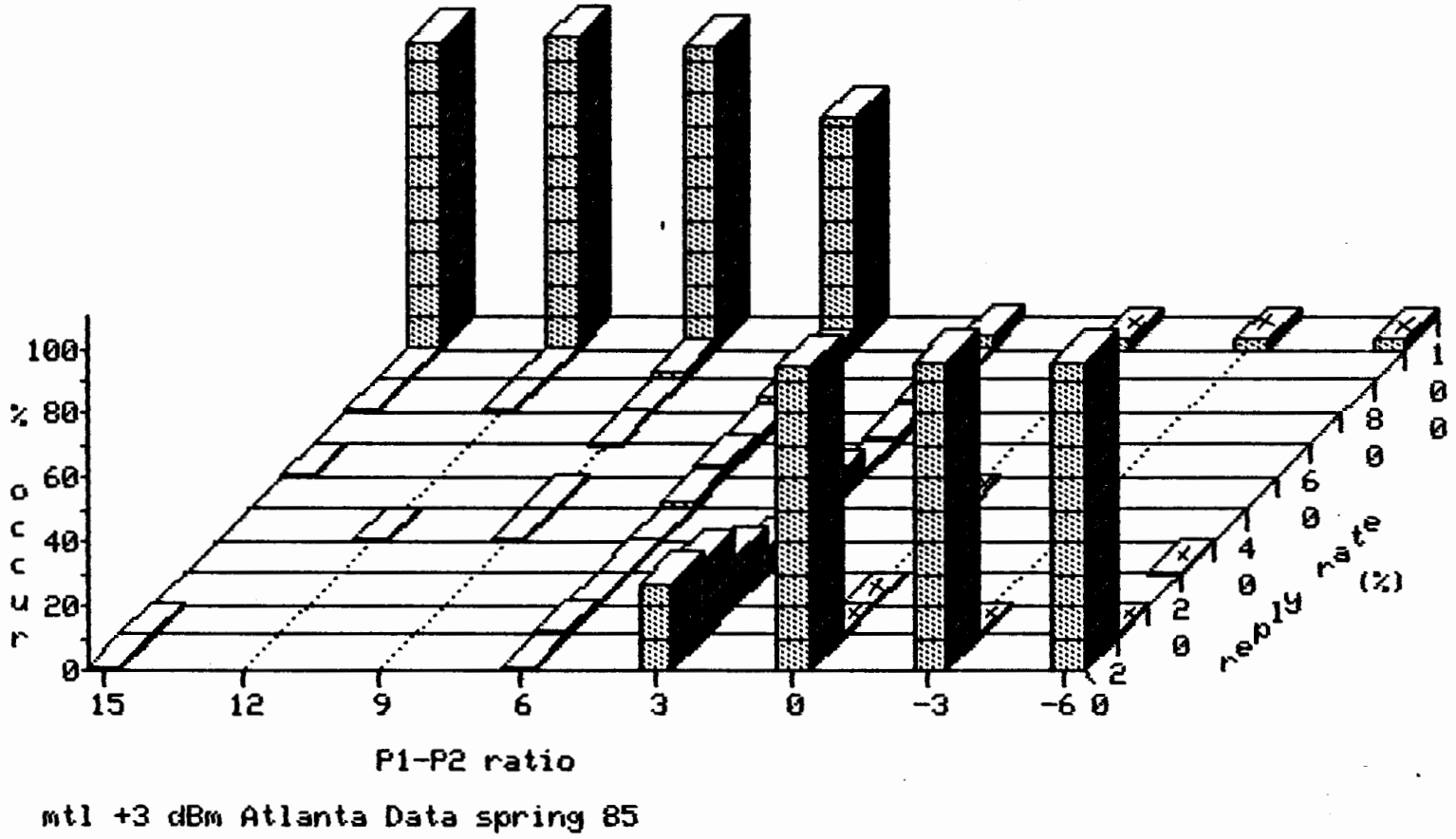


FIGURE 25. SLS AMPLITUDE CHARACTERISTICS DISTRIBUTION (MTL + 3 dB) - ATLANTA SAMPLE

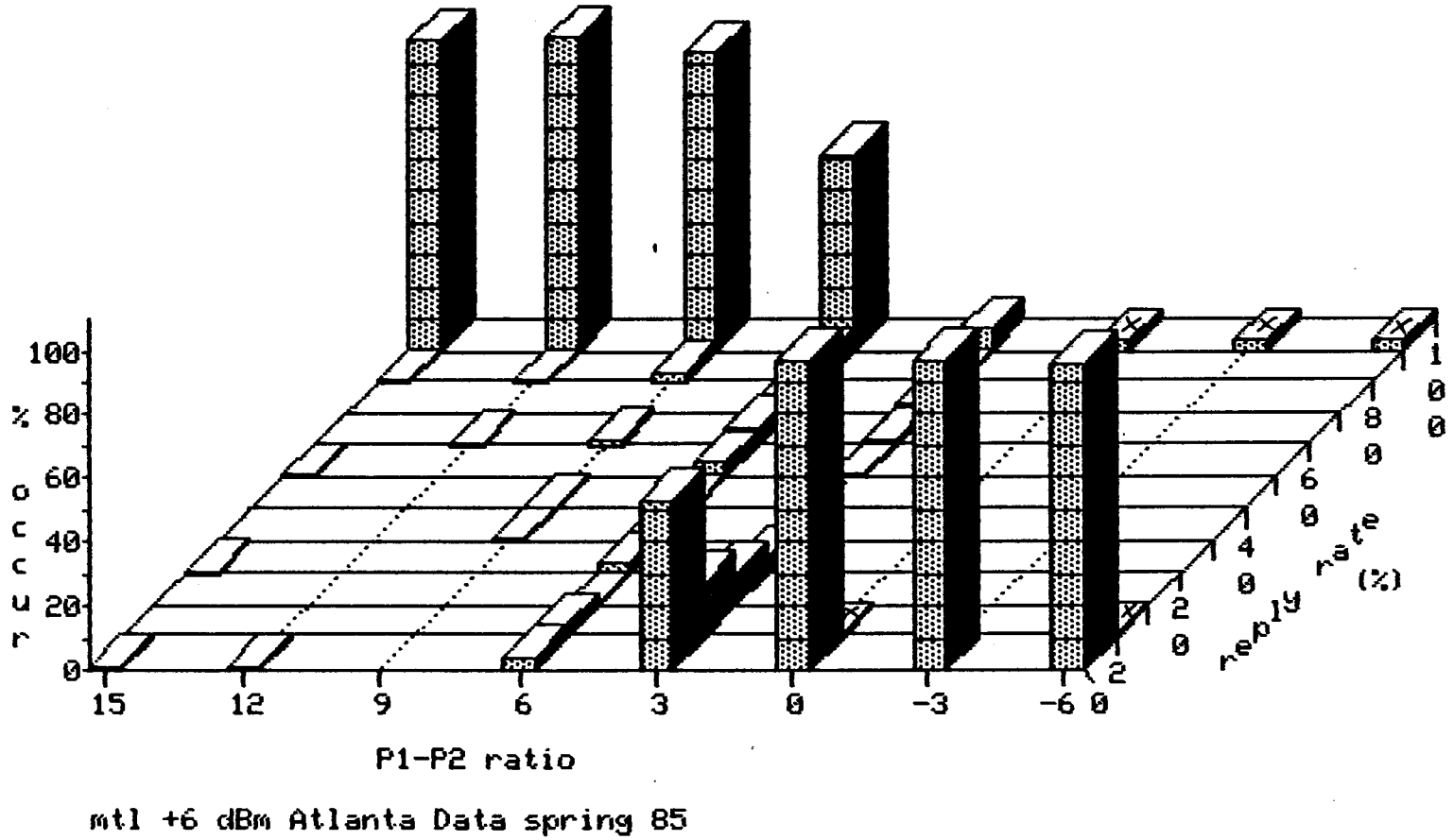


FIGURE 26. SLS AMPLITUDE CHARACTERISTICS DISTRIBUTION (MTL +6 dB) - ATLANTA SAMPLE

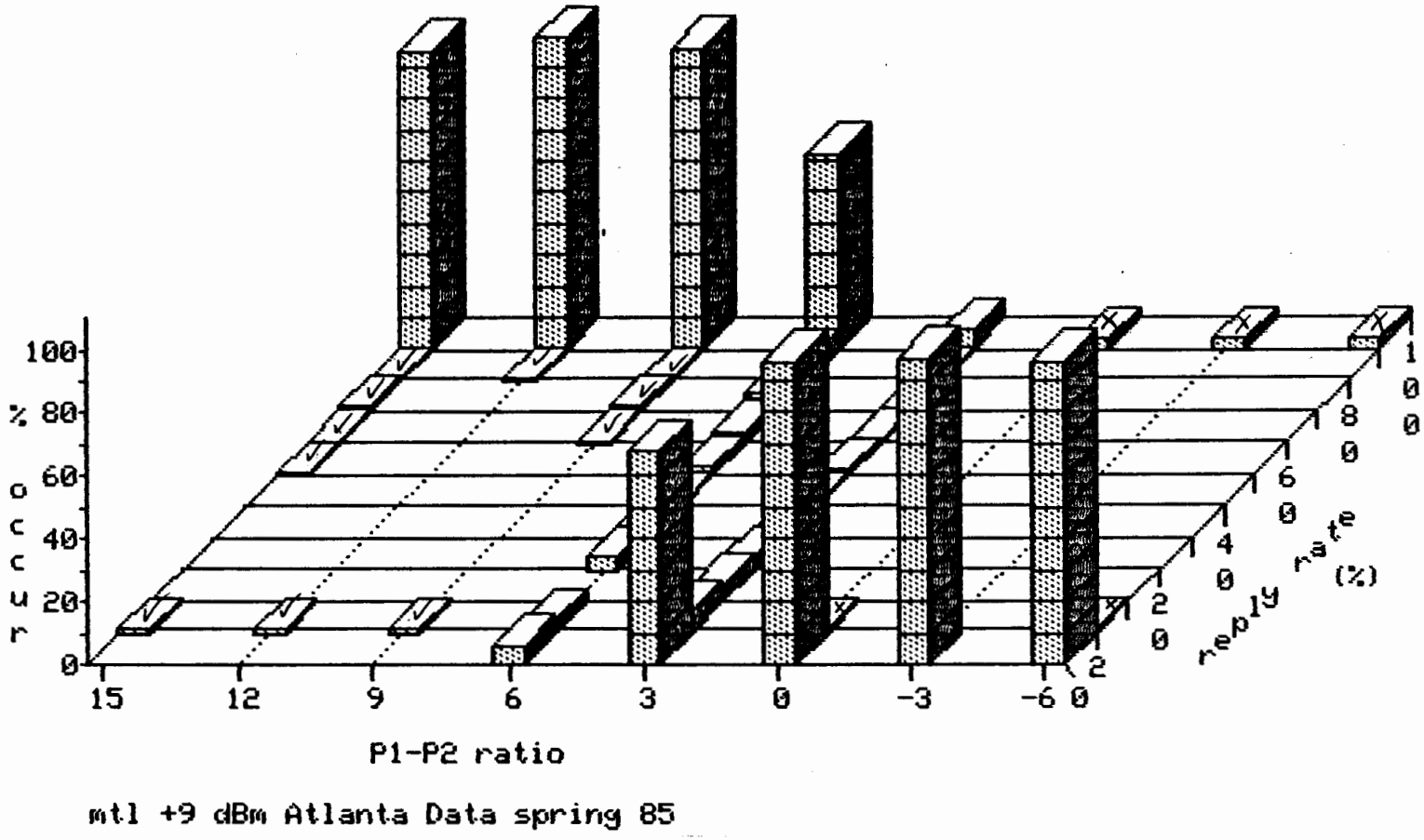


FIGURE 27. SLS AMPLITUDE CHARACTERISTICS DISTRIBUTION (MTL + 9 dB) - ATLANTA SAMPLE

The "must reply" area of the SLS specification applies when the signal level reaches MTL + 9 dB, so that the P2 pulse (if present) would be above the receiver noise. Failures to reply at a 90 percent rate or greater are indicated by a "check" on figure 27. A total of 12 transponders failed this criteria.

Figures 28, 29, and 30 are typical examples of transponders which failed to pass "must reply" portion of the SLS amplitude characteristics test. Normally, there was a "hole" of some sort in the pattern (see circled areas on the plots).

ALTITUDE COMPARISON. In this test (MTPA test No. 99) Mode S interrogations are made to our MTPA transponder in order to get the proper Mode C altitude data from our calibrated altimeter. These data are then compared to that received from the transponder being tested. The differences in these data are stored as the result of test No. 99. Figure 31 shows the distribution of data from the standard altitude for the Atlanta sample. Test 99 was run twice for each transponder. The number of samples is odd, because one transponder was switched from "no altitude" to "altitude on" between the two tests. The data were analyzed in more detail by selecting one or the other of the tests and using that for the characteristic of the transponder being tested. It shows that 107 tests (approximately 38 percent) replied to Mode C interrogations with "brackets only" or no altitude data. Of the remainder which did reply with altitude information, 27 (~9 percent) replied at a rate less than 90 percent. Ten (~5 percent) replied with altitude data outside the tolerance of plus or minus 125 feet. One replied with an error of 1,000 feet, and when the results were discussed with the pilot, he confirmed that he had been told by the ATC personnel that his altitude was erroneous.

POWER, SENSITIVITY, AND DELAY DATA. These parameters are checked by analysis of the reply data from all the other tests. The power and sensitivity are checked for the maximum value achieved, while the reply delay is checked for a minimum.

1. Reply Delay Data. The former algorithm used for determination of delay data (merely a search for the minimum value) was modified because of the large number of transponders whose delay varied widely as a function of other parameters. Figure 32 shows a typical example where delay is a function of interrogation pulse spacing. This transponder obviously does its timing off the P1 pulse and the delay is set to the nominal value of 3.0 μs at the middle of the interrogation acceptance window. As can also be seen from these data, this particular transponder had the interrogation acceptance window offset from the nominal interrogation spacing (8.0 and 21.0 μs for Modes A and C, respectively). In fact, this transponder did not respond at all at the nominal 21.0 μs Mode C spacing.

In order to get reply data which would be meaningful in the search for ATC system problems, the following change was made to the algorithm

N543GA TRANS #1 KING 76 3.0 FT -47 DB
SIDE LOBE SUPPRESSION TEST - 5

P1 LEVEL (-DBM)

P1-P2	75	72	69	66	63	60	57	54	51	48	45	42	39	36	33	30	27	24
	MTL			MTL+9														
15	91	100	100	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0
12	91	100	100	100	100	100	100	100	15	1	98	100	100	0	0	0	0	0
9	90	100	100	100	100	100	9	0	0	0	0	97	100	0	0	0	0	0
6	92	99	89	97	27	0	0	0	0	0	0	0	0	0	0	0	0	0
3	74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

FIGURE 28. INDIVIDUAL SAMPLE (MTPA TEST 5) - N543GA

4553F NARCO AT150 1.5 FT -50 DB
SIDE LOBE SUPPRESSION TEST - 5

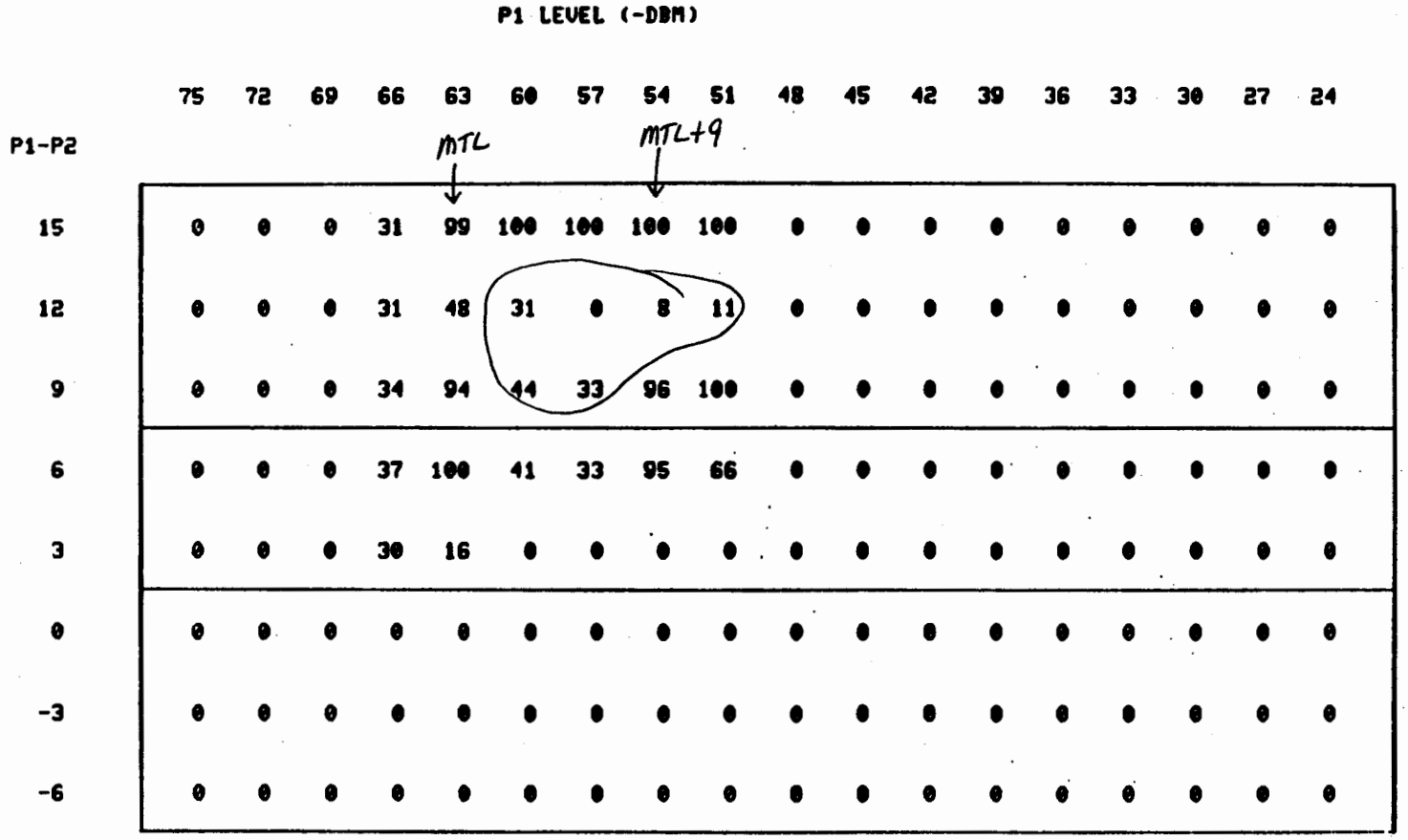


FIGURE 29. INDIVIDUAL SAMPLE (MTPA TEST 5) - N4553F

N15101 KING KT78 LETTER
SIDE LOBE SUPPRESSION TEST - 5

2.0 FT -47 DB

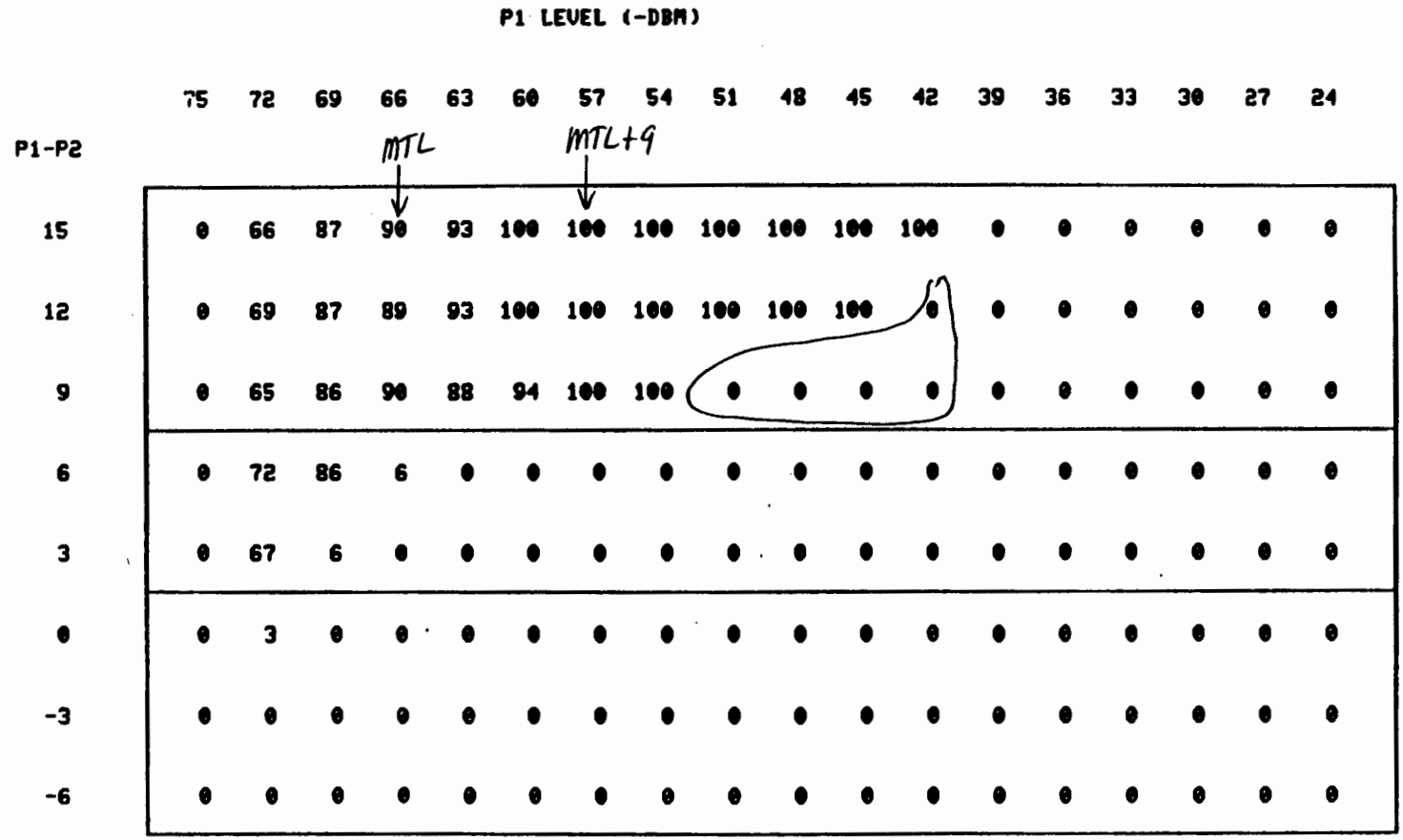


FIGURE 30. INDIVIDUAL SAMPLE (MTPA TEST 5) - N15101

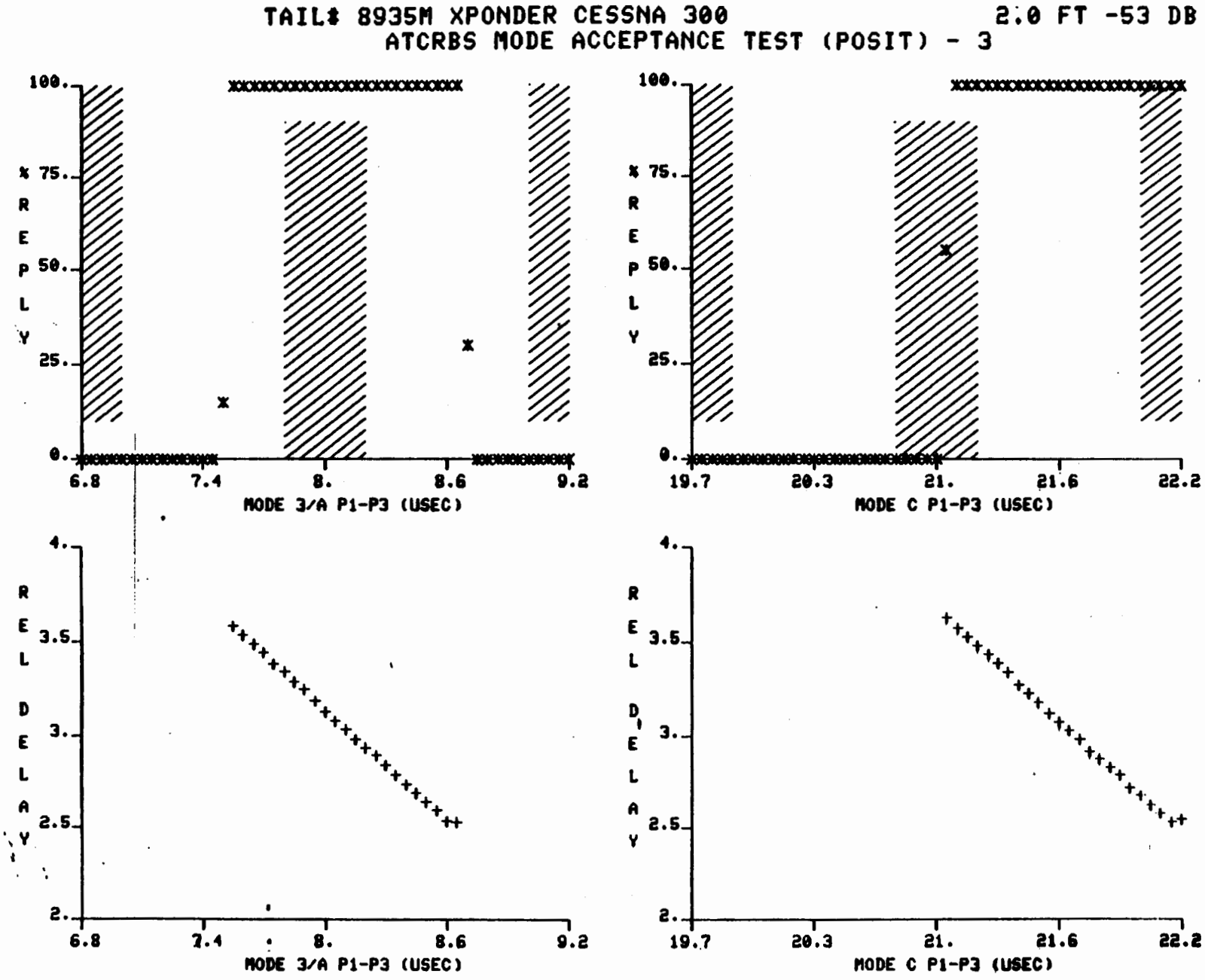


FIGURE 31. ALTITUDE ERROR DISTRIBUTION - ATLANTA SAMPLE

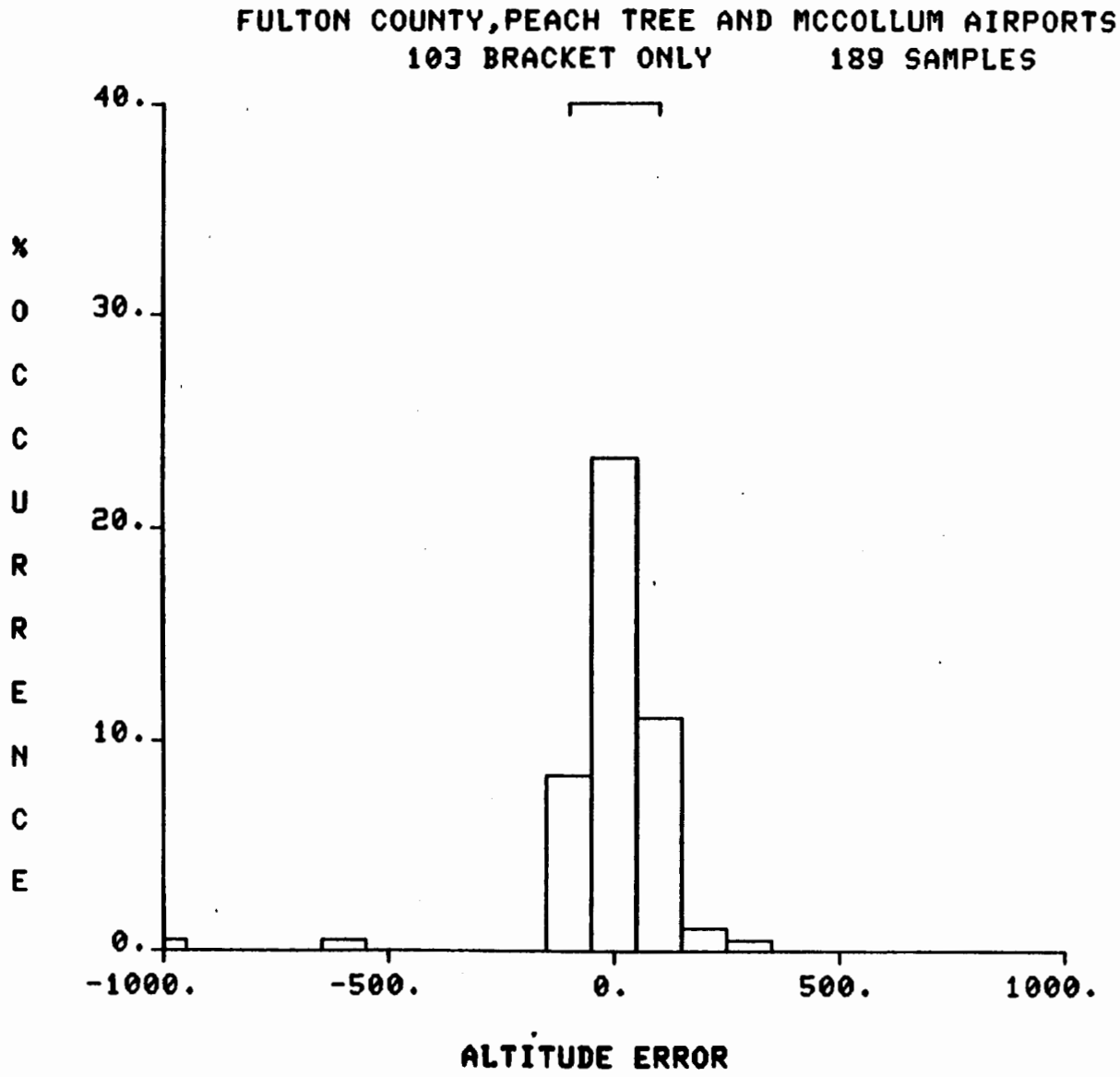


FIGURE 32. INDIVIDUAL SAMPLE - MODE ACCEPTANCE - N8935M

which determined the delay data for our sample. Since the interrogators' pulse characteristics are tightly controlled, the assumption was made that the interrogators were always at the nominal position for all variables during a particular test. Thus, even though a test varied a parameter on both sides of nominal (as all of them do), the delay data from that test was only used when the variable was at the nominal value. The new set of delay values (one from each test taken when the variable is at nominal) was then searched for the minimum. This value was used as the reply delay data for each transponder. Figure 33 shows the distribution of delay data for the Atlanta sample. Nine transponders, or approximately 5 percent, were outside the limits of 2.5 to 3.5 μs.

2. Reply Power Data. Figure 34 shows the distribution of reply power data from the 154 samples. After applying a 3 dB allowance for measurement error due primarily to the reflection environment discussed previously, 33 transponders (approximately 21 percent) fell outside the allowable limits. Most of the failures were on the high side of the specification. Almost all of the military planes tested fell into this category.

3. Sensitivity Data. Sensitivity tests (MTPA test No. 14) were run continuously as the aircraft taxied past the nose of the interrogation beam after the remainder of the tests had been completed. The results of each test (successive approximation search for the Modes A and C sensitivity value) were then examined and the highest value achieved was used as the sensitivity of that transponder. The reply power of each group was also used as an input to the power analysis above. Figures 35 and 36 show the distribution of sensitivity for Modes A and C, respectively. After allowing a plus and minus tolerance for measurement error, 39 transponders (~25 percent) failed to meet the sensitivity requirements for Mode A sensitivity. Only 147 samples are included in the Mode C sample as the remainder did not reply at nominal interrogation characteristics (investigation of more detailed data showed that the transponders did answer at other than nominal spacing (see figure 32 for example). Thirty-nine or 27 percent of the transponders failed to meet the Mode C sensitivity criteria.

REPLY RATE LIMITING. The reply rate limiting test consists of making interrogations at four different PRF's and recording the reply rates to those interrogations. The PRF's are 1,000, 1,400, 1,700, and 2,000 interrogations per second. The transponders should respond to at least 90 percent of the interrogations to a rate of at least 1,000 interrogations per second. (Transponders of aircraft designed to operate above 1,500 feet must respond at least 90 percent to a rate of 1,200 per second.) Figure 37 is a plot of the reply rate data from Atlanta. As shown, 10 percent failed to respond at least 90 percent at 1,000 interrogations per second. Approximately 5 percent showed no reply rate limiting at all at rates up to 2,000 interrogations per second.

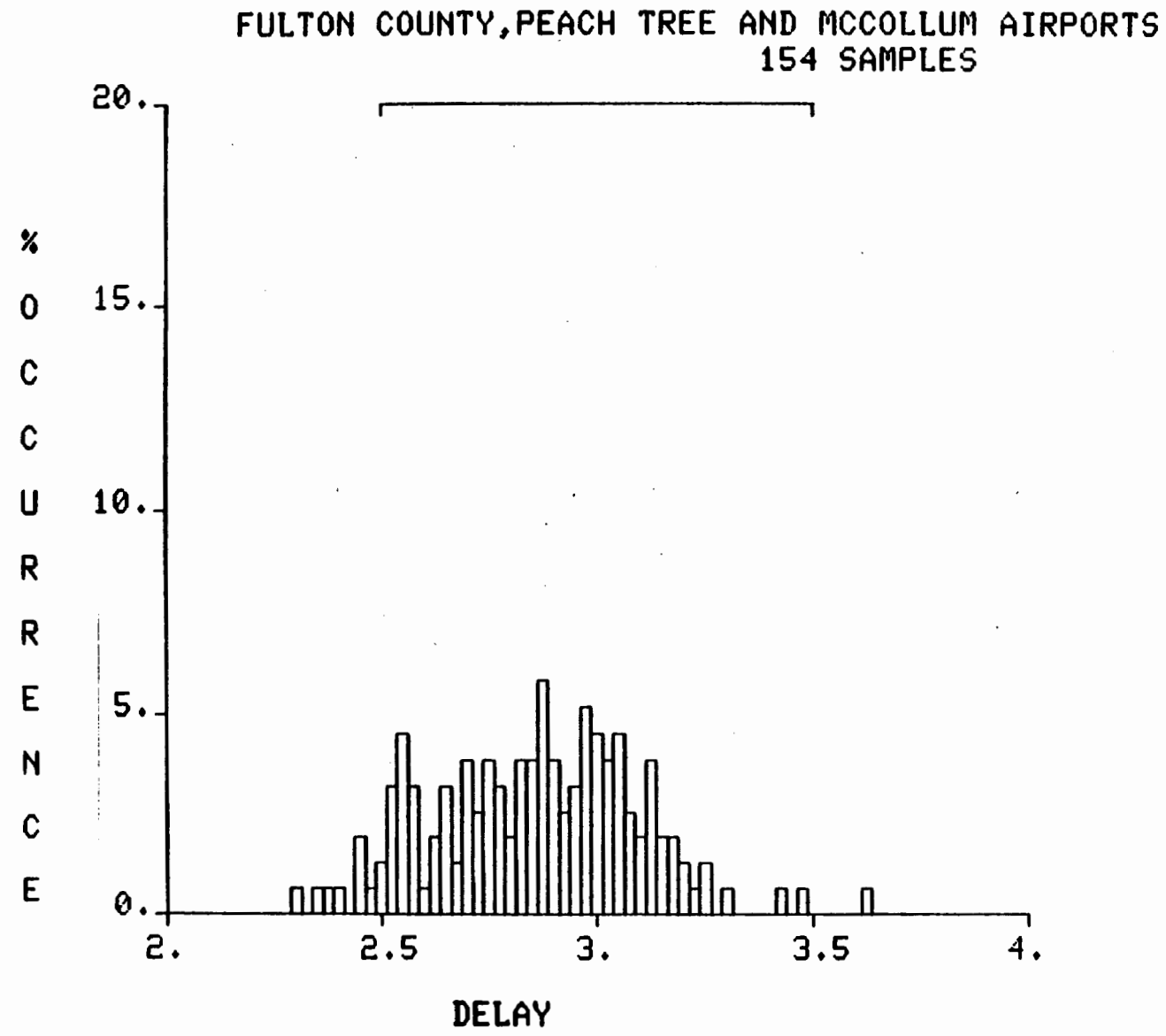


FIGURE 33. REPLY DELAY DISTRIBUTION - ATLANTA SAMPLE

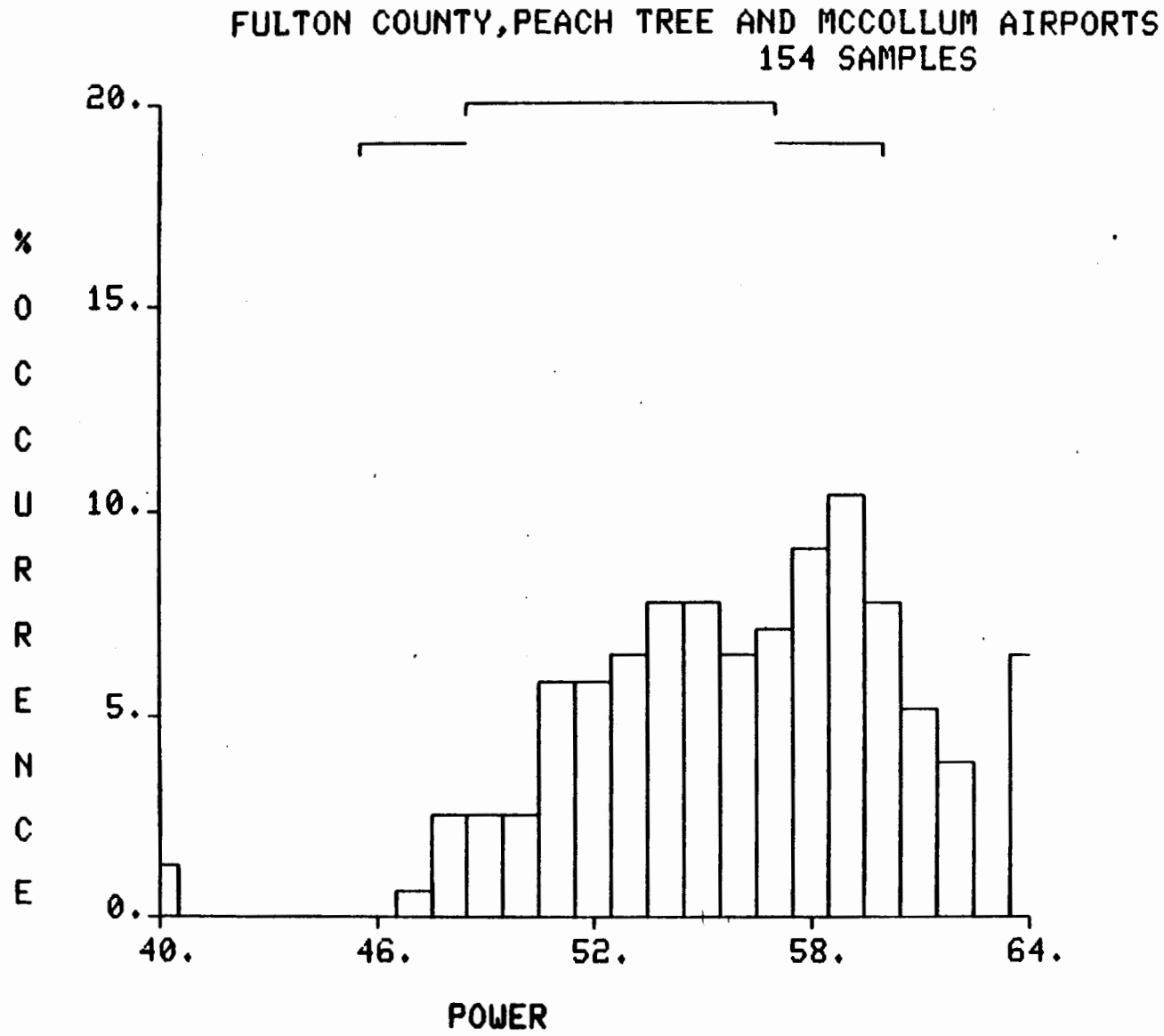


FIGURE 34. REPLY POWER DISTRIBUTION - ATLANTA SAMPLE

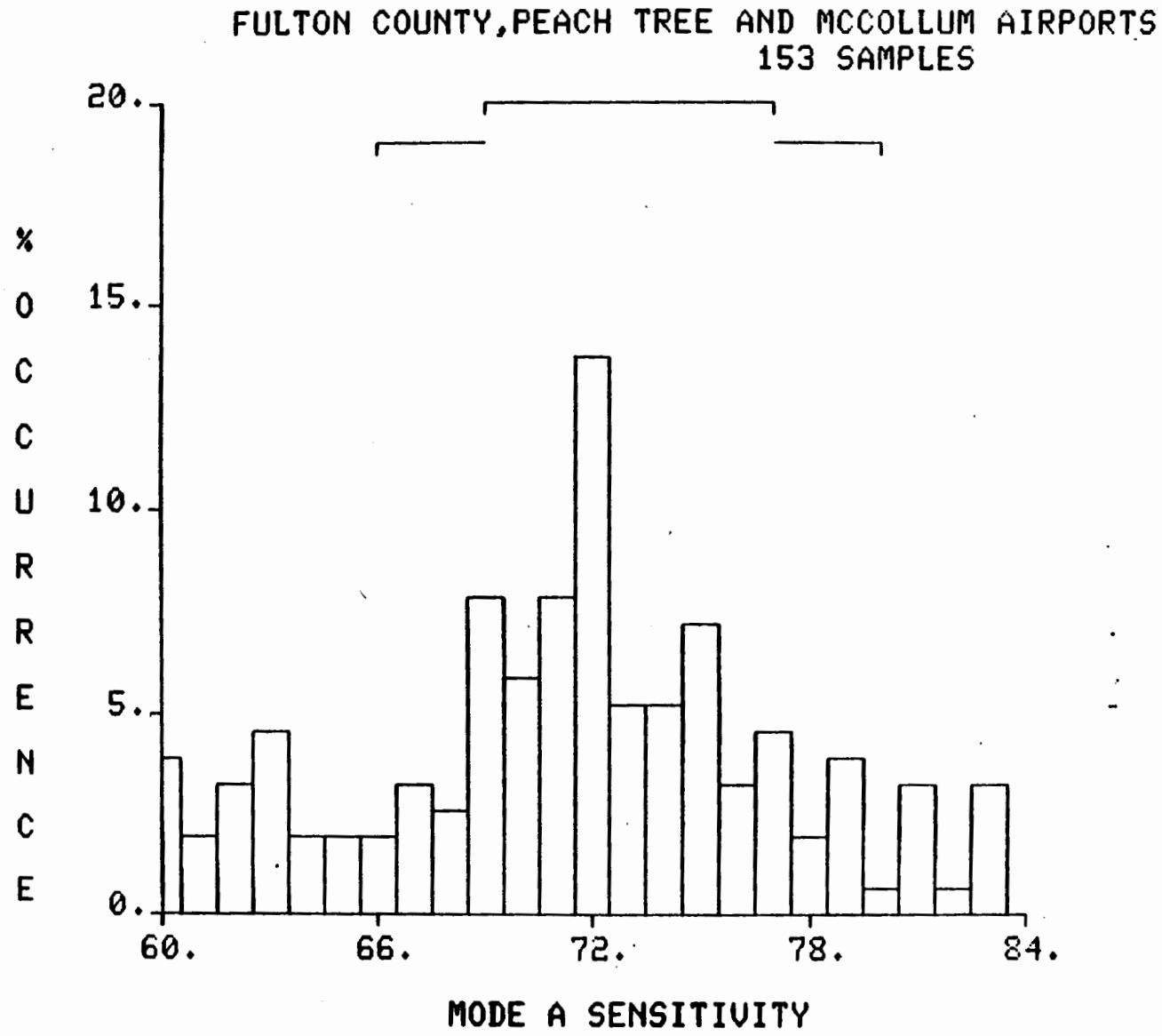


FIGURE 35. MODE A SENSITIVITY DISTRIBUTION - ATLANTA SAMPLE

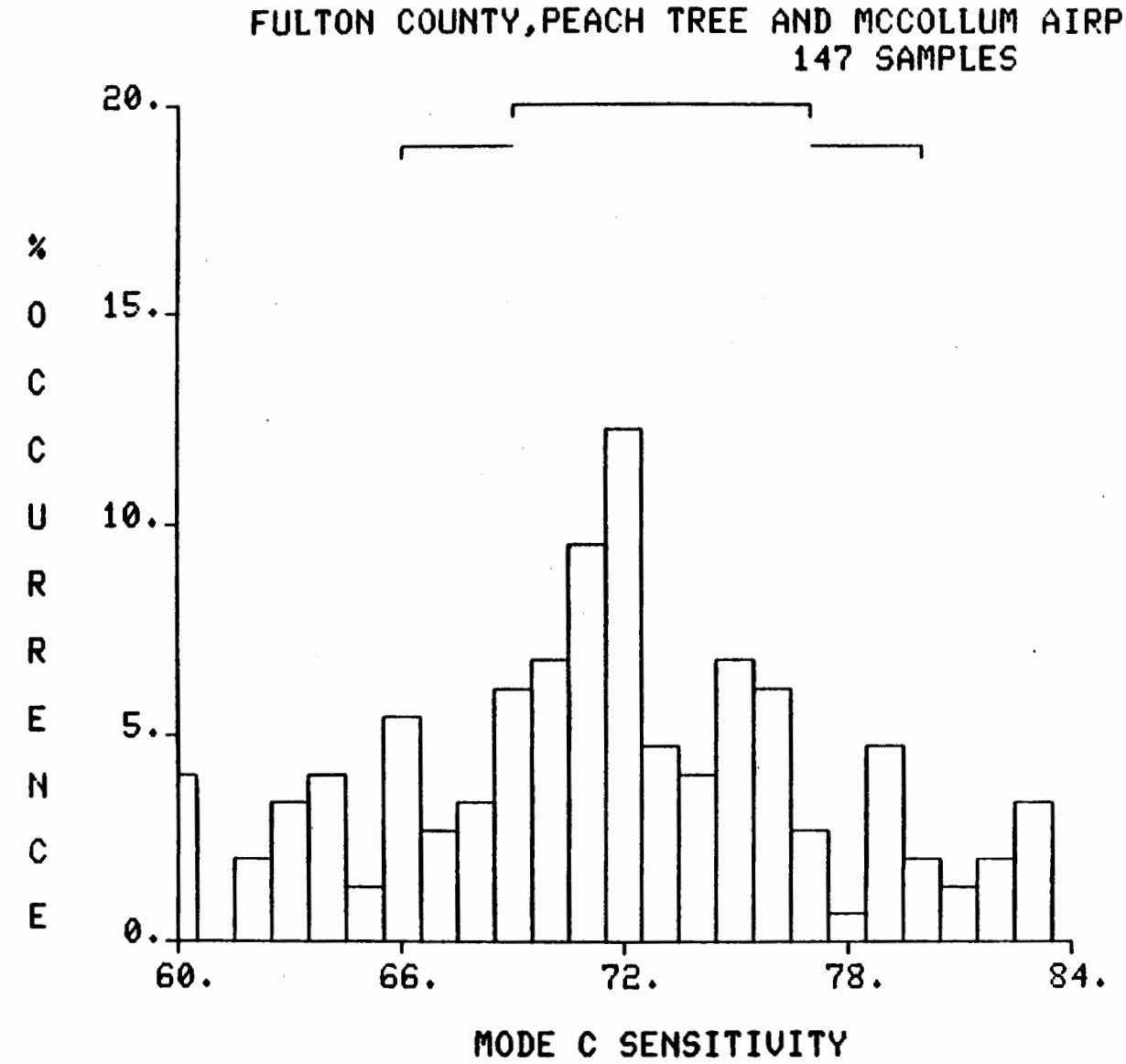


FIGURE 36. MODE C SENSITIVITY DISTRIBUTION - ATLANTA SAMPLE

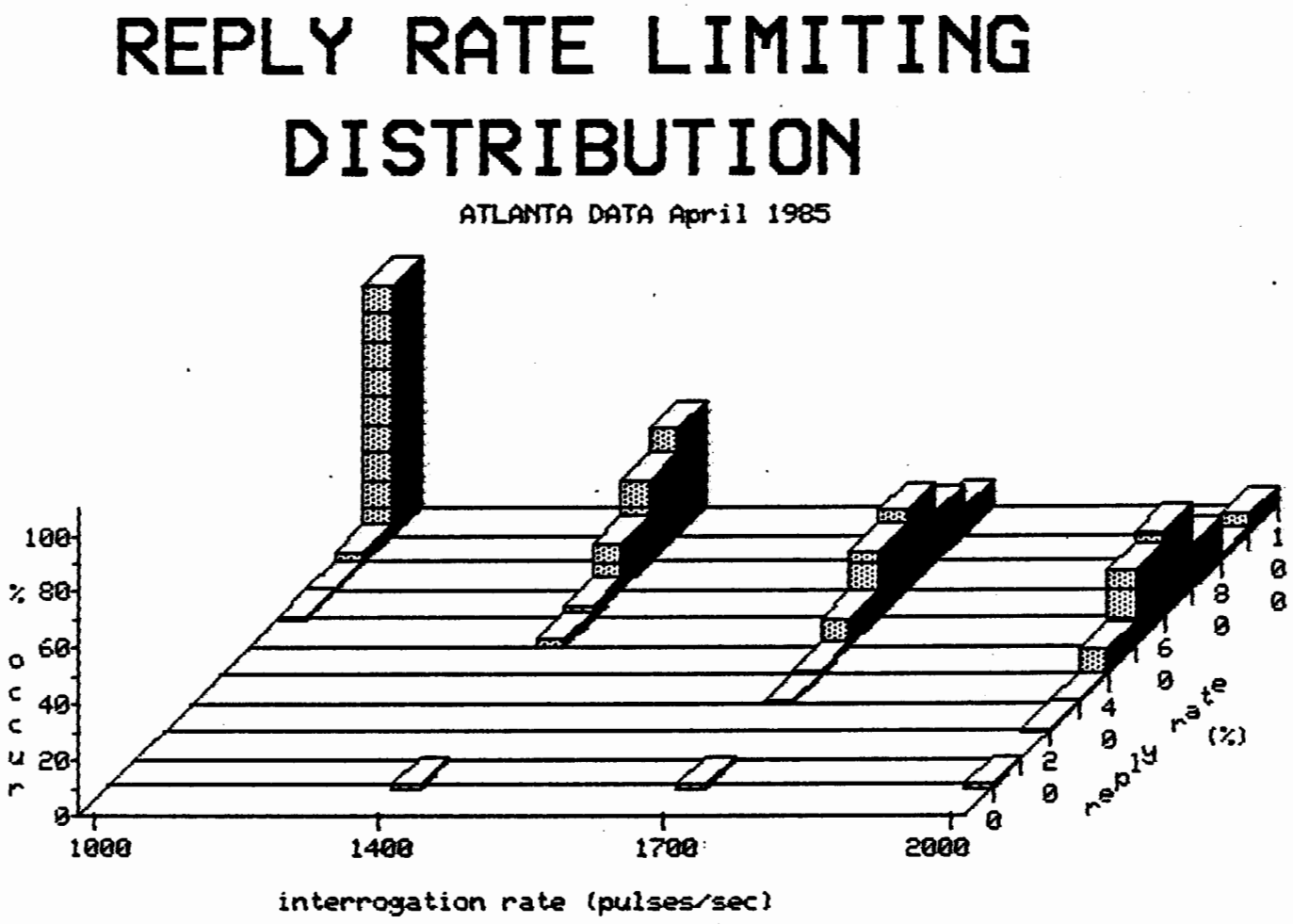


FIGURE 37. REPLY RATE LIMITING DISTRIBUTION - ATLANTA SAMPLE

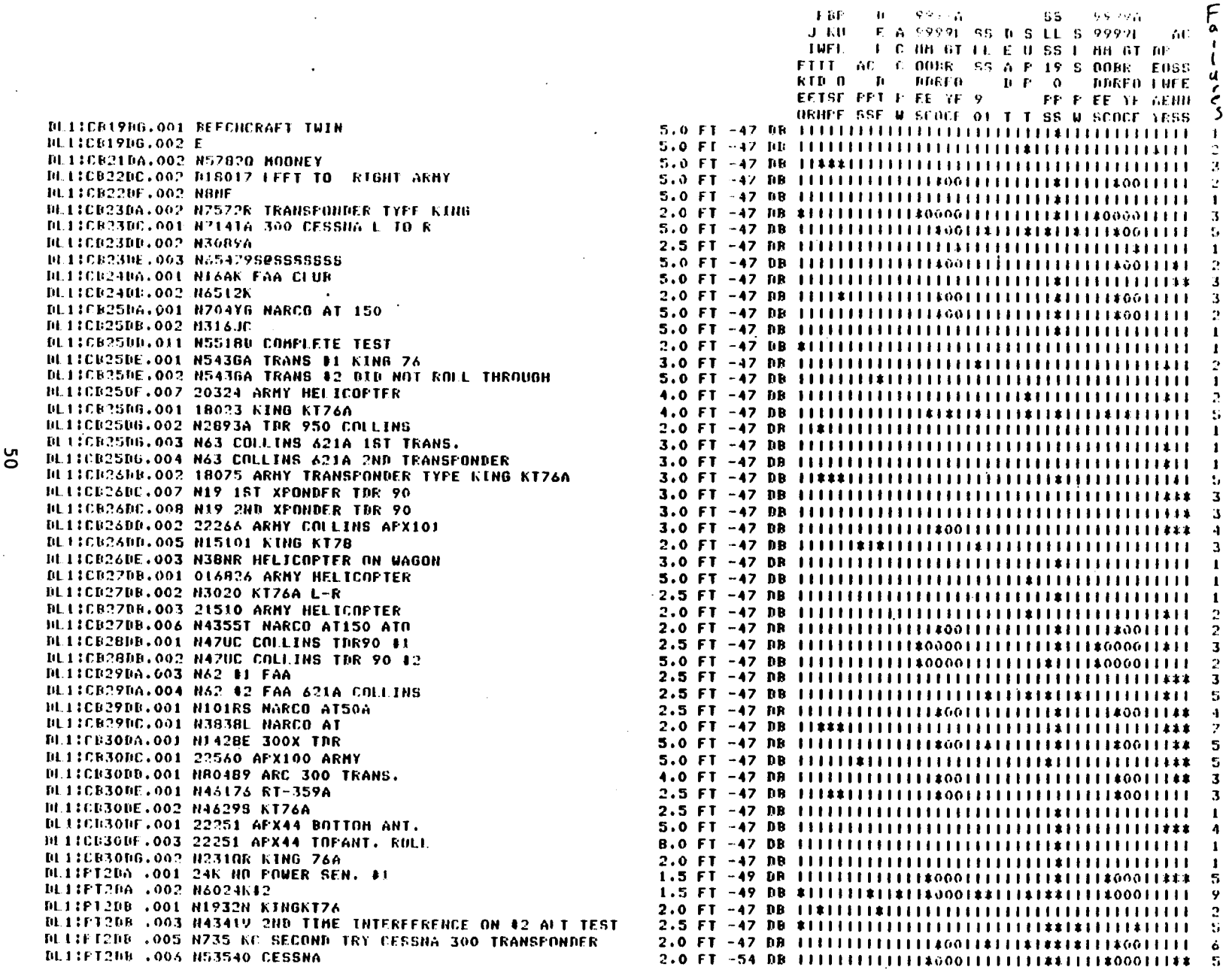


FIGURE 38. ATLANTA INDIVIDUAL TEST DATA SUMMARY - (SHEET 1 OF 3)

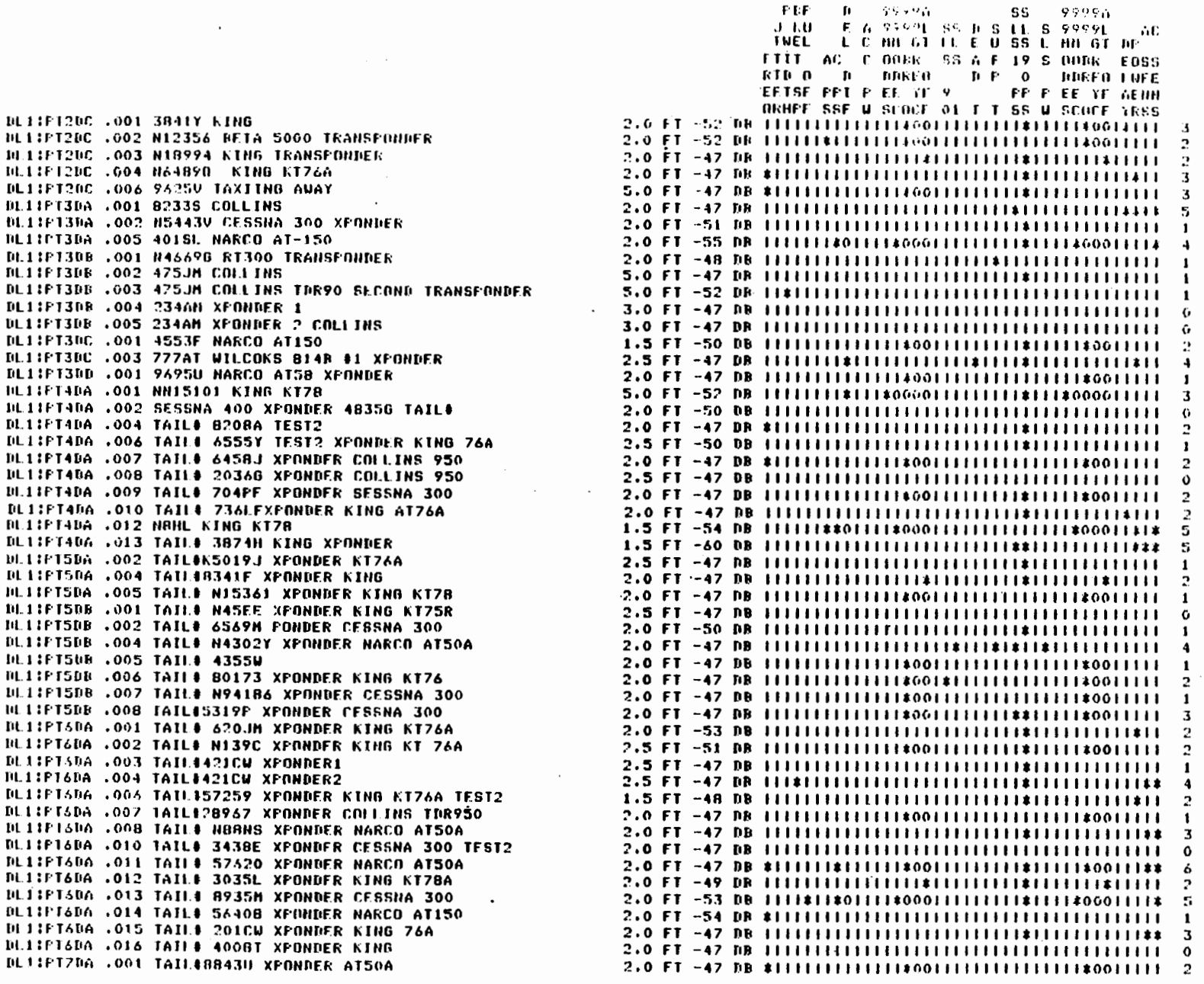


FIGURE 38. ATLANTA INDIVIDUAL TEST DATA SUMMARY - (SHEET 2 OF 3)

```
FBF   H   95996        SS   9999A
 J KU   E A 9999L SS D S LL S 9999L   AC
 IWEL   L C HH GT II F U SS L HH GT DF
FTIT  AC  C OOBK  SS A F 19 S OOBR  EOSS
RTD O   D   DHKFO    D P  6   DOKFO IWFE
EFTSF PPI P FE YF V      PP P FE YF AEHH
ORHPF SSF W SCOCF OI T T SS W SCOCF YRSS
```

DL1:P170A .002	TAIL#N98321 XPONDER KING	2.0 FT	-47 DB	II*IIIIIIIIIII*00IIIIIIIIIIIIIII*06IIIII	2
DL1:MC9DA .001	TAIL#4076W XPONDER KING KT76A	2.0 FT	-47 DB	IIIIIIIIIIIIII*IIIIIIIIIII*IIIIIIIIII*II	4
DL1:MC9DA .002	TAIL#28847 XPONDER NARCO AT150	2.0 FT	-47 DB	IIIIIIIIIIIIII*60IIIIIIIII*IIIIII*IIIIII	3
DL1:MC9DB .001	TAIL#N94709 XPONDER KING 78A	2.0 FT	-47 DB	IIIIIIIIIIIIIIIIIIIIIIIIII*IIIIIIIIIIIII	1
DL1:MC9DC .001	TAIL#79482 XPONDER BETA 5000	2.0 FT	-44 DB	IIIIII**0IIII*000I*IIIIII**IIII*000III**	9
DL1:MC9DD .001	TAIL#140739 XPONDER BENDIX TEST2	2.0 FT	-44 DB	IIIIIIIIIIIIIII*0I*IIIIIIIIIIIIII*0II*II	3
DL1:G .001	N97150 NARCO AT50A	5.0 FT	-37 DB	IIIIIII*IIIIII*00IIIIIIIIIIIIIII*00III**	4
DL1:G .002	N8258S KING KT76	2.0 FT	-44 DB	IIIIIIIIIIIIIIIIIIIIIIIII**IIIIIIIIII*II	3
DL1:G .003	N8282Z KING KT76A	2.0 FT	-44 DB	IIIIIIIIIIIIII*06I*IIIIIII*IIIII*00IIIII	3
DL1:G .004	N8274T CESSNA 300	2.0 FT	-44 DB	IIIIIIIIIIIIIIIIIIIIIII*II*IIII*I*IIIIII	4
DL1:G .005	N6453H KING KT76A INTERFERENCE	2.0 FT	-44 DB	IIIIIIIIIIIIIIIIIIIIIIIIII*IIIIIIIIIIIII	1
DL1:G .006	N757MC CESSNA 300	2.0 FT	-52 DB	IIIIIIIIIIIIII*00IIIIII*II*IIIII*06IIIII	3
DL1:MC10DA.001	TAIL#9350N	2.0 FT	-47 DB	IIIIII*IIIIIII*06IIIIIIIII*IIIII*00IIIII	3
DL1:MC10DA.003	TAIL#6340P XPONDER CESSNA 300	2.0 FT	-47 DB	IIIIIIIIIIIIII*00IIIIII*IIIIIIII*00IIIII	2
DL1:MC10DA.004	TAIL#6228C XPONDER KING KT76A	2.0 FT	-47 DB	IIIIIIIIIIIIIIIIIIIIIIIII**IIIIIIIIIII**	4
DL1:MC10DA.005	TAIL#94445 XPONDER CESSNA	2.0 FT	-47 DB	IIIIIII*IIIIII*00IIIIIIIIIIIIIII*00IIIII	2
DL1:MC10DA.006	TAIL#4937H XPONDER CESSNA 300	2.0 FT	-47 DB	IIIIIIIIIIIIII*00IIIIII*II*IIIII*06IIIII	3
DL1:MC10DA.007	TAIL#8219Y SHIELDING PROB.	2.0 FT	-44 DB	IIIIIIIIIIIIIIIIII**IIIII**IIIIIIIII*I*I	6
DL1:MC10DB.001	N734WR RT 359A FUEL TRUCK & HELI.	2.0 FT	-47 DB	IIIIIIIIIIIIII*00IIIIII*IIIIIIII*00IIIII	2
DL1:MC10DB.004	N221AM HELICOPTER 3RD TRY	3.0 FT	-47 DB	IIIIIIIIIIIIIIIIIIIIIIIIII*IIIIIIIIIII**	3
DL1:MC10DB.005	N2791T KING KT76A #1 TRANS.	2.0 FT	-47 DB	IIIIIIIIIIIIIIIIIIIIIIIII**IIIIIIIIIIIII	2
DL1:MC10DB.006	N2791T REGENCY #2 TRANS.	2.0 FT	-47 DB	*IIIIIIIIIIIII*00IIIIIIIIIIIIIII*00IIIII	2
DL1:MC10DB.007	TAIL#2777Y XPONDER KING KT76	2.0 FT	-47 DB	IIIIIII**IIIII*00IIIIIIIIIIIIIII*00IIIII	3
DL1:MC11DA.001	N7026P NARCO AT50A	2.0 FT	-47 DB	IIIIIIIIIIIIII*00IIIIIIIII*IIIII*00II*II	3
DL1:MC11DA.002	TAIL#8876X XPONDER KING KT76A	2.0 FT	-47 DB	IIIIIIIIIIIIIIIIII*IIIIIII*IIIIIIIIIII**	4
DL1:MC11DA.003	TAIL#8961U	2.0 FT	-47 DB	IIIIIIIIIIIIII*00IIIIIIIII*IIIII*00II*II	3
DL1:MC11DA.004	TAIL#65740 XPONDER CESSNA 300	2.0 FT	-47 DB	IIIIIIIIIIIIIIIIIIIIIII*II*IIIIIIIIIII**	4
DL1:MC11DA.005	N44979 NARCO	2.0 FT	-47 DB	IIIIIIIIIIIIIIIIIIIIIIIIII*IIIIIIIIII*II	2
DL1:MC11DA.006	N92658 KING KT78	2.0 FT	-47 DB	IIIIII**IIIII***0IIIIIIIII*IIII***0I*II*	8
DL1:MC12DA.001	N6707M	2.0 FT	-47 DB	IIIIIIIIIIIIII*00IIIIII*IIIIIIII*60III**	4
DL1:MC12DA.002	N5555Y PASSED BEAM	2.0 FT	-47 DB	IIII*II*0IIII*000*IIIIIIII*IIII*000II***	8
DL1:MC12DA.003	N990AR KING KT76A #2	2.5 FT	-47 DB	*IIIIIIIIIIIIIIIIIIIIIIIII*IIIIIIIIIIIII	2
DL1:MC12DA.004	N990AR TRANS. #1	2.5 FT	-47 DB	IIIIIIIIIIIIIIIIII*IIIIIII*IIIIIIIIIII**	4
DL1:MC12DA.005	TAIL#53890 XPONDER CESSNA 300	2.0 FT	-47 DB	III**I*I0*III**0*IIIIII*II*IIIII**0IIIII	10
DL1:MC12DA.006	TAIL#64136 XPONDER CESSNA300 INTEFERENCE SEN.	2.0 FT	-47 DB	II*IIIIIIIIIIII*00IIIIIIIII*IIIII*00II**	5
DL1:MC12DA.007	TAIL#538MC COLLINS 1	2.0 FT	-47 DB	IIIIIIIIIIIIIIIIIIIIIIIIII*IIIIIIIII*III	2
DL1:MC12DA.008	TAIL#538MC COLLINS 2	2.0 FT	-47 DB	IIIIIIIIIIIIIIIIII*IIIIIII*IIIIIIIIIII**	4
DL1:MC12DA.010	TAIL#507MC HELI. COLLINS	3.0 FT	-47 DB	IIIIIIIIIIIIII*00*IIIIIIIIIIIIII*00I*III	3
DL1:MC12DA.011	N39494 KING 78 NO SENS.	5.0 FT	-47 DB	IIIIIIII0IIIII*00IIIIIIIII*IIIII*00III**	4
DL1:MC12DA.012	TAIL#7026P NARCO AT58	2.0 FT	-47 DB	IIIIIIIIIIIIII*00*IIIIIIII*IIIII*00II*II	4
DL1:MC12DA.013	N2524Y	2.0 FT	-47 DB	IIIIII**0IIII*000*IIIIIIIIIIIII*000II*I*	6
DL1:MC12DB.001	N555FC KT76A	2.0 FT	-47 DB	IIIIIIIIIIIIIIIIIIIIIIIIII*IIIIIIIIIIIII	1
DL1:MC13DA.001	TAIL#52806 XPONDER R235A	2.0 FT	-47 DB	IIIIIIIIIIIIII*00IIIIII*IIIIIIII*00III**	4
DL1:MC13DA.002	TAIL#81177 XPONDER KING KT76A	2.0 FT	-51 DB	IIIIIIIIIIIIIIIIIIIIIIIIII*IIIIIIIIIIIII	1
DL1:MC13DA.004	TAIL#4621R COLLINS	2.0 FT	-47 DB	*IIIIIIIIIIIII*00IIIIIIIIIIIIIII*00II*II	3
DL1:MC13DA.005	TAIL#3598J NARCO AT150	2.0 FT	-47 DB	IIIIIIIIIIIIIIIIIIIIIIIIII*IIIIIIIIIIIII	1
DL1:MC13DA.007	TAIL#6344V CESSNA 300 TES2	2.0 FT	-47 DB	IIIIIIIIIIIIIIIIIII*III*IIIIIIIIIIIIII*I	3
DL1:MC13DA.008	TAIL#47850 KING KT76A	2.0 FT	-47 DB	*IIIIIIIIIIIII*00IIIIIIIII*IIIII*00IIIII	3
DL1:MC13DB.001	N5345T KING INC. TEST	2.0 FT	-47 DB	IIIIIIIIIIIIIIIIIIIIIII*II*IIII*000III**	5
DL1:MC13DC.001	TAIL#5581W NARCO AT150	2.0 FT	-50 DB	IIIIIIIIIIIIII*00IIIIIIIIIIIIIII*00I*I*I	3
DL1:MC13DC.002	N26076 KING KT76	2.0 FT	-47 DB	IIIIIIIIIIIIII*00IIIIIIIII*IIIII*00IIIII	2

FIGURE 38. ATLANTA INDIVIDUAL TEST DATA SUMMARY - (SHEET 3 OF 3)

ANALYSIS OF THE FAILURES AND THEIR EFFECT ON THE ATC SYSTEM.

A program was written to examine all the data collected for the entire sample and output a summary sheet containing the parameter(s) failed, if any, for each of the transponders. The summary output of this program is shown in figure 38. An "*" indicates a failure of the parameter at the top of the column (i.e., the first entry "Beechcraft twin" failed to reply at least 90 percent to the SLS pulse spacing test at all required points). A "0" indicates that, for some reason, the parameter was not tested. As an example, aircraft "D18017" was not tested for altitude characteristics as it replied "brackets only" to the altitude test. These data were then used in order to examine each of the failures in an effort to determine the effect on the ATC system. The failures will be discussed by parameter.

1. Frequency. Approximately 9 percent of the transponders tested fell outside the allowable limits of 1087 to 1093 MHz. As the reply pulse frequency deviates from the center frequency (1090 MHz), the receiver output begins to show distortion in both amplitude and pulse shape. Within the receiver bandwidth (the FAA ground sites are normally 1086 to 1094 MHz), the distortion is not significant. The pulse will be attenuated approximately 2.5 dB and stretched to about 550 ns, compared to an input pulse at 1090 MHz which would produce the proper pulse width of 450 ns. As the frequency deviation reaches beyond approximately 4.7 MHz, however, the distortion of the output pulse becomes severe. Beyond this point, in addition to more attenuation, the pulse splits into a pulse pair approaching a limit of 1/bandwidth of the receiver or approximately 0.125 ns. The one sample encountered at a frequency of 1096.8 would almost surely not survive the thresholding process of the digitizers as the video output of the receiver would be attenuated by approximately 15 dB and each pulse would appear as a pulse pair approximately 250 ns wide.

The pilot of this plane had received a letter from the FAA indicating a potential problem with his transponder. The data from his complete test is furnished as appendix B. This transponder never reached a 90 percent reply rate in any of the tests. If this transponder uses the transmitter frequency source as the local oscillator for its receiver (as many designs do), the problem of pulse distortion would occur in its receiver and could account for the overall poor performance because of only this one (frequency) parameter.

The receiver of the MTPA system has a bandwidth of 20 MHz, so the distortion due to the MTPA receiver of the off frequency signal is negligible.

2. Bracket Spacing. The ground system bracket detectors are normally set to accept bracket pairs spaced at 20.1 to 20.4 μs in order to accommodate out of tolerance transponders. As a result of this widened acceptance zone, of the six transponders out of the specified limits only one would have probably not been detected as its spacing was 20.55 μs.

3. Pulse Width. Most of the ground systems contain "pseudo-lead edge" logic, which inserts extra lead edges into the code determination logic when the input pulse exceeds a certain value. The assumption is that a wide pulse is really the result of the overlapping of code pulses from two ATCRBS replies, so one lead edge is inserted at the true lead edge of the wide pulse and the second is inserted at a point 400 to 500 ns before the trailing edge. This enables the decoder to resolve code problems in a "garble or overlapping" situation. This parameter is normally site dependent, but a normal value is approximately 600 ns. Some of the transponders with wide output pulses would probably trigger this pseudo-lead edge mechanism and may result in the declaration of two targets where only one really exists (split targets).

4. Code Pulse offset Transponders which failed this specification would probably be detected with the wrong code. Depending on the sampling point of the code pulses on each reply, the correct code could occasionally be decoded, but the validity of the code data would be low.

One transponder replied with the wrong code during the test. At that time we were not requesting the pilot to reply a specific code. The problem came to light during the discussion of the test results with the pilot. After that time the pilots were requested to reply with code 5777. In this way we could at least ascertain if most code bits worked (if the bit were always "on" we still would not know it).

5. Mode Acceptance--Pulse Spacing. The transponders which failed this parameter will perform at a level which depends on the accuracy of the interrogator timing. Even if the transmitters are exactly at the nominal spacing, seven transponders would not reply to Mode C interrogations. In addition to the loss of altitude data, the probability of detecting the target at all would suffer if the detection algorithm uses the Mode C data.

6. Dead Time/Suppression Time. If the dead or suppression time is excessive, the reply probability will be degraded as the system tries to interrogate a transponder which has just been suppressed or replied to another interrogation. Although 14 percent failed the suppression time, the majority failed by 4 μs or less.

7. SLS Acceptance--Pulse Spacing. Since this test was the most frequently failed (only 41 percent passed), it deserves special consideration. This compares with 65 to 70 percent (in the area where 90 percent replies are required) as measured in the Philadelphia sample taken in 1983. As stated previously, the acceptance area of the transponder was usually too wide or skewed to one side or the other. Most of the transponders still suppressed when the P1-P2 spacing was 2.8 μs. If there is any Mode 1 activity, these transponders would see this interrogation as a suppression pair and suppress. It is also possible that some other RF activity with a pulse width of approximately 3 μs (a rise time of about 100 ns or less

is also required) produces a pulse pair in the receiver output of the transponders because of the off frequency characteristics of a bandwidth limited receiver. If this signal were an omnidirectional radiating pattern, the suppression time of this group of transponders would be greatly increased, which would cause a drop in the probability of a reply when interrogated by the ATC system.

8. SLS Amplitude Characteristics. The primary problem here appeared to be small ranges of signals where the transponders did not respond at a 90 percent rate when required (especially at a P1/P2 ratio of 9 dB). This could lead to spotty coverage as those signal levels are encountered during the flight. Those which did not suppress at all would probably result in "ring around" targets when near the interrogator in range.

9. Altitude Comparison. Approximately 38 percent of the transponders were not "altitude equipped" as they replied with only brackets to Mode C interrogations. The 5 percent with altitude errors present a serious problem to both TCAS and the ATC system.

10. Reply Delay Data. Since so many transponders' reply data were a function of the interrogation pulse spacing, it is important that these pulses be maintained at their nominal value (this is especially true for the TCAS interrogators) to avoid range errors.

11. Sensitivity and Power. Failure of these two parameters will result in a reduction of the range of coverage from the ATC interrogator, or in an increased loss of replies when the aircraft is in the process of making a turn.

The remaining parameter measurements compare reasonably well with those collected previously. Thus, if the Atlanta area is experiencing more problems than normally encountered, it may well be the activation of the more easily triggered suppression mechanism of the transponders based there.

RECOMMENDATION

In general, the failure rates of the transponders tested in Atlanta are comparable with those previously tested (i.e., Philadelphia and Dayton) with one exception. That is the susceptibility of the Atlanta-based transponders to suppression initiation. Only 41 percent passed the SLS pulse spacing tests compared to a 65 to 70 percent pass rate at Philadelphia. (This is the only data available on this parameter.)

If the ATCRBS problem is more severe at Atlanta, the parameter discussed above is a candidate as the possible cause as it is the only one significantly different from the previous data.

It is important to say that the tests only show a vulnerability to suppression initiation. The main problem is suppression action as a result of interrogations which should not be recognized as a suppression pair. In order to cause a problem for the ATC system, something in the environment must initiate a suppression by some interrogation.

This can be either a pulse pair within the bandwidth of the transponder receiver (1030+BW) or a single pulse with a fast rise time outside the bandwidth of the receiver (i.e., a 2.8 μs pulse with a fast rise time at a frequency of 1020 MHz will exit the receiver as a pulse pair at 2.8 μs). The majority of the Atlanta transponders could then be suppressed by the single pulse.

The fact that the transponders are illegally suppressed could, therefore, make them available a lower percentage of the time to reply to interrogations from an ATC system.

It is recommended that the environment be investigated to determine if interference of the type decribed above exists in the Atlanta area.

SUMMARY

A total of 154 different transponders were checked at three different general aviation airports in the Atlanta, Georgia, area. The planes were stopped at one edge of the MTPA interrogation where the tests were conducted. The pilots were then instructed to taxi across the interrogation pattern while power, sensitivity, and reply delay measurements were made.

Figure 39 gives a summary of the testing of the Atlanta sample. As indicated, the most failed parameter was the requirement to reply at a 90 percent rate in the SLS pulse spacing test, where 59 percent of the transponders failed to comply. This compares to a 35 percent failure rate at Philadelphia, the only other site where data on this parameter were collected.

Seven transponders out of the 154 tested passed all 24 parameters tested. Five additional transponders passed all parameters, but replied with "brackets only" to the Mode C interrogations and were failed by MTPA for that parameter. Thus, approximately 7 percent of the transponders passed all tests for which they were equipped. An additional 38 failed to reply at a 90 percent rate during the SLS decoding accuracy test as their only problem and/or replied with "brackets only" to Mode C. Another 43 failed one other parameter (in addition to the previous ones), 24 failed two others, and 49 failed three or more additional parameters.

ALL PARAMETERS MEASURED AT MTL UNLESS OTHERWISE STATED
TEST 2 MUST REPLY GREATER THAN 5%.

FREQUENCY	15	OUT OF	154	= %	9
JITTER	0	OUT OF	154	= %	0
PULSE WIDTH	8	OUT OF	154	= %	5
BRACKET SPACING	6	OUT OF	154	= %	3
PULSE POSITION OFFSET	8	OUT OF	154	= %	5
MODE A PULSE SPACING	8	OUT OF	154	= %	5
MODE C PULSE SPACING	13	OUT OF	154	= %	8

TEST 3 MUST REPLY GREATER THAN 50% BOTH MODES TO MEASURE DELAY DIFFERENCE

DELAY DIFFERENCE A-C	7	OUT OF	146	= %	4
MODE ACCEPTANCE PULSE WIDTH	2	OUT OF	154	= %	1
DEAD TIME	1	OUT OF	154	= %	0
SUPPRESSION TIME	22	OUT OF	154	= %	14
SLS PULSE SPACING <1%	18	OUT OF	154	= %	11
SLS PULSE SPACING >90%	91	OUT OF	154	= %	59
SLS PULSE WIDTH	5	OUT OF	154	= %	3
SLS DYNAMIC RANGE >90%	16	OUT OF	154	= %	10
SLS DYNAMIC RANGE <1%	9	OUT OF	154	= %	5
INSUFFICIENT MODE S REPLIES	8	OUT OF	307	= %	2
MODE C REPLIES <90%	27	OUT OF	299	= %	9
BRACKETS ONLY	107	OUT OF	280	= %	38
GREY CODE VALID <90%	13	OUT OF	180	= %	7
ALTIMETER OFFSET	10	OUT OF	171	= %	5
REPLY DELAY	9	OUT OF	154	= %	5
REPLY POWER	33	OUT OF	154	= %	21
MODE A SENSITIVITY	39	OUT OF	154	= %	25
MODE C SENSITIVITY	39	OUT OF	154	= %	25

This data is taken from test 15 where the transponder is not necessarily sufficiently above MTL to apply the spec. The true data is taken from test 5 where MTL is known:

22 = Total failures ≈ 14%
12 - failed to meet the 90% portion
6 - failed to meet the 1% portion
4 - failed to suppress at all

This is not a failure! The Mode S Transponder was inadvertently left off during the test and thus no calibrated altitude data was available.

PASSED ALL PARAMETERS 7 = 4%
PASSED ALL OR FAILED BRACKETS ONLY 12 = 7%
PASSED ALL OR FAILED BO AND/OR SLS90 PS 38 = 24%
FAILED ONLY 1 OTHER PARAMETER 43 = 27%
FAILED 2 OTHER PARAMETERS 24 = 15%
FAILED 3 OR MORE OTHER PARAMETERS 49 = 31%

FIGURE 39. ATLANTA OVERALL TEST DATA SUMMARY

APPENDIX A

MTPA CALIBRATION DATA FROM PEACHTREE/DEKALB AIRPORT

LIST OF ILLUSTRATIONS

Figure A-1 is a copy of the screen after the calibration process has been completed. It shows a history of the events during the run. The name of the MTPA program is "COUPLE." The name of the calibration file for the day is "PT2." The sensitivity, power, and delay data were collected twice on the calibrated cable to check for repeatability prior to moving the transponder to the car for the calibration run on the ramp. Function "2" (Transponder in Remote Location) was then selected and the car was positioned at one of the edges of the interrogation pattern. Data were then collected as the car was driven through the pattern to the opposite side. The couple program searched these data looking for the maximum power, sensitivity, and the minimum delay. (The arrows in the left hand column indicate that one of these parameters was updated during that set of tests.) When the power and sensitivity have both decreased by 10 dB from the maximum value achieved during the run, the file is then closed by selecting function "3" and entering the approximate distance for use in the vertical offset table selection.

Figures A-2 through A-6 are the data from the pattern run after calibration. The values of power, sensitivity, and delay which would be used as the true parameters for that transponder are circled on figure A-2. When compared to those from the calibrated cable (see figure A-1), it is seen that the sensitivity and delay values are very close but the power is off by about 1.4 dB. The plot of the power data (figure A-3) shows a dip where the maximum should have occurred. This could have been caused by a number of reasons (reflections, interference, etc.), but is well within our tolerance.

Figure A-7 is the summary sheet of the complete set of tests (File-name=ATL1) run on the calibrated transponder. The arrows on the left side indicate parameters which are out of the specified limits. The arrows beside "Mode S reply rate" merely mean that the transponder in MTPA which supplies the calibrated value for the Mode C code was turned off during this run. The delay data are also low (3.167 rather than 3.182) when compared to the bench value. This is a result of selecting the lowest value of delay which occurs during any test. (Some of the tests affect the delay.)

```
R COUPLE

 M. T. P. A. COUPLING PROGRAM

ENTER CALIBRATION FILENAME  *PT2
 1 - TRANSPONDER ON CALIBRATED CABLE
 2 - TRANSPONDER IN REMOTE LOCATION
 3 - DATA COLLECTION COMPLETE

      ENTER  FUNCTION   1
 CAL SEN =-77. POW = 57.9 DEL = 3.185
 1 - TRANSPONDER ON CALIBRATED CABLE
 2 - TRANSPONDER IN REMOTE LOCATION
 3 - DATA COLLECTION COMPLETE

      ENTER  FUNCTION   1
 CAL SEN =-77. POW = 57.7 DEL = 3.182
 1 - TRANSPONDER ON CALIBRATED CABLE
 2 - TRANSPONDER IN REMOTE LOCATION
 3 - DATA COLLECTION COMPLETE

      ENTER  FUNCTION   2
 EXTRACT DATA  (N=0)

PAUSE --   <CR>  WHEN  READY
->      SEN =-49. POW = 46.2 DEL = 4.121
->      SEN =-51. POW = 48.1 DEL = 4.120STOP --
->      SEN =-53. POW = 49.5 DEL = 4.114
->      SEN =-54. POW = 51.3 DEL = 4.109.
->      SEN =-55. POW = 52.4 DEL = 4.107
->      SEN =-56. POW = 52.6 DEL = 4.104
->      SEN =-56. POW = 53.0 DEL = 4.106
->      SEN =-57. POW = 53.3 DEL = 4.103
->      SEN =-57. POW = 53.5 DEL = 4.104
->      SEN =-57. POW = 53.5 DEL = 4.103
->      SEN =-58. POW = 53.5 DEL = 4.102
->      SEN =-58. POW = 53.7 DEL = 4.100
->      SEN =-58. POW = 54.5 DEL = 4.099
->      SEN =-58. POW = 54.5 DEL = 4.104
->      SEN =-58. POW = 54.6 DEL = 4.102
->      SEN =-58. POW = 55.0 DEL = 4.104
->      SEN =-58. POW = 54.6 DEL = 4.103
->      SEN =-58. POW = 54.1 DEL = 4.105
        SEN =-57. POW = 54.5 DEL = 4.108
        SEN =-57. POW = 54.2 DEL = 4.109
        SEN =-56. POW = 53.5 DEL = 4.111
        SEN =-56. POW = 53.0 DEL = 4.113
        SEN =-55. POW = 51.9 DEL = 4.112
        SEN =-54. POW = 51.2 DEL = 4.118
        SEN =-52. POW = 49.8 DEL = 4.120
        SEN =-51. POW = 49.0 DEL = 4.128
        SEN =-50. POW = 48.0 DEL = 4.131
        SEN =-49. POW = 47.5 DEL = 4.133
        SEN =-48. POW = 46.7 DEL = 4.135
        SEN =-46. POW = 45.5 DEL = 4.140
REMOTE SEN =-58. POW = 55.0 DEL = 4.099

 1 - TRANSPONDER ON CALIBRATED CABLE
 2 - TRANSPONDER IN REMOTE LOCATION
 3 - DATA COLLECTION COMPLETE

      ENTER  FUNCTION   3
 ENTER DISTANCE  (100->800)  400
```

on calibrated cable

on calibrated cable

PROMPT Selection

2 + Selection

Calibration Run

Calibration run

Final Selection

400 + for use in lookup table selection

FIGURE A-1. SAMPLE FIELD CALIBRATION DATA RUN

```
ENTER DATA FILE NAME      *PATPT2
 1 SEN= 54. POWER= 37.0 DELAY=  3.293
 2 SEN= 54. POWER= 36.9 DELAY=  3.294
 3 SEN= 54. POWER= 37.0 DELAY=  3.294
 4 SEN= 54. POWER= 37.0 DELAY=  3.292
 5 SEN= 54. POWER= 37.0 DELAY=  3.295
 6 SEN= 54. POWER= 37.0 DELAY=  3.293
 7 SEN= 54. POWER= 37.0 DELAY=  3.294
 8 SEN= 54. POWER= 37.0 DELAY=  3.293
 9 SEN= 54. POWER= 36.9 DELAY=  3.294
10 SEN= 54. POWER= 37.0 DELAY=  3.302
11 SEN= 53. POWER= 37.0 DELAY=  3.303
12 SEN= 53. POWER= 35.7 DELAY=  3.300
13 SEN= 53. POWER= 34.3 DELAY=  3.297
14 SEN= 54. POWER= 33.7 DELAY=  3.285
15 SEN= 55. POWER= 35.7 DELAY=  3.256
16 SEN= 59. POWER= 39.7 DELAY=  3.240
17 SEN= 61. POWER= 42.8 DELAY=  3.228
18 SEN= 63. POWER= 45.2 DELAY=  3.212
19 SEN= 67. POWER= 46.6 DELAY=  3.206
20 SEN= 68. POWER= 48.1 DELAY=  3.202
21 SEN= 70. POWER= 49.8 DELAY=  3.197
22 SEN= 71. POWER= 51.5 DELAY=  3.195
23 SEN= 72. POWER= 52.3 DELAY=  3.194
24 SEN= 73. POWER= 53.3 DELAY=  3.194
25 SEN= 74. POWER= 53.7 DELAY=  3.189
26 SEN= 74. POWER= 54.5 DELAY=  3.191
27 SEN= 75. POWER= 55.0 DELAY=  3.189
28 SEN= 75. POWER= 55.5 DELAY=  3.188
29 SEN= 76. POWER= 55.8 DELAY=  3.187
30 SEN= 76. POWER= 56.3 DELAY=  3.186
31 SEN= 76. POWER= 56.4 DELAY=  3.186
32 SEN= 76. POWER= 56.2 DELAY=  3.184
33 SEN= 77. POWER= 55.7 DELAY=  3.182
34 SEN= 76. POWER= 55.7 DELAY=  3.185
35 SEN= 76. POWER= 56.4 DELAY=  3.181
36 SEN= 75. POWER= 56.3 DELAY=  3.180
37 SEN= 74. POWER= 55.5 DELAY=  3.181
38 SEN= 74. POWER= 55.2 DELAY=  3.182
39 SEN= 74. POWER= 54.5 DELAY=  3.179
40 SEN= 73. POWER= 53.9 DELAY=  3.186
41 SEN= 72. POWER= 53.5 DELAY=  3.182
42 SEN= 72. POWER= 52.3 DELAY=  3.181
43 SEN= 71. POWER= 51.2 DELAY=  3.184
44 SEN= 70. POWER= 49.8 DELAY=  3.193
45 SEN= 68. POWER= 48.7 DELAY=  3.193
46 SEN= 67. POWER= 47.3 DELAY=  3.194
47 SEN= 66. POWER= 45.7 DELAY=  3.199
48 SEN= 64. POWER= 44.6 DELAY=  3.205
49 SEN= 62. POWER= 41.4 DELAY=  3.215
50 SEN= 60. POWER= 38.6 DELAY=  3.225
51 SEN= 58. POWER= 36.9 DELAY=  3.236
52 SEN= 58. POWER= 35.9 DELAY=  3.239
53 SEN= 57. POWER= 35.3 DELAY=  3.246
54 SEN= 57. POWER= 34.9 DELAY=  3.250
```

FIGURE A-2. SAMPLE ANTENNA PATTERN RUN

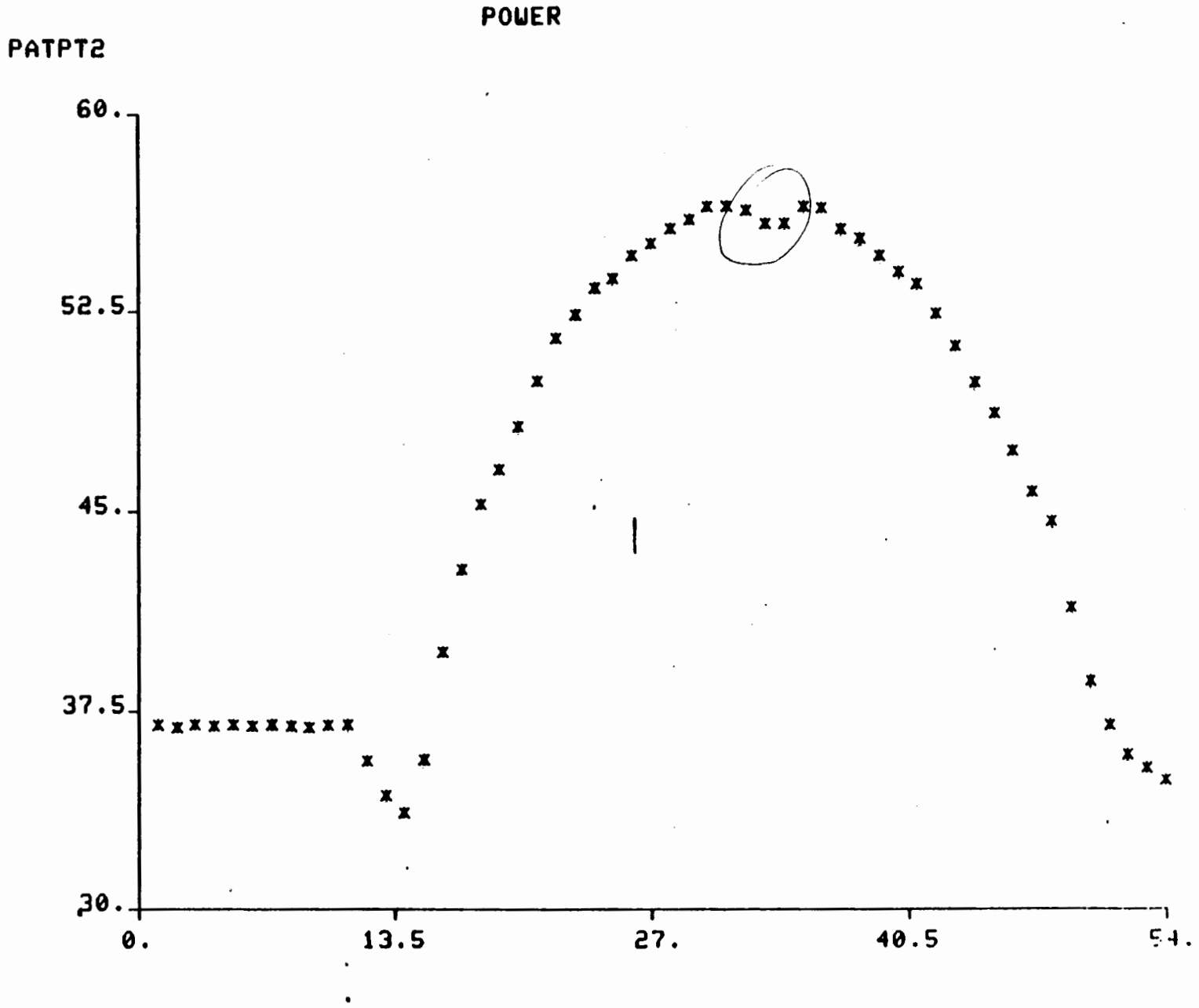


FIGURE A-3. SAMPLE ANTENNA PATTERN PLOT (POWER)

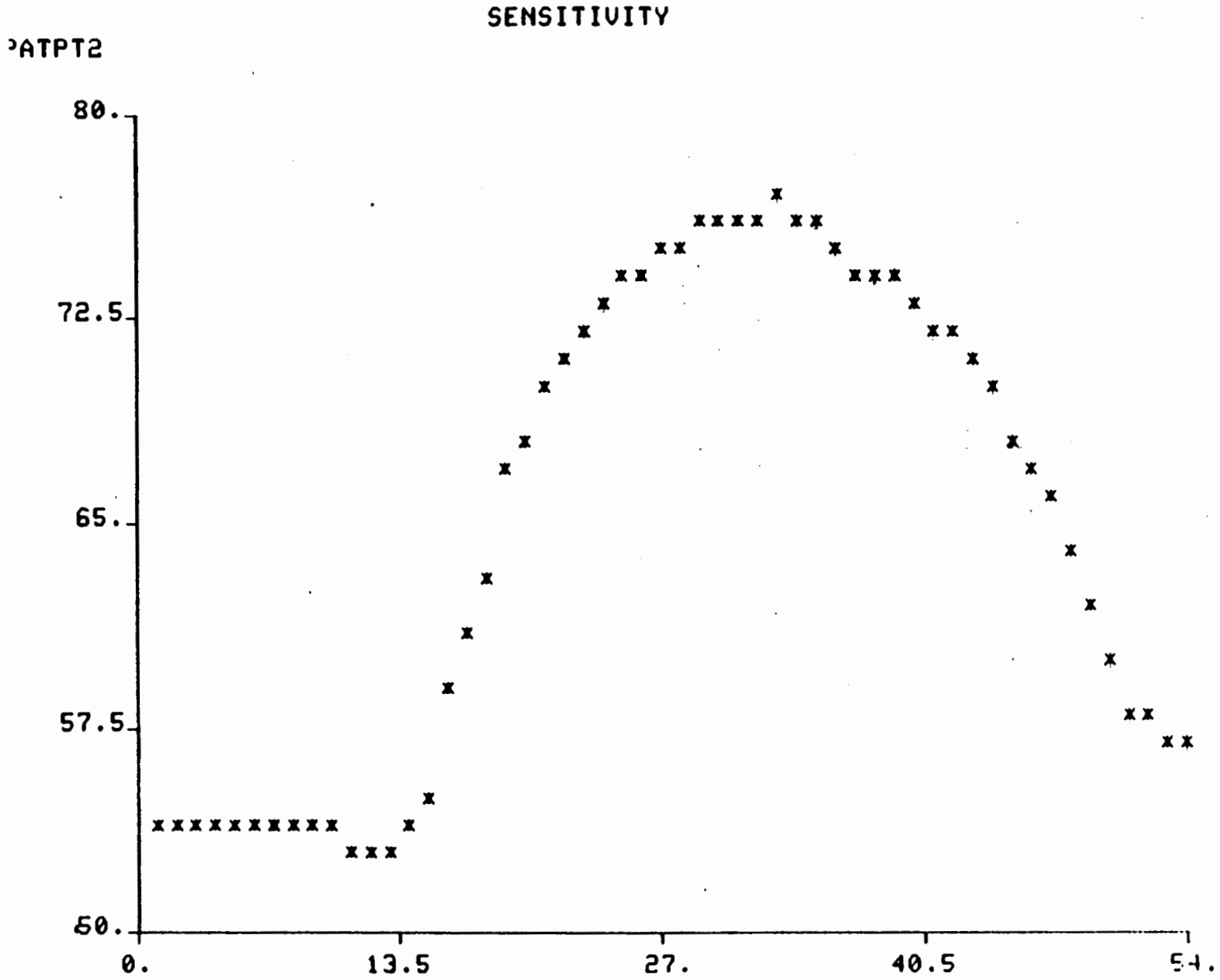


FIGURE A-4. SAMPLE ANTENNA PATTERN PLOT (SENSITIVITY)

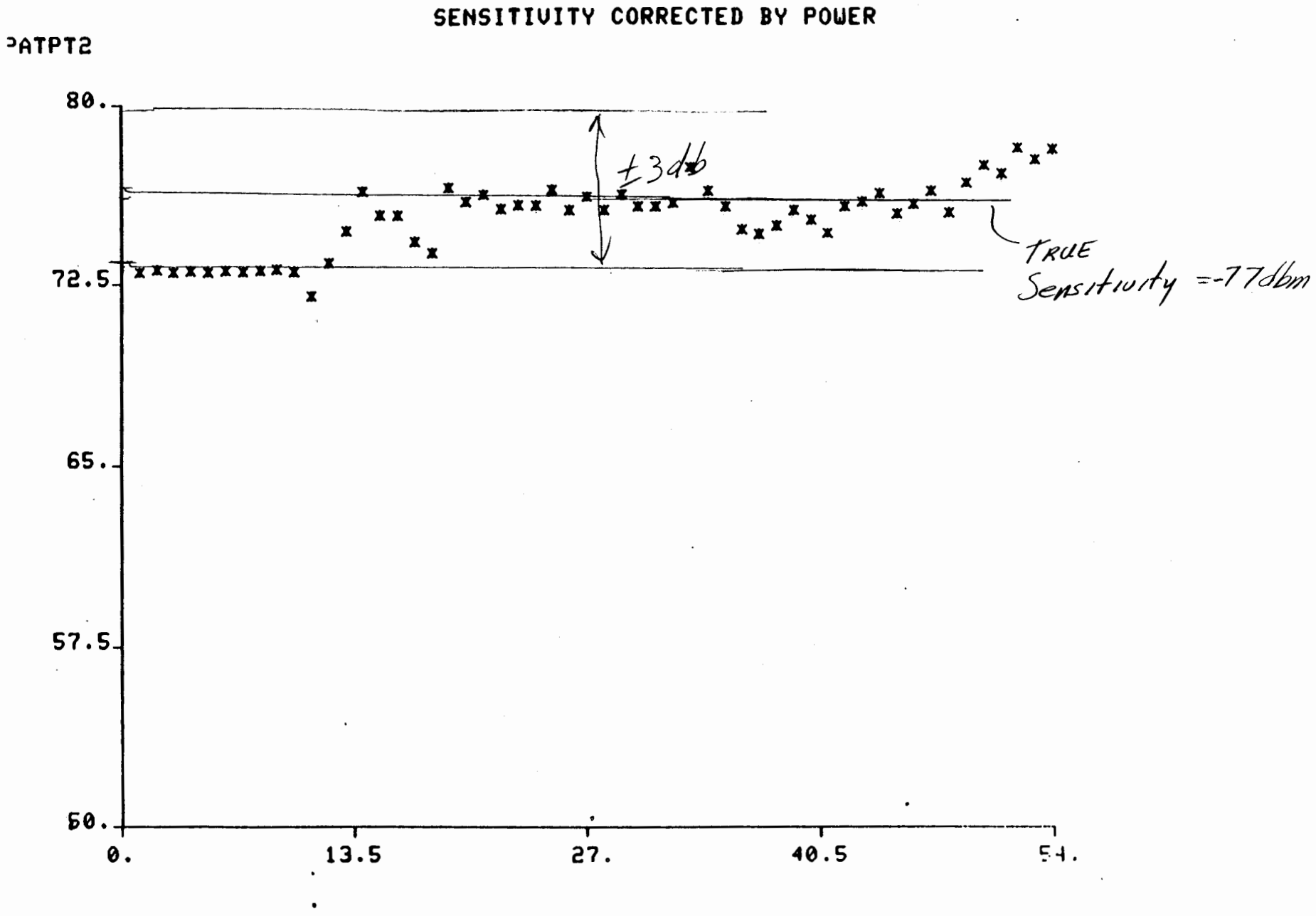


FIGURE A-5. SAMPLE ANTENNA PATTERN PLOT (SENSITIVITY CORRECTED BY POWER)

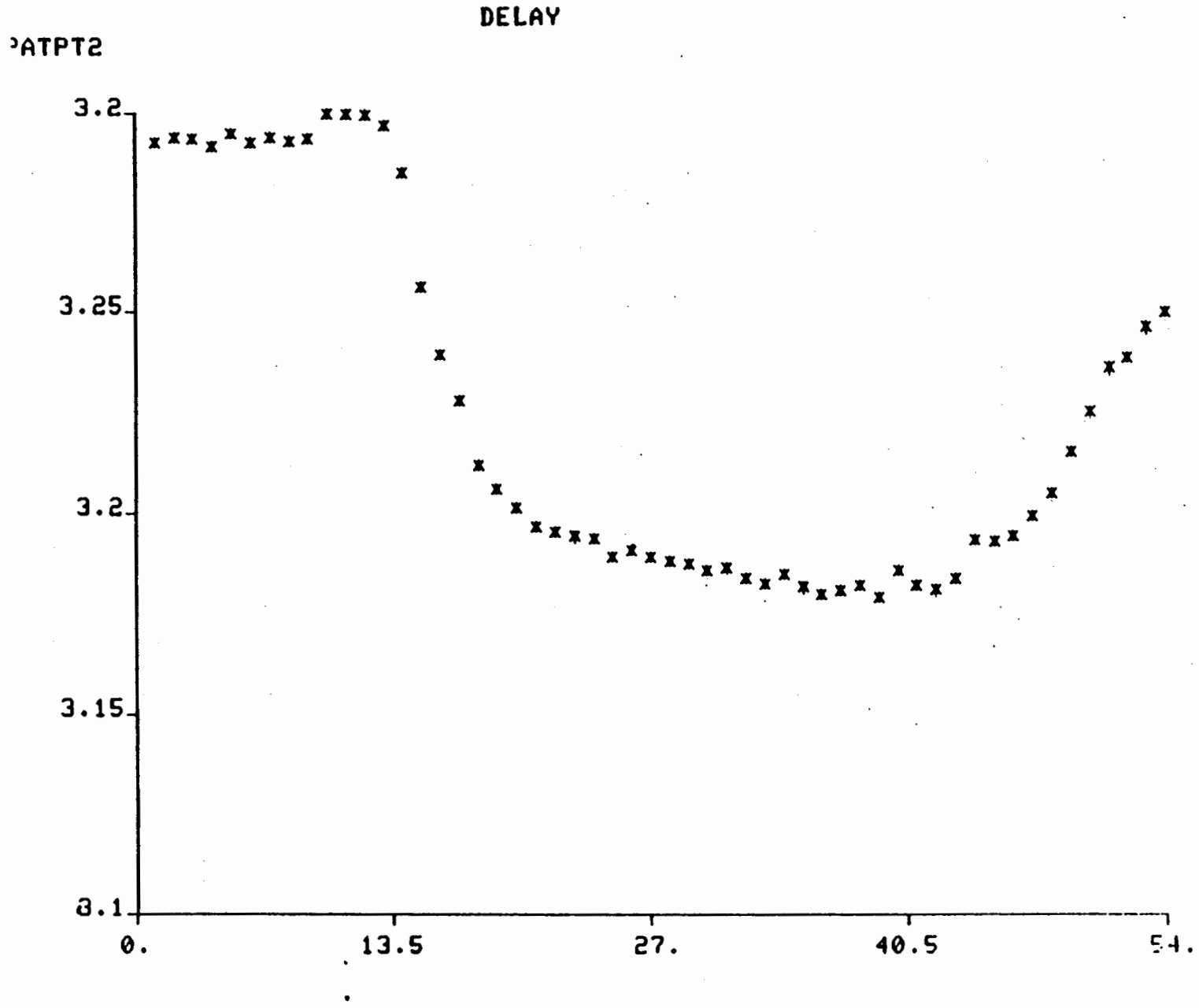


FIGURE A-6. SAMPLE ANTENNA PATTERN PLOT (REPLY DELAY)

F. A. A. TECHNICAL CENTER TRANSPONDER SUMMARY

THIS TEST DOES NOT PRECLUDE TRANSPONDER CERTIFICATION

PTSHK1 5.0 FT -47 DB

PTD2 .001 02-APR-85 08:09:32

	CODE	5252				
	FREQUENCY	1090.5 MHZ				1090 +/- 3
	JITTER	0.018 USEC				NTE .100 USEC
	PULSE WIDTH	0.452 USEC				.450 +/- .100 USEC
	BRACKET SPACING	20.310 USEC				20.300 +/- .100 USEC
	MAX CODE PULSE OFFSET	0.010 USEC				NTE .100 USEC
	MODE A ACCEPTANCE (PS)	7.75	->	8.40	USEC	<7.8 -> >8.2 USEC
	MODE C ACCEPTANCE (PS)	20.75	->	21.40	USEC	<20.8 -> 21.2 USEC
	DELAY DIFFERENCE (MODE A-C) (US)	0.007				NTE .200 USEC
	ATCRBS ACCEPTANCE (PW)	0.425	->	0.925	USEC	
->	MODE S REPLY RATE	0.0 %				
	P1-P2 RATIO (REP >= 90%) @ -50 DBM	15 **	12 **	9 **	** **	>=9
	P1-P2 RATIO (REP <= 1%) @ -50 DBM	** -6 **	-3 **	0	6 3	<=0
->	DEAD TIME	130.0 USEC				NTE 125.0 USEC
	SUPPRESSION TIME	26.0 USEC				35.0 +/- 10 USEC
	REPLY RATE (1000)	100 %				
	REPLY RATE (1400)	68 %				
	REPLY RATE (1700)	50 %				
	REPLY RATE (2000)	49 %				
	S.L.S. ACCEPTANCE (PS)	(< 1%) 1.75	->	2.30	USEC	<1.85 -> >2.15 USEC
	S.L.S. ACCEPTANCE (PW)	0.300	->	1.500	USEC	
->	MODE S REPLY RATE	0.0 %				
	REPLY DELAY	3.167 USEC				3.000 +/- .500 USEC
	REPLY POWER	56.5 DBM				45.5 - 60 DBM
	MODE A SENSITIVITY	-77 DBM				66-80 DBM
	MODE C SENSITIVITY	-77 DBM				66-80 DBM

FIGURE A-7. SAMPLE TEST SUMMARY SHEET (CALIBRATION VEHICLE)

APPENDIX B

ANALYSIS OF TRANSPONDERS OF N6024K

APPENDIX B - LIST OF ILLUSTRATIONS

This aircraft had two transponders which were checked by the MTPA. The summary data from each test is included as this appendix. Accurate power and sensitivity data were not taken on transponder No. 1 so that the second transponder could be checked. Power and sensitivity data were taken on the second transponder after completion of the remainder of the tests.

The figures for transponder No. 1 are all labeled "sheet 1." The companion figures for transponder No. 2 are labeled "sheet 2." Figure B-1 is the test matrice for the two transponders. Figure B-2 is the summary.

Transponder No. 1 shows only two problems: (1) it has no reply rate limiting, and (2) it did not reply to the Mode C interrogations of the altitude tests. This is somewhat puzzling, as it answered 100 percent to the interrogations of the Mode C acceptance spacing test (see figure B-5). The interrogations of the altitude test are nominal spacing and the same interrogation power as those of test 3.

Transponder No. 2, however, failed many parameters (see figure B-2). The fact that the frequency is so far off could explain why many of the other parameters failed. If the transmit frequency is used as the local oscillator, the interrogation signals from MTPA would be approximately 6.9 MHz from the center frequency of the transponders' receiver. This would certainly result in attenuation and distortion of the interrogation signals. The reply rate on most of the tests is less than 100 percent, as is evidenced by any of the test figures for transponder No. 2. Apparently, there was much antenna sheilding during the tests as the power readings gathered during test 15 show a reply power of 26.5 dBm. test 2 shows 27 or 28 dBm, and the true power was 51.5 dBm. Thus, the signals were between 20 and 25 dB down from the maximum during the tests. The reply power of transponder No. 2 was also about 4 dB lower than that of transponder No. 1 according to figures B-3 and B-10.

The summaries of the sensitivity tests with the reply power above 40 dBm are listed in the following table:

TABLE B-1. ATCRBS SENSITIVITY TEST RESULTS

MATRIX NO.	A SENS.	A DEL.	C SENS	C DEL.	POWER (A)	POWER (C)
71	-58	2.661	-59	2.662	40	43
72	-64	2.638	-62	2.646	45	47
73	-62	2.617	-66	2.628	49	51
74	-68	2.603	-68	2.614	51	51
75	-69	2.599	-68	2.618	51	51
76	-68	2.606	-67	2.622	50	50
77	-67	2.611	-66	2.631	49	47
78	-65	2.615	-65	2.632	47	46
79	-64	2.618	-65	2.638	46	47
80	-64	2.621	-64	2.641	46	47
81	-63	2.630	-62	2.646	47	45
82	-63	2.634	-63	2.654	44	43
83	-64	2.639	-63	2.661	43	43
84	-62	2.646	-62	2.665	42	42
85	-62	2.659	-62	2.679	41	40

As indicated, the nose of the interrogation beam was crossed by the plane at approximately the time tests 73 to 75 were being conducted. Since the interrogation power was set to -49 dBm for the tests conducted while the aircraft was stationary, and the aircraft antenna was approximately 20 dB down from the nose, the majority of the tests were conducted at or near the MTL of the transponders. This makes the data of some of the tests somewhat questionable (all tests which require a 90 percent reply rate, i.e., dead time, suppression time), but all reply characteristic type tests are valid.

24K NO POWER SEN. #1 1.5 FT -49 DB

02-APR-85 08:51:46

TEST MATRIX

	1	2	3	4	5	6	7	8	9
		2	3	4	99	15	6	7	8	12
10	13	14	5	99	14	14	14	14	14	14
20	14	14	14	14	14	14	14	14	14	14
30	14	14	14	14	14	14	14	14	14	14
40	14	14	14	14	14	14	14	14	14	14
50	14	14	14	14	14	14	14	14	14	14
60	14	14	14	14	14	14	14	14	14	14
70	14	14	14	14	14	14	14	14	14	14
80	14	14	14	14	14	14	14	14	14	14
90	14	14	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	

FIGURE B-1. TEST MATRIX TRANSPONDER (SHEET 1 OF 2)

N6024K#2 1.5 FT -49 DB

02-APR-85 08:54:27

TEST MATRIX

		1	2	3	4	5	6	7	8	9
		2	3	4	99	15	6	7	8	12
10	13	14	5	99	14	14	14	14	14	14
20	14	14	14	14	14	14	14	14	14	14
30	14	14	14	14	14	14	14	14	14	14
40	14	14	14	14	14	14	14	14	14	14
50	14	14	14	14	14	14	14	14	14	14
60	14	14	14	14	14	14	14	14	14	14
70	14	14	14	14	14	14	14	14	14	14
80	14	14	14	14	14	14	14	14	14	14
90	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	

FIGURE B-1. TEST MATRIX TRANSPONDER (SHEET 2 OF 2)

F. A. A. TECHNICAL CENTER TRANSPONDER SUMMARY

THIS TEST DOES NOT PRECLUDE TRANSPONDER CERTIFICATION

24K NO POWER SEN. #1 1.5 FT -49 DB

PT2DA .001 02-APR-85 08:51:46

	CODE	1200				
	FREQUENCY	1090.8	MHZ			1090 +/- 3
	JITTER	0.020	USEC			NTE .100 USEC
	PULSE WIDTH	0.397	USEC			.450 +/- .100 USEC
	BRACKET SPACING	20.310	USEC			20.300 +/- .100 USEC
	MAX CODE PULSE OFFSET	0.006	USEC			NTE .100 USEC
	MODE A ACCEPTANCE (PS)	7.70	->	8.45	USEC	<7.8 -> >8.2 USEC
	MODE C ACCEPTANCE (PS)	20.75	->	21.40	USEC	<20.8 -> 21.2 USEC
	DELAY DIFFERENCE (MODE A-C) (US)	0.024				NTE .200 USEC
	ATCRBS ACCEPTANCE (PW)	0.525	->	1.500	USEC	
->	MODE C REPLY RATE	0.0	%			
	P1-P2 RATIO (REP >= 90%) @ -50 DBM	15 **	12 **	9 **	6 **	>=9
	P1-P2 RATIO (REP <= 1%) @ -50 DBM	** -6 **	-3 **	0 **	**	<=0
	DEAD TIME	45.0	USEC			NTE 125.0 USEC
	SUPPRESSION TIME	38.0	USEC			35.0 +/- 10 USEC
	REPLY RATE (1000)	99	%			
	REPLY RATE (1400)	100	%			
	REPLY RATE (1700)	99	%			
	REPLY RATE (2000)	99	%			
	S.L.S. ACCEPTANCE (PS)	(< 1%) 1.80	->	2.40	USEC	<1.85 -> >2.15 USEC
	S.L.S. ACCEPTANCE (PW)	0.350	->	1.500	USEC	
->	MODE C REPLY RATE	0.0	%			
	REPLY DELAY	2.819	USEC			3.000 +/- .500 USEC
->	REPLY POWER	31.0	DBM			48.5 - 57 DBM

no limiting

not tested

FIGURE B-2. TEST SUMMARY SHEET - TRANSPONDER (SHEET 1 OF 2)

F. A. A. TECHNICAL CENTER TRANSPONDER SUMMARY

THIS TEST DOES NOT PRECLUDE TRANSPONDER CERTIFICATION

N6024K$2 1.5 FT -49 DB

PT2DA .002 02-APR-85 08:54:27

	CODE	1200				
->	FREQUENCY	1096.9	MHZ			1090 +/- 3
	JITTER	0.062	USEC			NTE .100 USEC
	PULSE WIDTH	0.362	USEC			.450 +/- .100 USEC
	BRACKET SPACING	20.255	USEC			20.300 +/- .100 USEC
	MAX CODE PULSE OFFSET	-0.040	USEC			NTE .100 USEC
	MODE A ACCEPTANCE (PS)	7.80	->	8.20	USEC	<7.8 -> >8.2 USEC
->	MODE C ACCEPTANCE (PS)	20.80	->	20.95	USEC	<20.8 -> 21.2 USEC
	DELAY DIFFERENCE (MODE A-C) (US)	0.027				NTE .200 USEC
->	ATCRBS ACCEPTANCE (PW)	0.750	->	1.500	USEC	
->	MODE C REPLY RATE	0.0 %				
->	P1-P2 RATIO (REP >= 90%)	@ -50 DBM	** ** ** ** ** ** ** **			>=9
->	P1-P2 RATIO (REP <= 1%)	@ -50 DBM	** -6 ** -3 ** ** ** **			<=0
->	DEAD TIME	140.0	USEC			NTE 125.0 USEC
->	SUPPRESSION TIME	50.0	USEC			35.0 +/- 10 USEC
	REPLY RATE (1000)	81	%			
	REPLY RATE (1400)	56	%			
	REPLY RATE (1700)	45	%			
	REPLY RATE (2000)	37	%			
->	S.L.S. ACCEPTANCE (PS)	(< 1%) 1.95	->	2.40	USEC	<1.85 -> >2.15 USEC
	S.L.S. ACCEPTANCE (PW)	0.300	->	1.500	USEC	
->	MODE C REPLY RATE	0.0 %				
	REPLY DELAY	2.599	USEC			3.000 +/- .500 USEC
	REPLY POWER	51.5	DBM			48.5 - 57 DBM
	MODE A SENSITIVITY	-69	DBM			69-77 DBM
	MODE C SENSITIVITY	-70	DBM			69-77 DBM

FIGURE B-2. TEST SUMMARY SHEET - TRANSPONDER (SHEET 2 OF 2)

24K NO POWER SEN. #1 1.5 FT -49 DB
ATCRBS REPLY TEST - 2

PULSE	POSITION	POWER
1 - F1	0.000	0.0
2 - C1	0.000	0.0
3 - A1	0.006	30.9
4 - C2	0.000	0.0
5 - A2	0.000	0.0
6 - C4	0.000	0.0
7 - A4	0.000	0.0
8 - B1	0.000	0.0
9 - D1	0.000	0.0
10 - B2	0.001	31.0
11 - D2	0.000	0.0
12 - B4	0.000	0.0
13 - D4	0.000	0.0
14 - F2	0.010	31.0

CODE = 1200

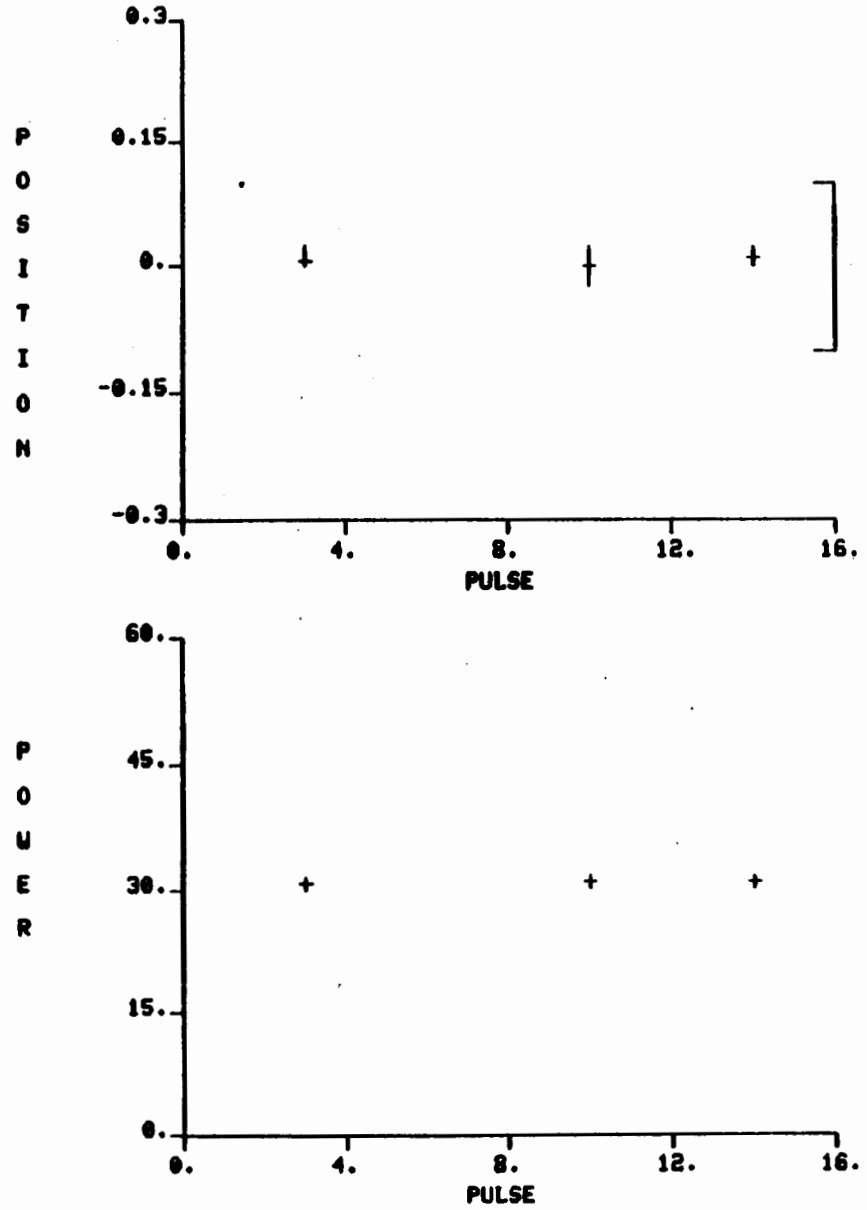


FIGURE B-3. MTPA TEST 2 SUMMARY SHEET (1) (SHEET 1 OF 2)

N6024K$2 1.5 FT -49 DB

ATCRBS REPLY TEST - 2

PULSE	POSITION	POWER
1 - F1	0.000	0.0
2 - C1	0.000	0.0
3 - A1	-0.012	28.0
4 - C2	0.000	0.0
5 - A2	0.000	0.0
6 - C4	0.000	0.0
7 - A4	0.000	0.0
8 - B1	0.000	0.0
9 - D1	0.000	0.0
10 - B2	-0.040	27.2
11 - D2	0.000	0.0
12 - B4	0.000	0.0
13 - D4	0.000	0.0
14 - F2	-0.045	27.4

CODE = 1200

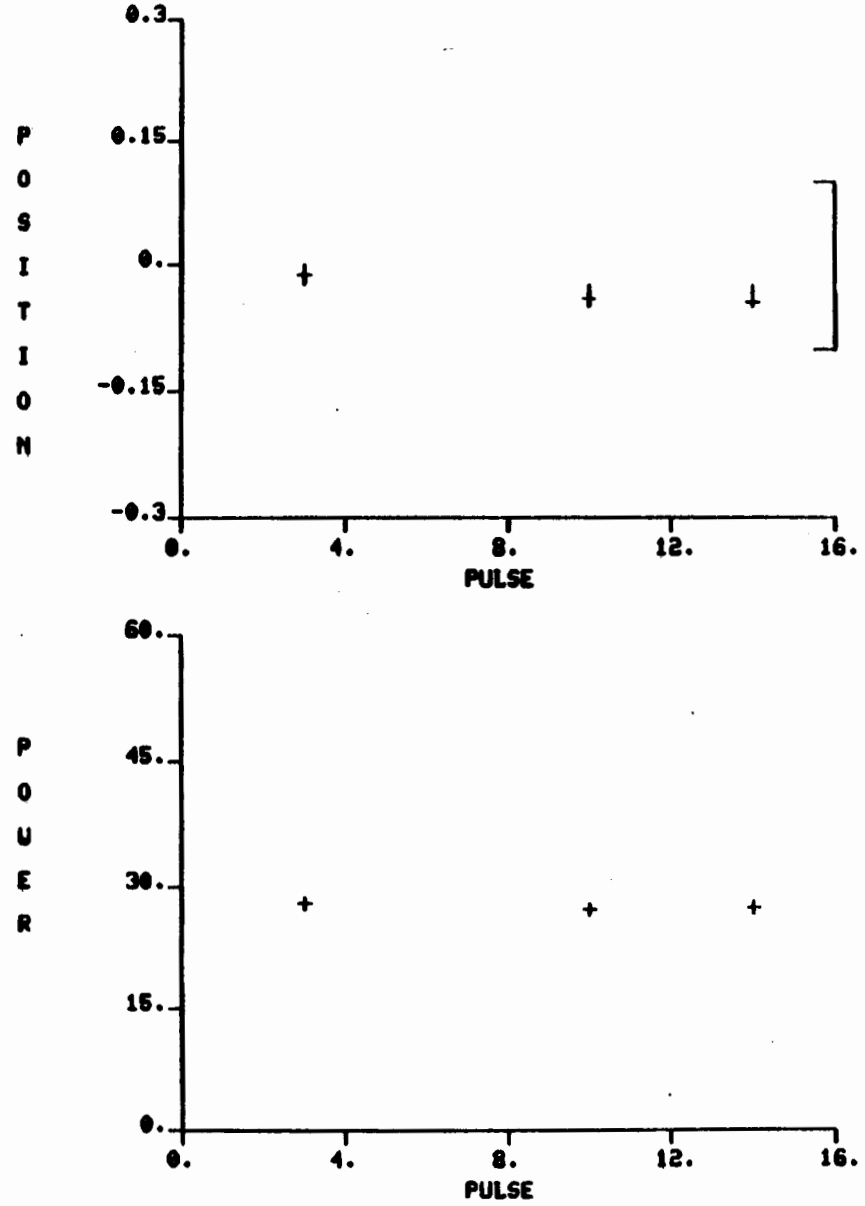


FIGURE B-3. MTPA TEST 2 SUMMARY SHEET (1) (SHEET 2 OF 2)

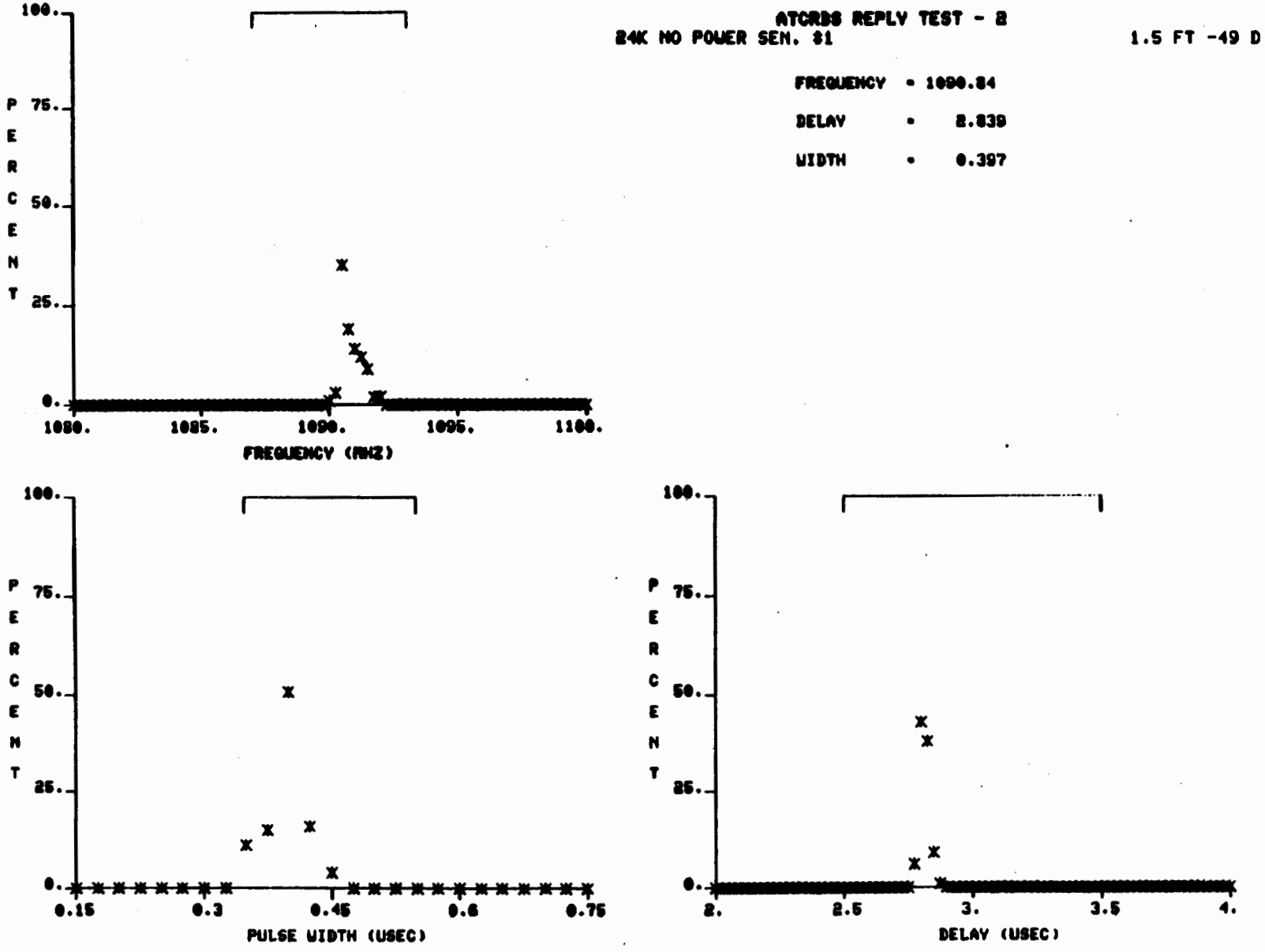


FIGURE B-4. MTPA TEST 2 SUMMARY SHEET (2) (SHEET 1 OF 2)

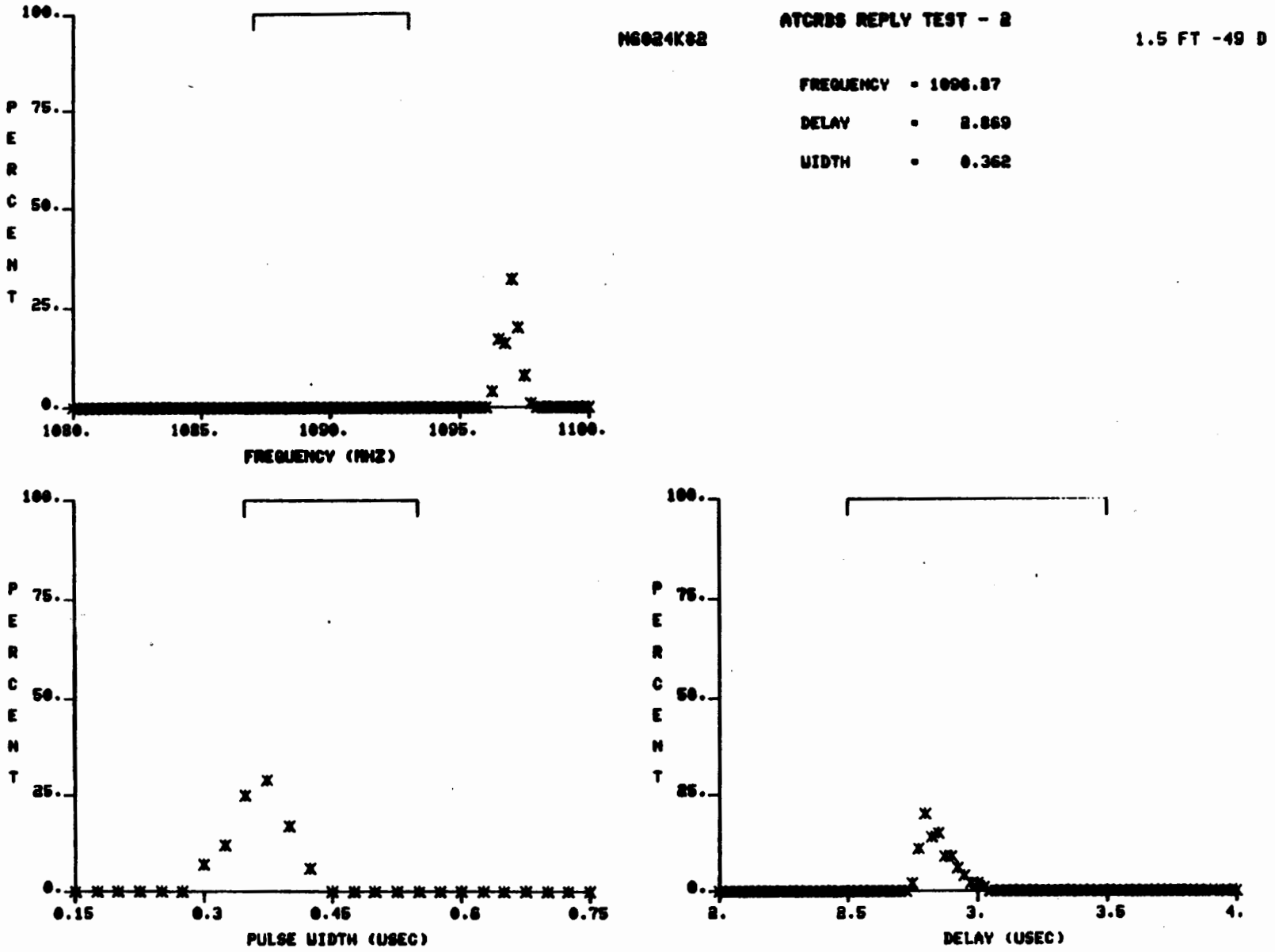


FIGURE B-4. MTPA TEST 2 SUMMARY SHEET (2) (SHEET 2 OF 2)

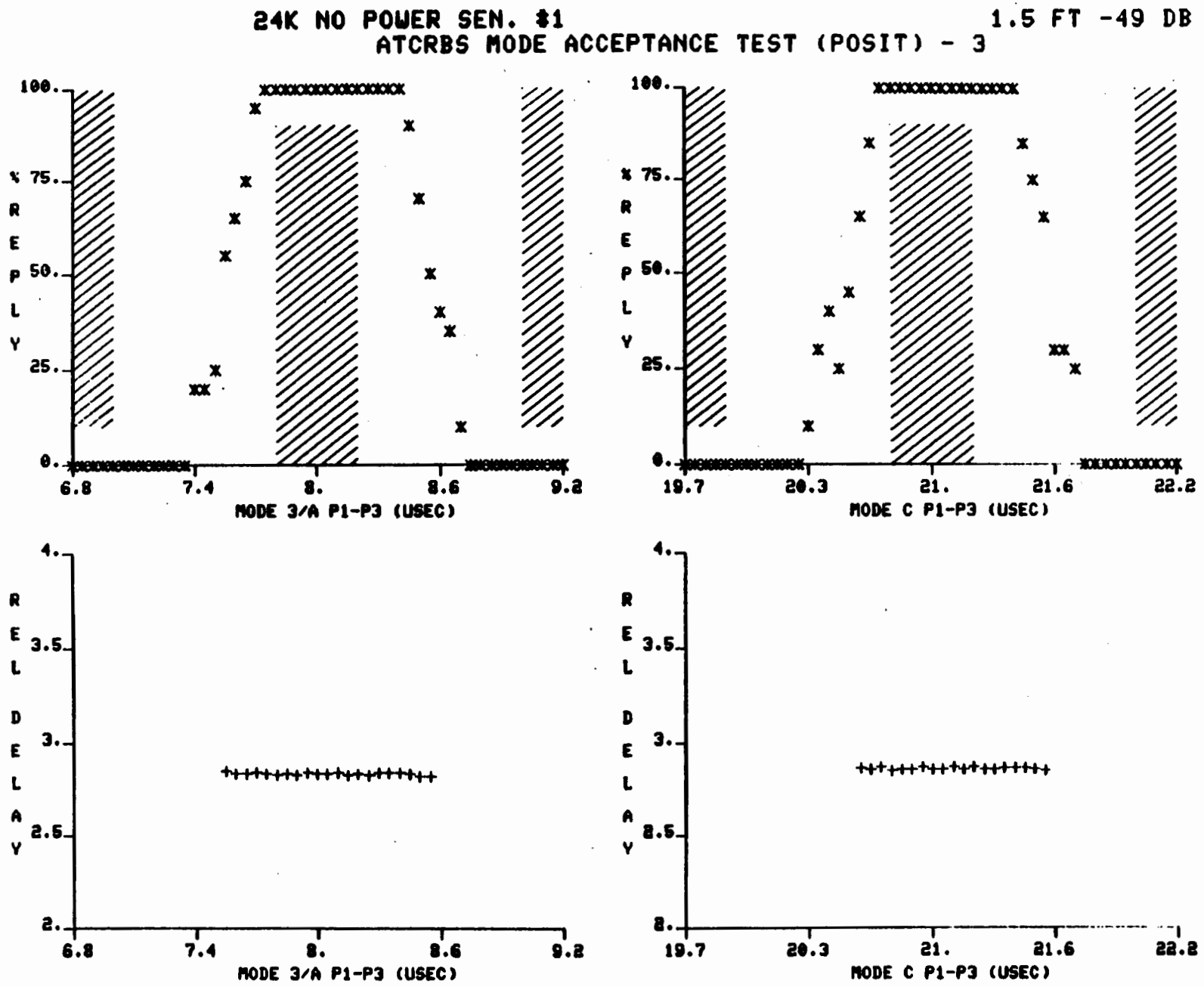


FIGURE B-5. MTPA TEST 3 SUMMARY SHEET (SHEET 1 OF 2)

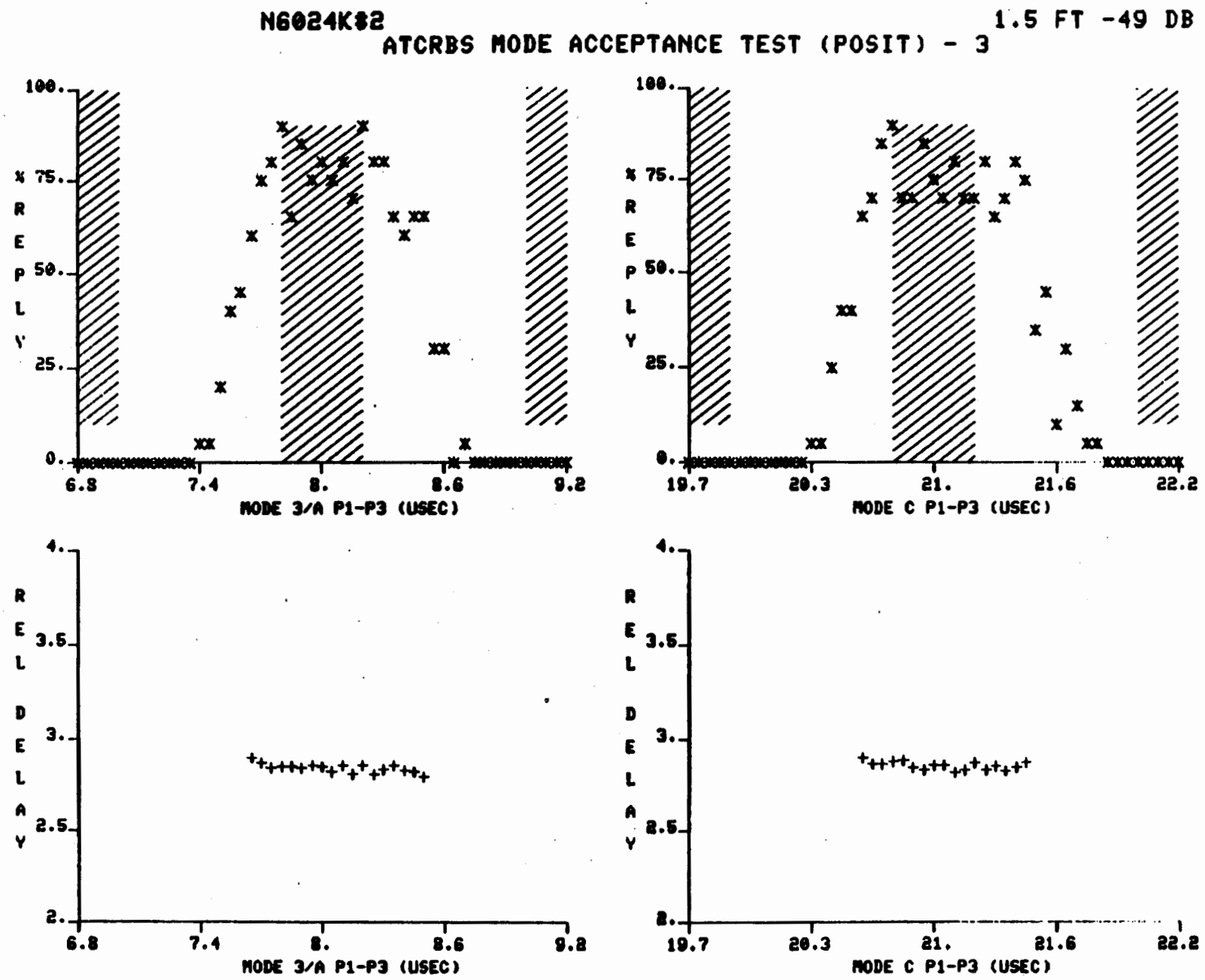


FIGURE B-5. MTPA TEST 3 SUMMARY SHEET (SHEET 2 OF 2)

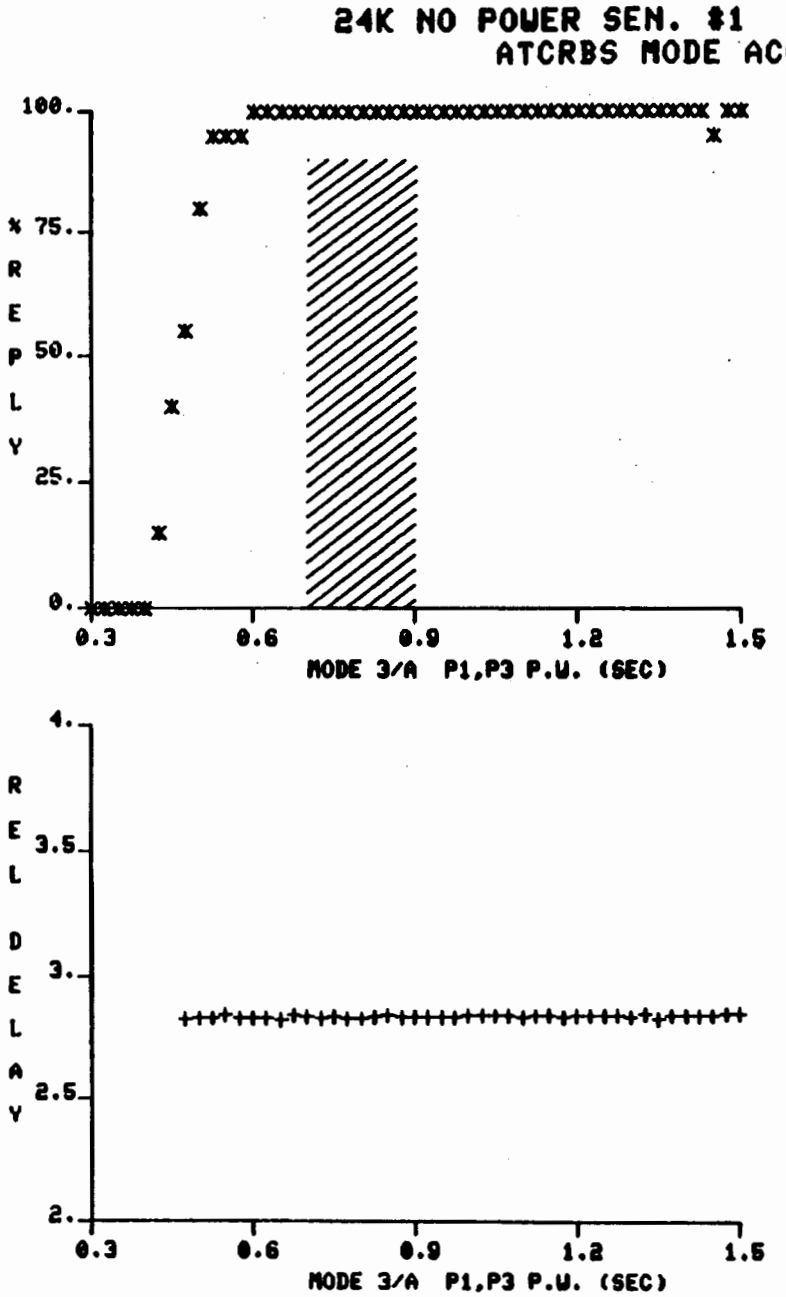


FIGURE B-6. MTPA TEST 4 SUMMARY SHEET (SHEET 1 OF 2)

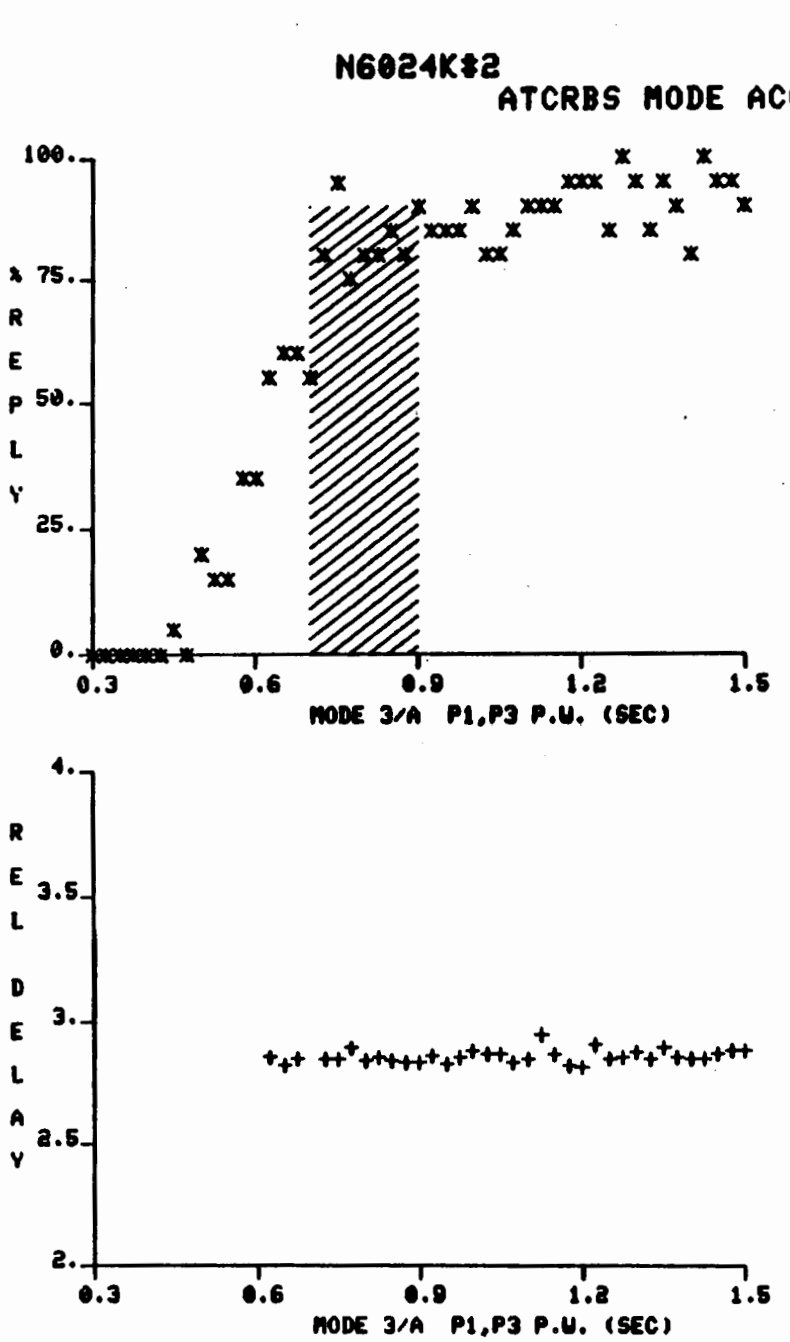
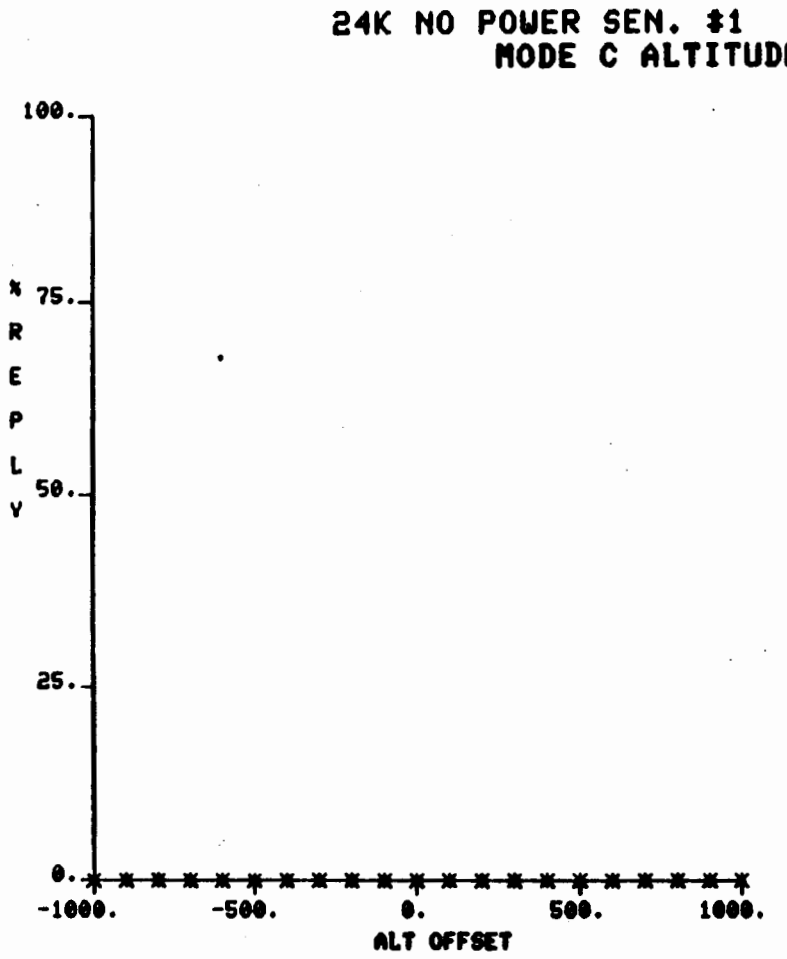


FIGURE B-6. MTPA TEST 4 SUMMARY SHEET (SHEET 2 OF 2)

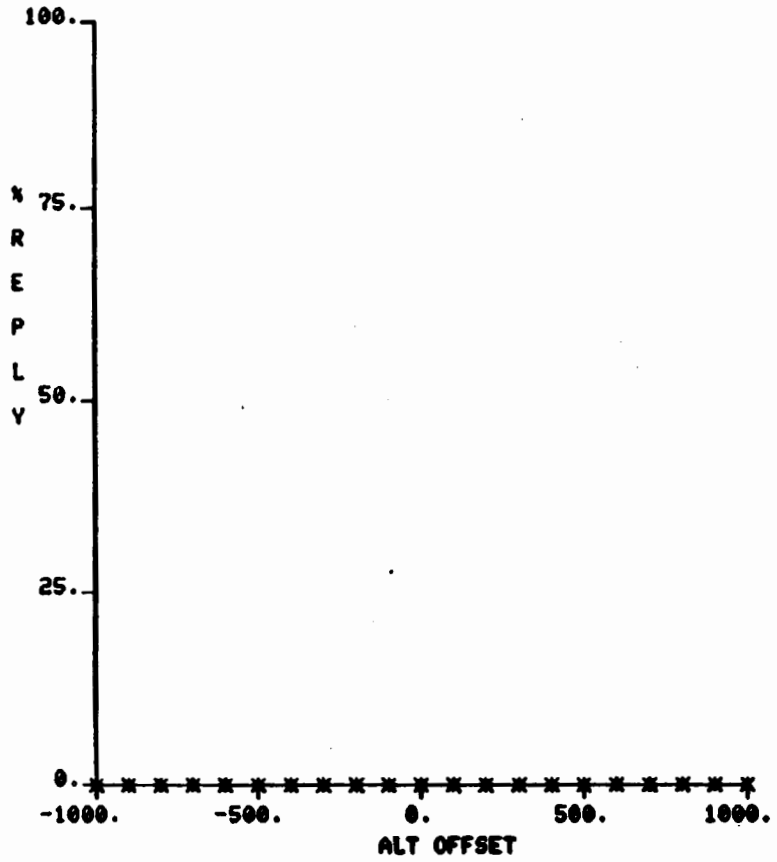


STANDARD TRANSPONDER - 900. FEET 100. % VALID REPLY
TEST TRANSPONDER - 0. FEET 0. % VALID REPLY
0. REPLY 0. % BRACKET REPLY

FIGURE B-7. MTPA TEST 99 SUMMARY SHEET (1st RUN) (SHEET 1 OF 2)

N6024K$2 1.5 FT -49 DB

MODE C ALTITUDE VERIFICATION - 99



STANDARD TRANSPONDER = 900. FEET 100. % VALID REPLY

TEST TRANSPONDER = 0. FEET 0. % VALID REPLY

0. REPLY 0. % BRACKET REPLY

FIGURE B-7. MTPA TEST 99 SUMMARY SHEET (1st RUN) (SHEET 2 OF 2)

24K NO POWER SEN. #1 1.5 FT -49 DB
SIDE LOBE SUPPRESSION TEST - 15

P1-P2	P1 LEVEL (-DBM) 60	50
15	0	100
12	0	100
9	0	100
6	0	99
3	0	31
0	0	0
-3	0	0
-6	0	0

FIGURE B-8. MTPA TEST 15 SUMMARY SHEET (SHEET 1 OF 2)

N6024K$2
SIDE LOBE SUPPRESSION TEST - 15

1.5 FT -49 DB

P1-P2	P1 LEVEL (-DBM) 60	50
15	0	53
12	0	53
9	0	58
6	0	57
3	0	53
0	0	13
-3	0	0
-6	0	0

FIGURE B-8. MTPA TEST 15 SUMMARY SHEET (SHEET 2 OF 2)

24K NO POWER SEN. #1
SIDE LOBE SUPPRESSION TEST - 15

1.5 FT -49 DB

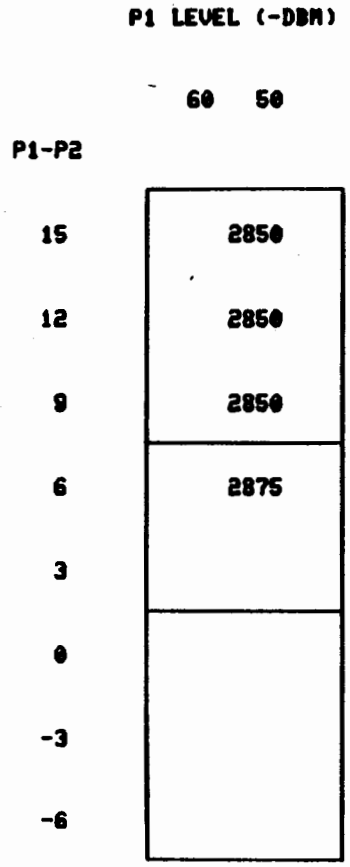


FIGURE B-9. MTPA TEST 15 SUMMARY SHEET (DELAY) (SHEET 1 OF 2)

N6024K$2
SIDE LOBE SUPPRESSION TEST - 15

1.5 FT -49 DB

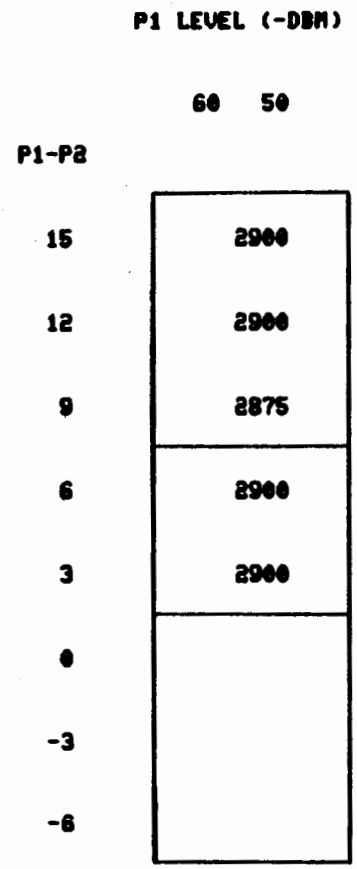


FIGURE B-9. MTPA TEST 15 SUMMARY SHEET (DELAY) (SHEET 2 OF 2)

24K NO POWER SEN. #1
SIDE LOBE SUPPRESSION TEST - 15

1.5 FT -49 DB

P1-P2	P1 LEVEL (-DBM) 60	50
15	30.5	
12	30.5	
9	30.5	
6	30.5	
3		
0		
-3		
-6		

FIGURE B-10. MTPA TEST 15 SUMMARY SHEET (POWER) (SHEET 1 OF 2)

N6024K$2
SIDE LOBE SUPPRESSION TEST - 15

1.5 FT -49 DB

P1-P2	P1 LEVEL (-DBM) 60	50
15	26.5	
12	26.5	
9	26.5	
6	26.5	
3	26.5	
0		
-3		
-6		

FIGURE B-10. MTPA TEST 15 SUMMARY SHEET (POWER) (SHEET 2 OF 2)

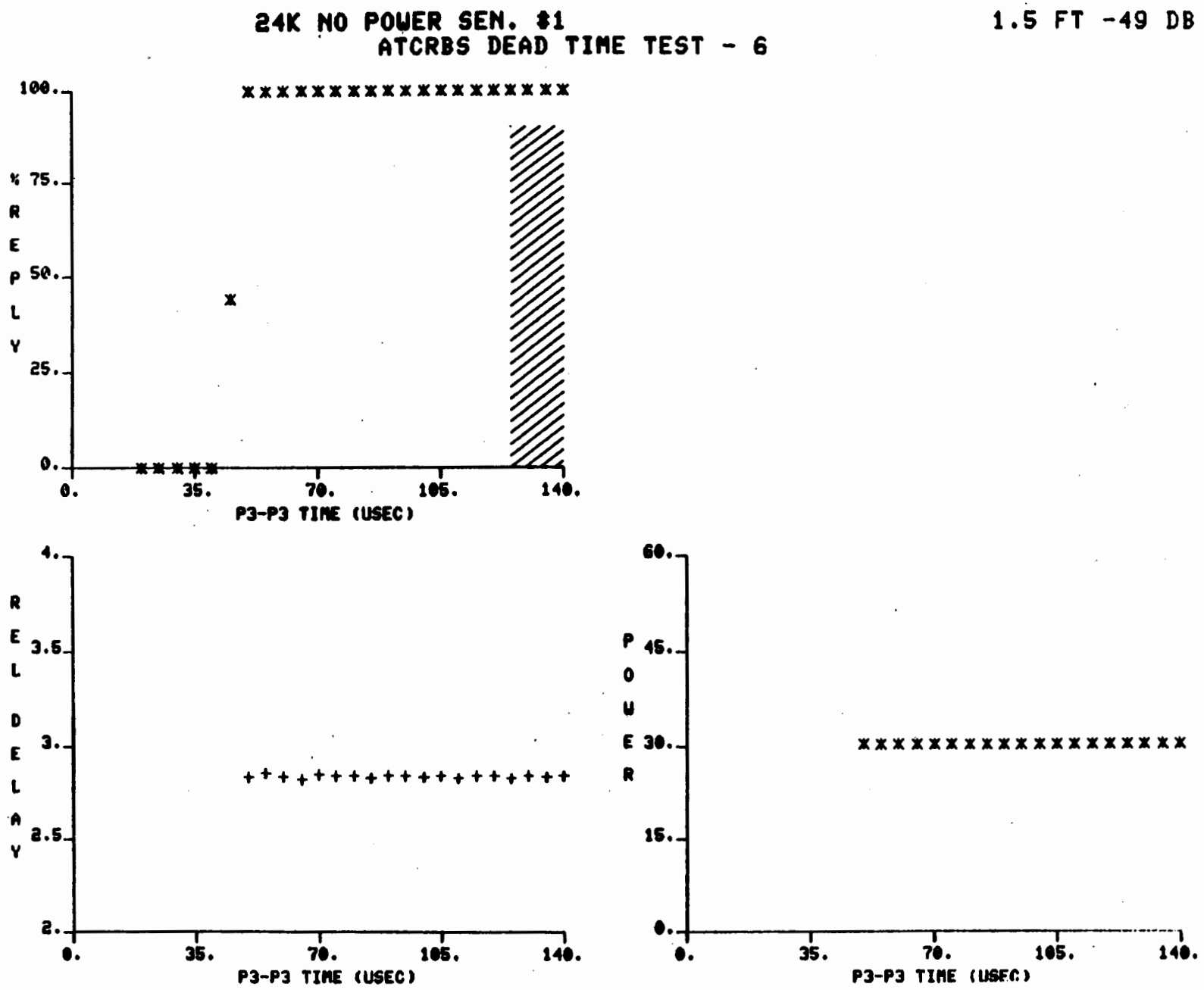


FIGURE B-11. MTPA TEST 6 SUMMARY SHEET (SHEET 1 OF 2)

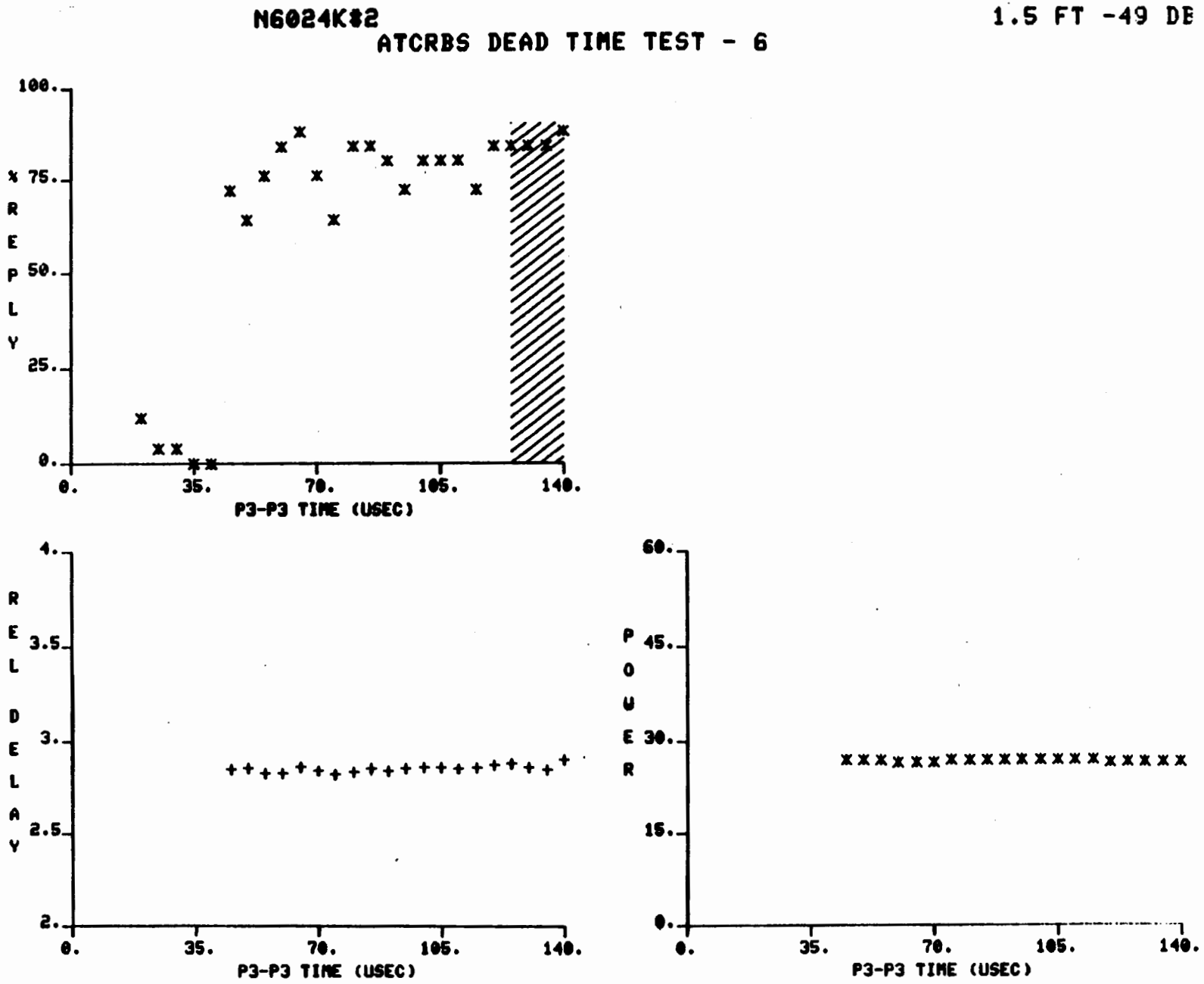


FIGURE B-11. MTPA TEST 6 SUMMARY SHEET (SHEET 2 OF 2)

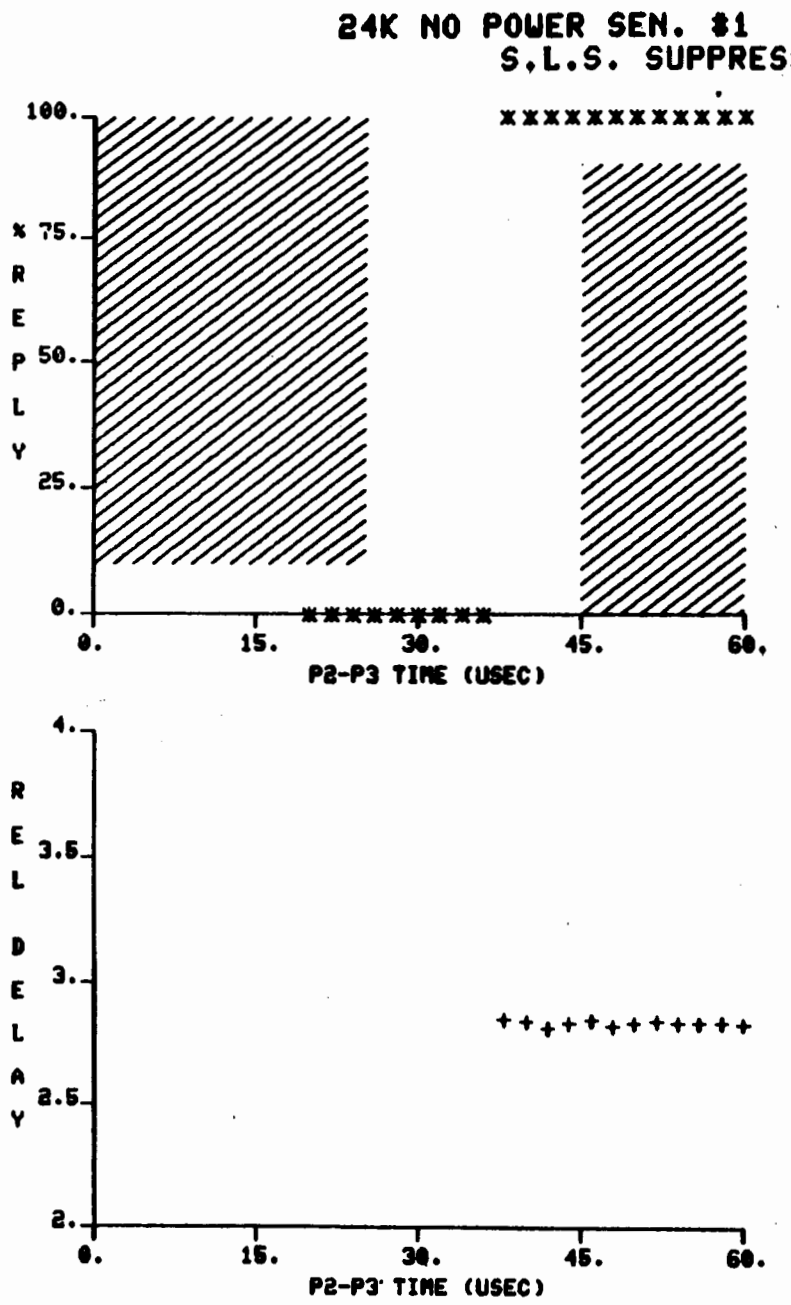


FIGURE B-12. MTPA TEST 7 SUMMARY SHEET (SHEET 1 OF 2)

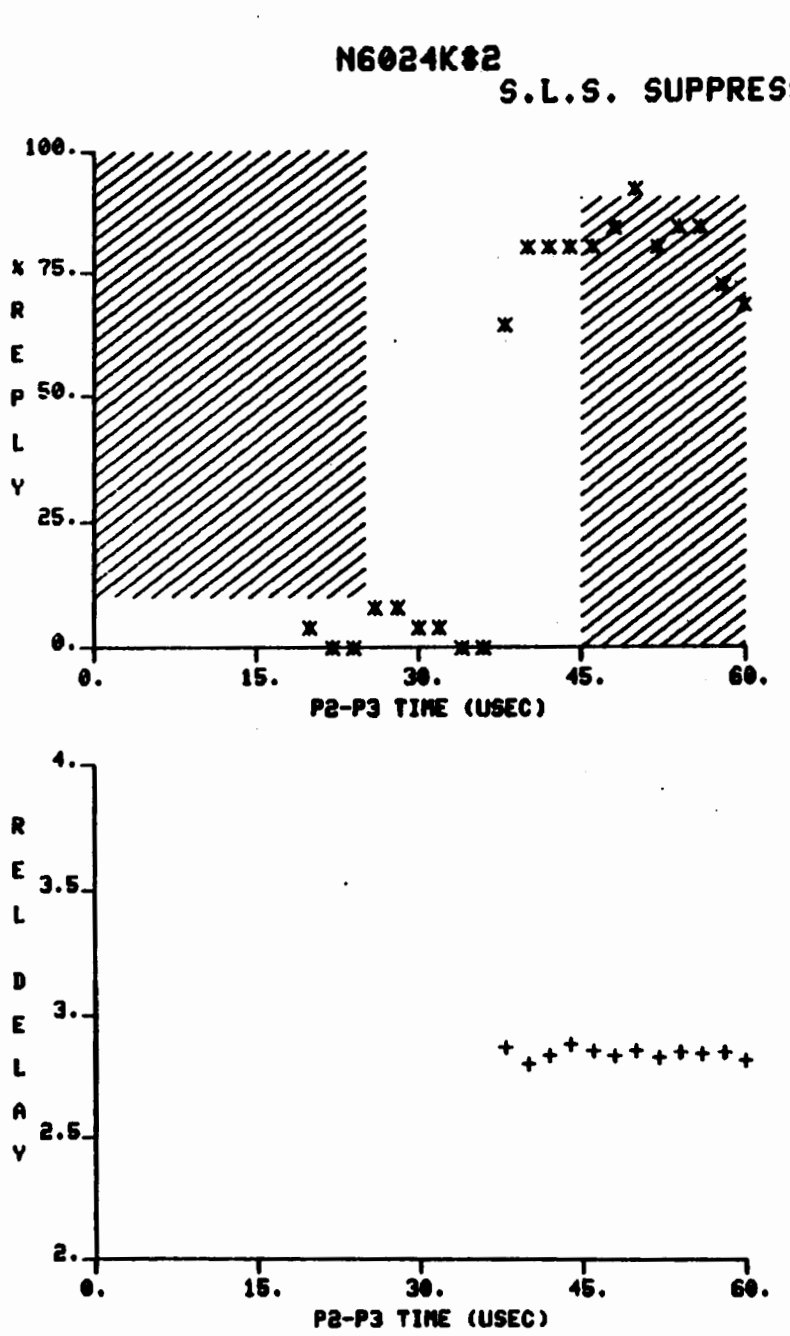


FIGURE B--12. MTPA TEST 7 SUMMARY SHEET (SHEET 2 OF 2)

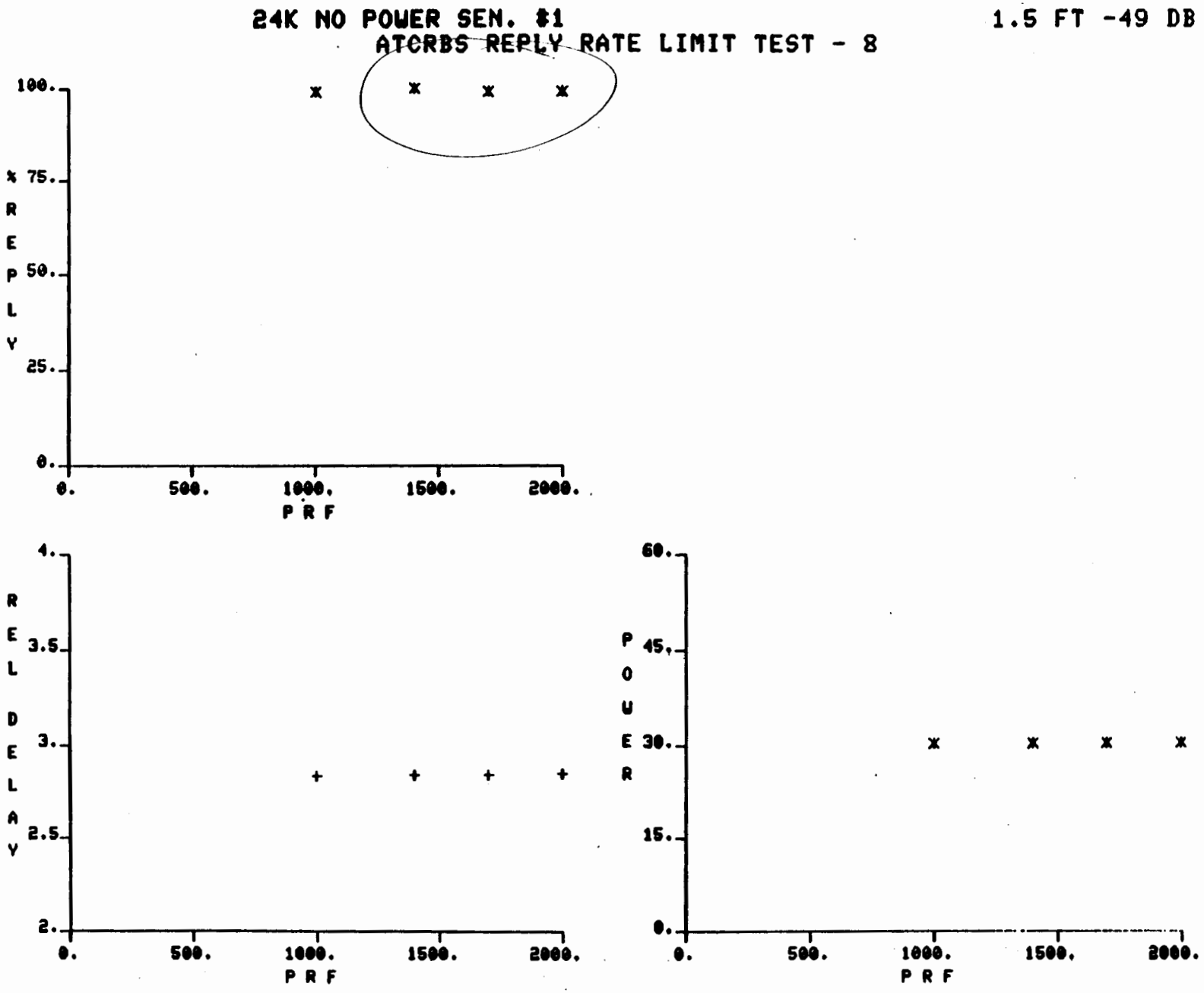


FIGURE B-13. MTPA TEST 8 SUMMARY SHEET (SHEET 1 OF 2)

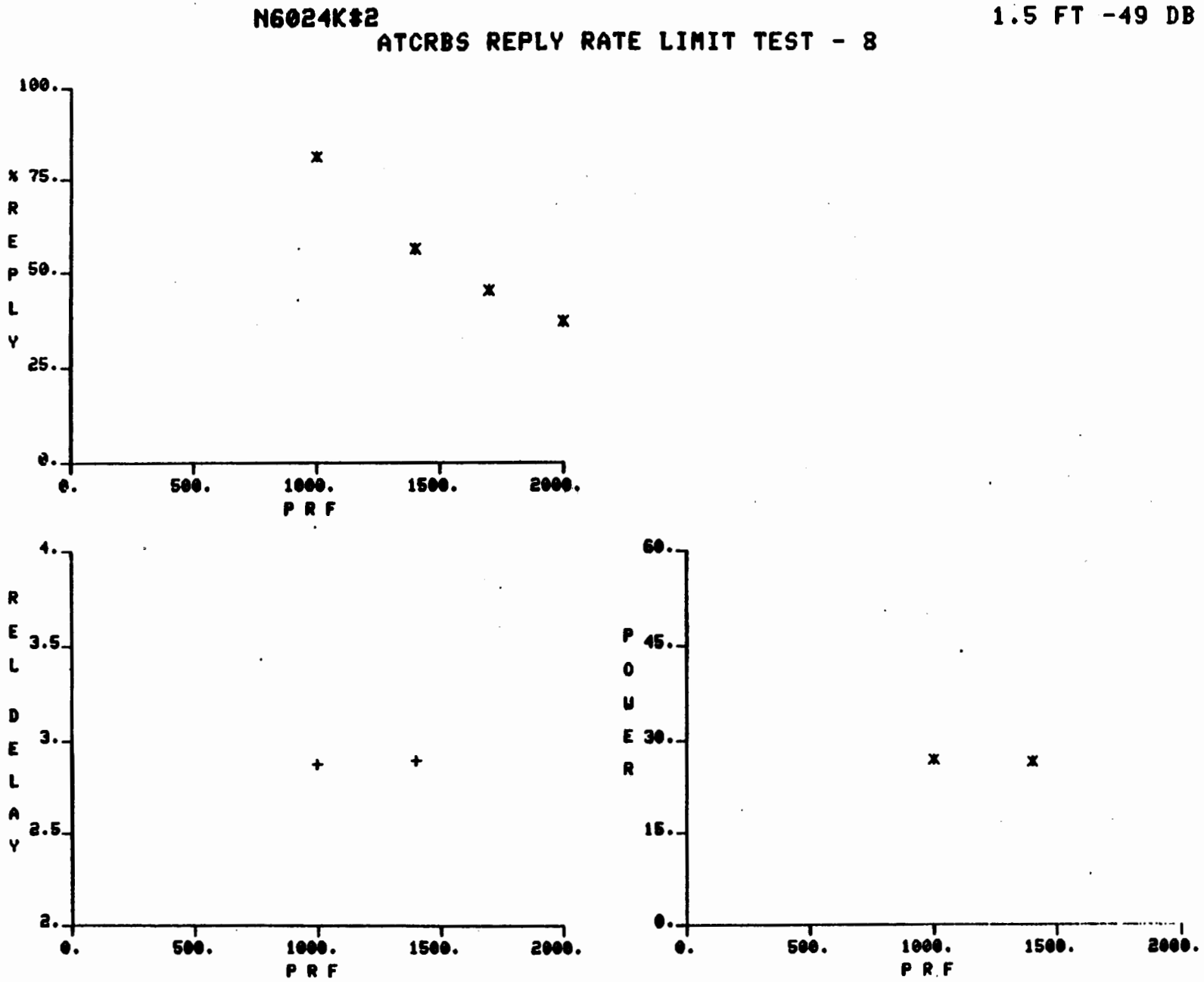


FIGURE B-13. MTPA TEST 8 SUMMARY SHEET (SHEET 2 OF 2)

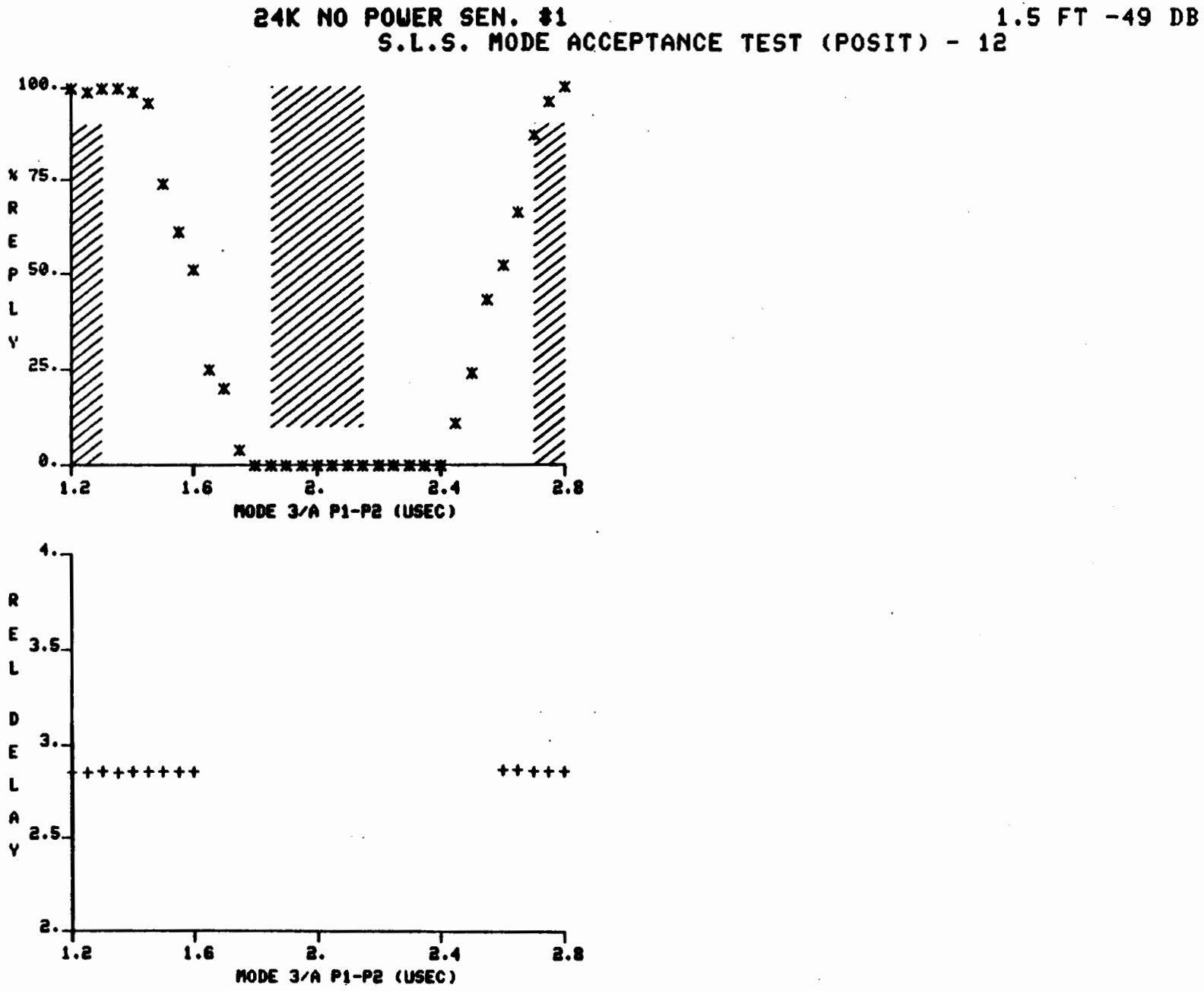


FIGURE B-14. MTPA TEST 12 SUMMARY SHEET (SHEET 1 OF 2)

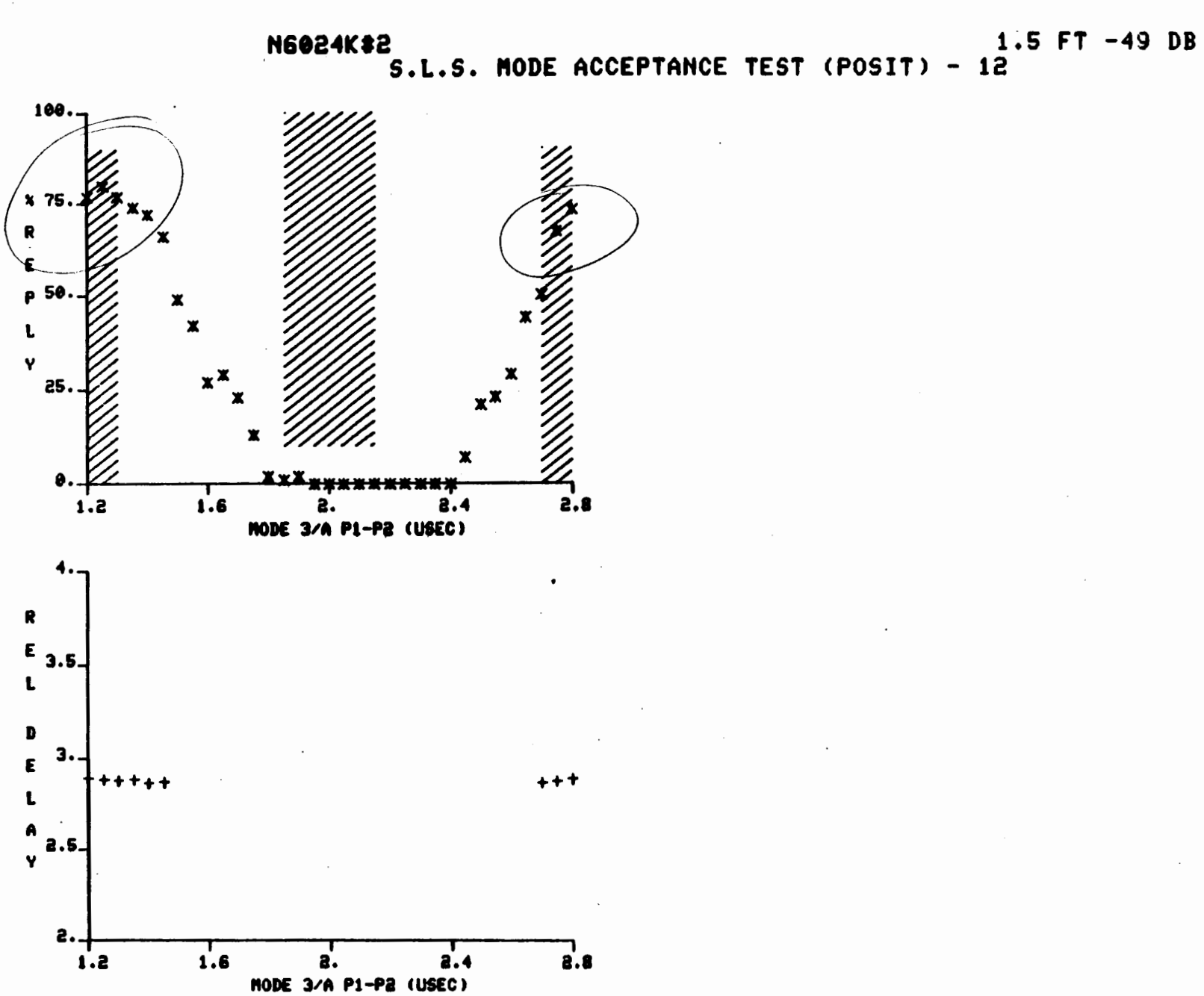


FIGURE B-14. MTPA TEST 12 SUMMARY SHEET (SHEET 2 OF 2)

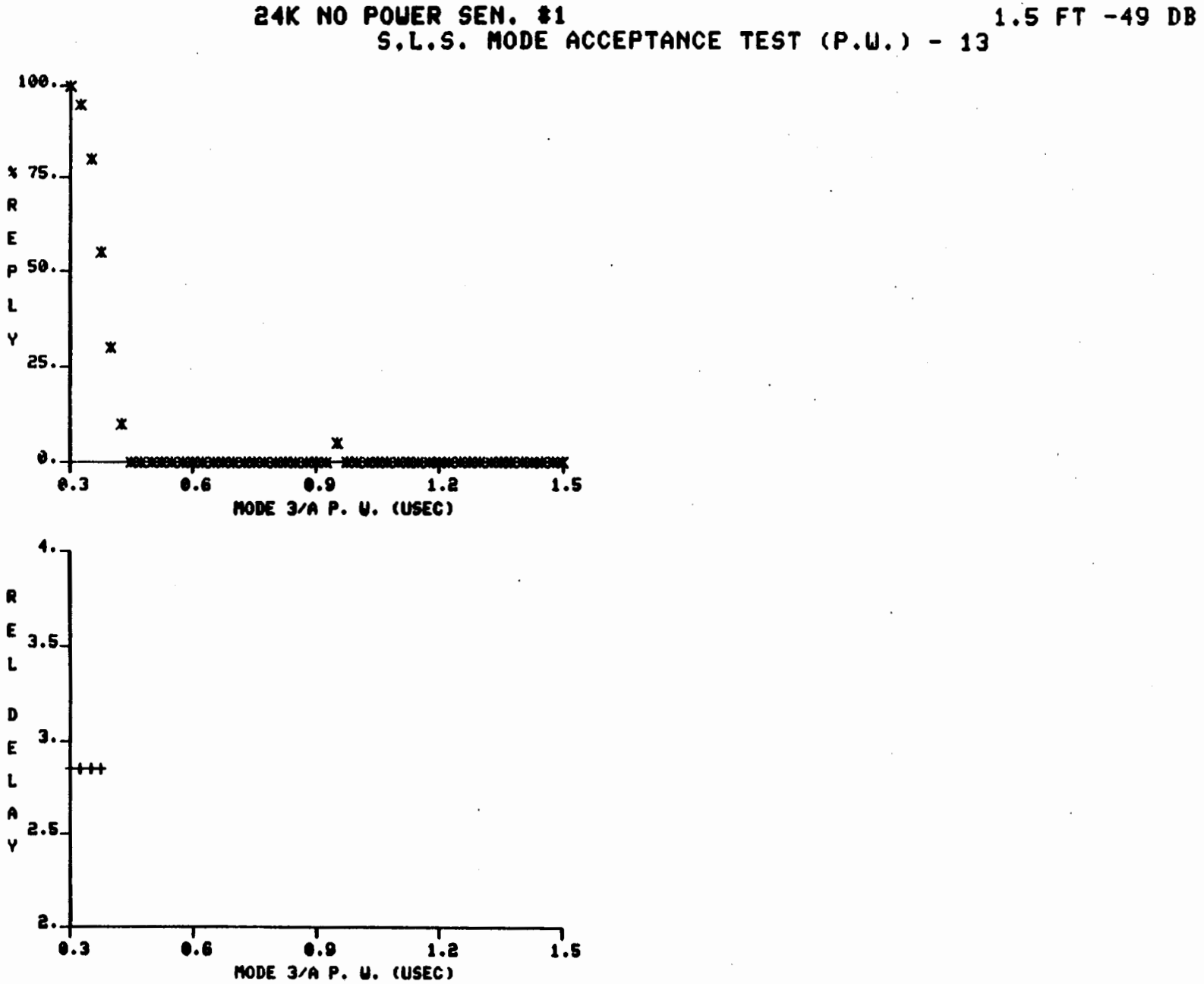


FIGURE B-15. MTPA TEST 13 SUMMARY SHEET (SHEET 1 OF 2)

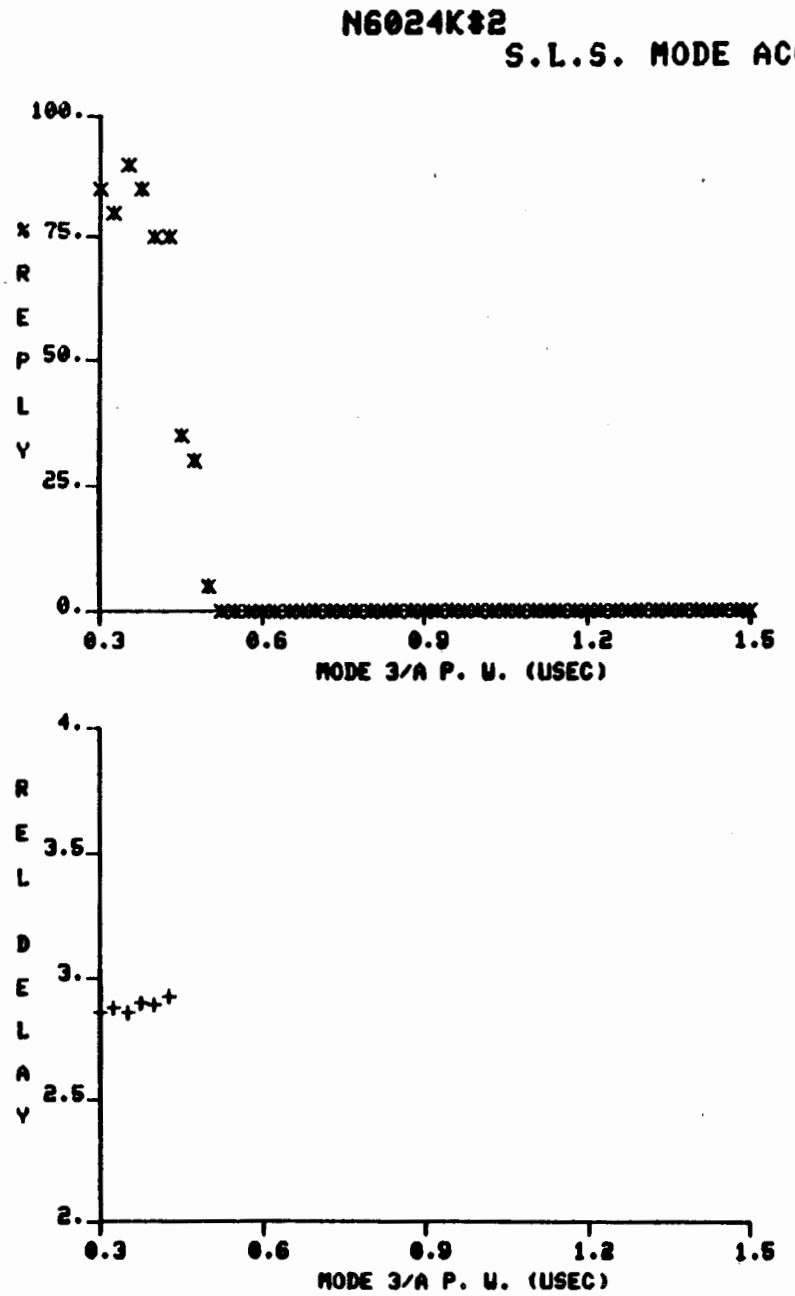


FIGURE B-15. MTPA TEST 13 SUMMARY SHEET (SHEET 2 OF 2)

24K NO POWER SEN. #1 1.5 FT -49 DB
ATCRBS SENSITIVITY TEST - 14

	SENSITIVITY	POWER	DELAY
MODEA	0	0	2.855
MODEC	0	0	2.878

never reached 90% reply rate

this program filters all power readings below +40 dBm

FIGURE B-16. MTPA TEST 14 SUMMARY SHEET (SHEET 1 OF 2)

N6024K$2 1.5 FT -49 DB

ATCRBS SENSITIVITY TEST - 14

	SENSITIVITY	POWER	DELAY
MODEA	0	0	2.867
MODEC	0	0	2.853

never reached 90% reply rate

this program filters all power readings below +40dbm

FIGURE B-15. MTPA TEST 14 SUMMARY SHEET (SHEET 2 OF 2)

24K NO POWER SEN. #1 1.5 FT -49 DB
SIDE LOBE SUPPRESSION TEST - 5

P1 LEVEL (-DBM)

P1-P2	75	72	69	66	63	60	57	54	51	48	45	42	39	36	33	30	27	24
15	0	0	0	0	0	0	0	24	100	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	5	99	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	11	99	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	11	99	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	10	77	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	5	2	0	0	0	0	0	0	0	0	0
-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

FIGURE B-17. MTPA TEST 5 SUMMARY SHEET (SHEET 1 OF 2)

N6024K82
SIDE LOBE SUPPRESSION TEST - 5

1.5 FT -49 DB

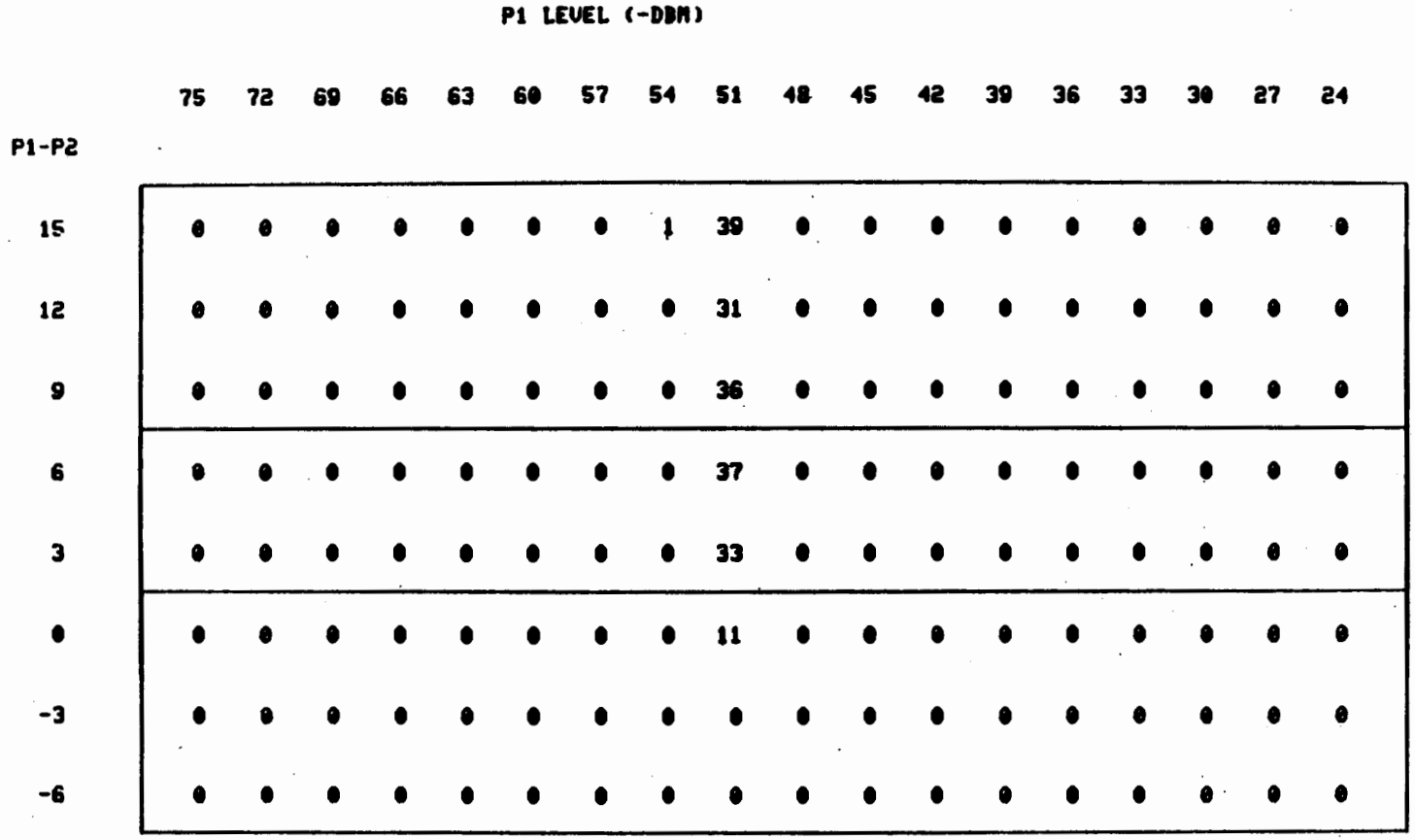


FIGURE B-17. MTPA TEST 5 SUMMARY SHEET (SHEET 2 OF 2)

24K NO POWER SEN. #1
SIDE LOBE SUPPRESSION TEST - 5

1.5 FT -49 DB

P1 LEVEL (-DBM)

P1-P2	75	72	69	66	63	60	57	54	51	48	45	42	39	36	33	30	27	24
15									2896									
12									2909									
9									2904									
6									2911									
3									2918									
0																		
-3																		
-6																		

FIGURE B-18. MTPA TEST 5 SUMMARY SHEET (DELAY) (SHEET 1 OF 2)

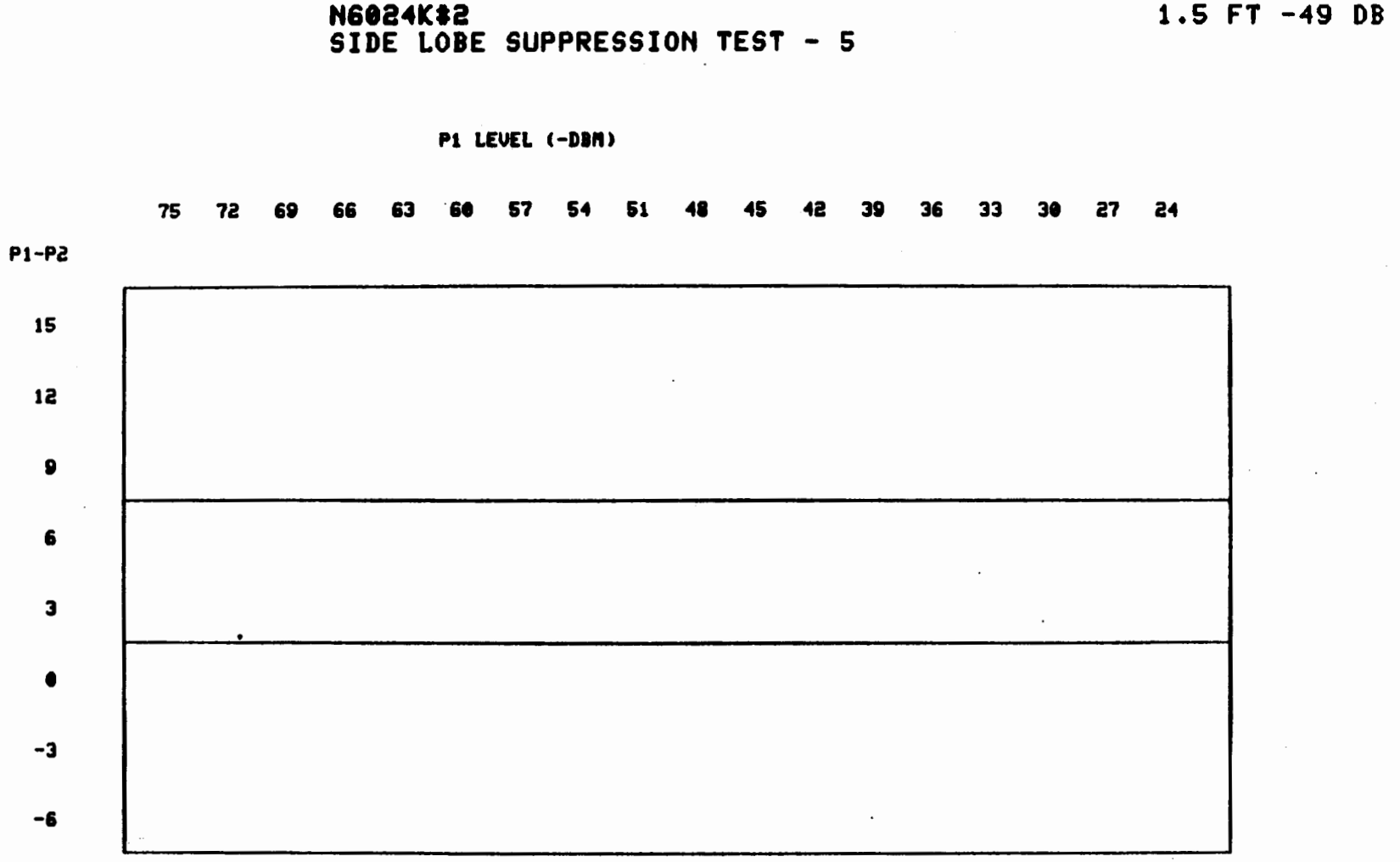


FIGURE B-18. MTPA TEST 5 SUMMARY SHEET (DELAY) (SHEET 2 OF 2)

24K NO POWER SEN. #1 1.5 FT -49 DB
SIDE LOBE SUPPRESSION TEST - 5

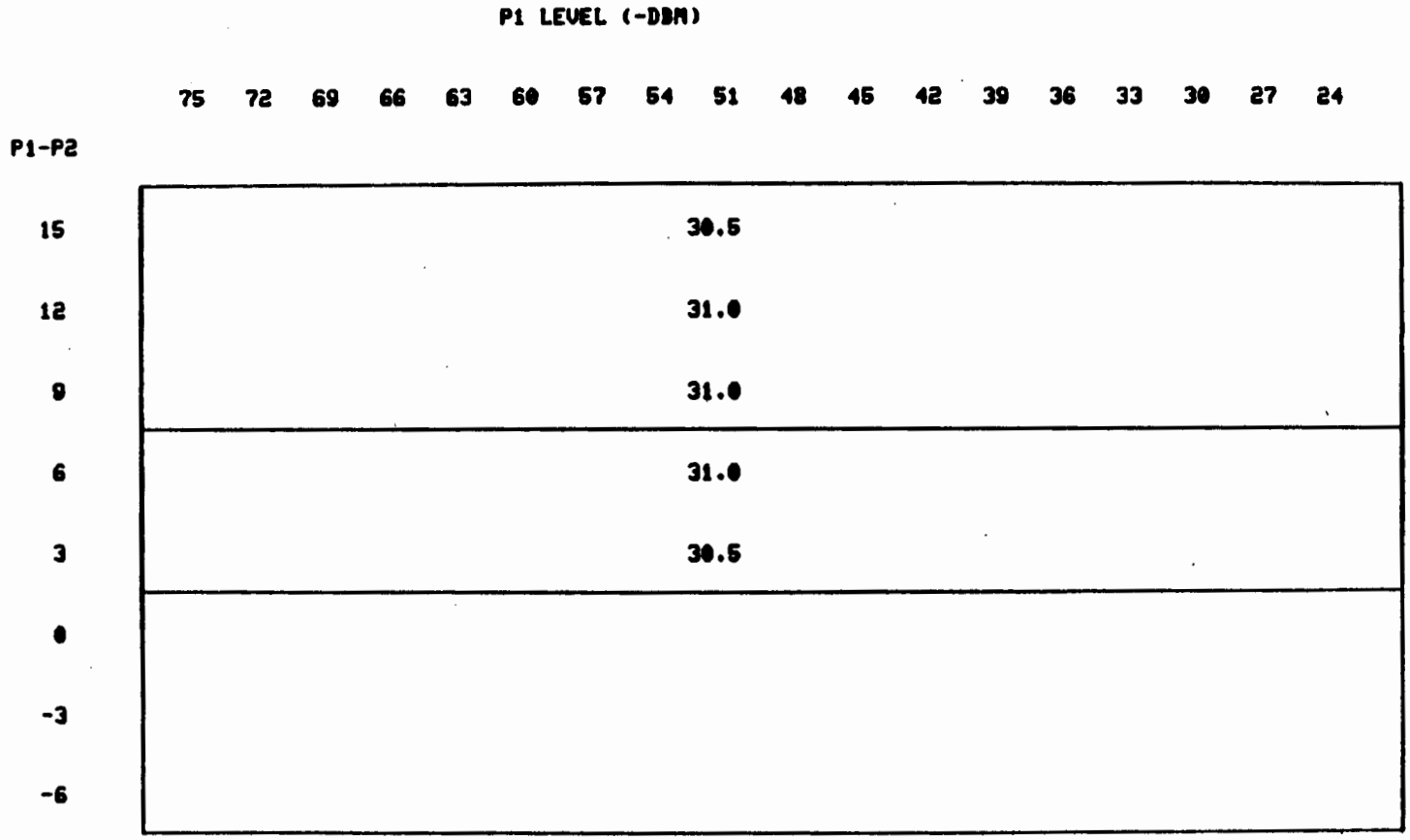


FIGURE B-19. MTPA TEST 5 SUMMARY SHEET (POWER) (SHEET 1 OF 2)

N6024K$2
SIDE LOBE SUPPRESSION TEST - 5

1.5 FT -49 DB

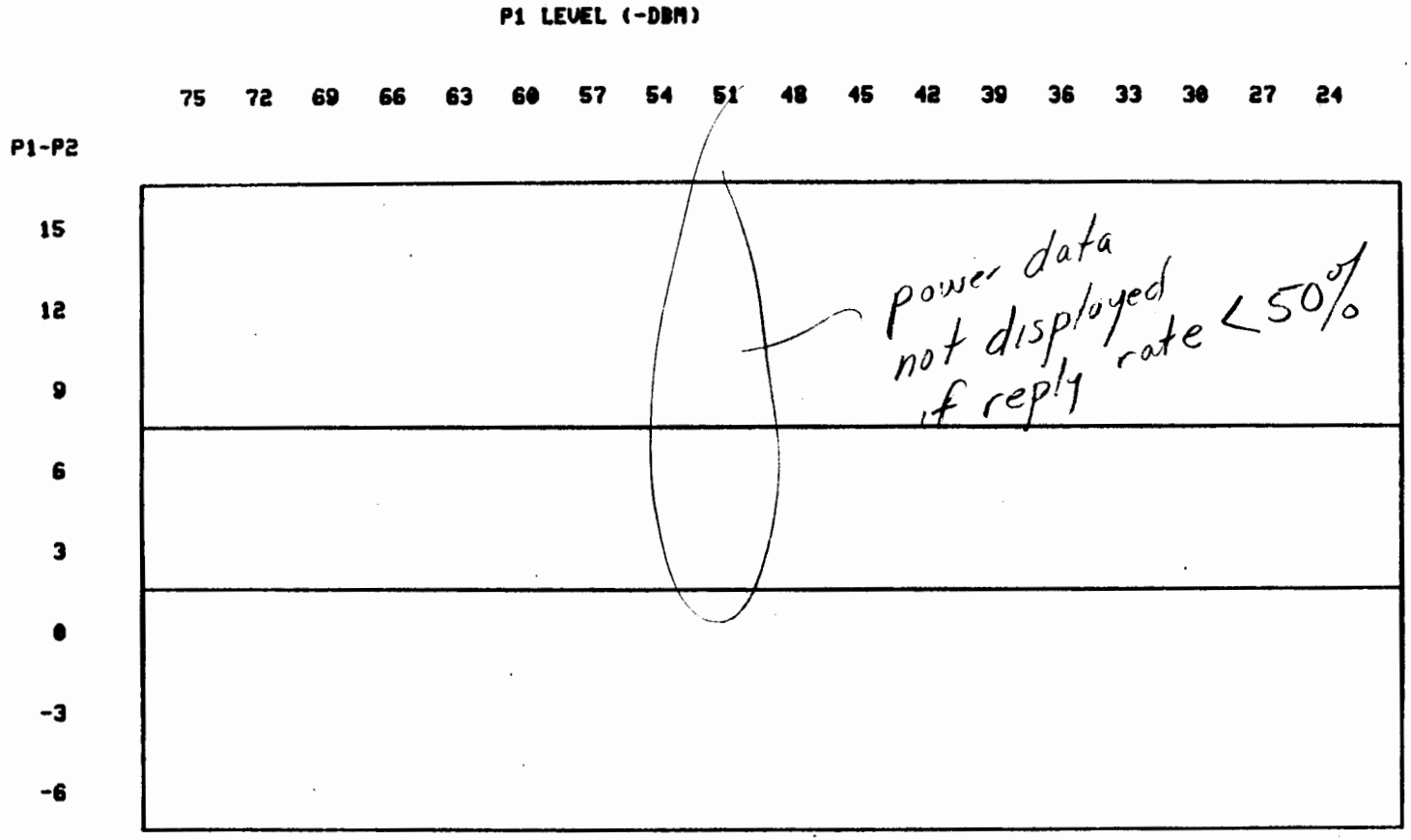
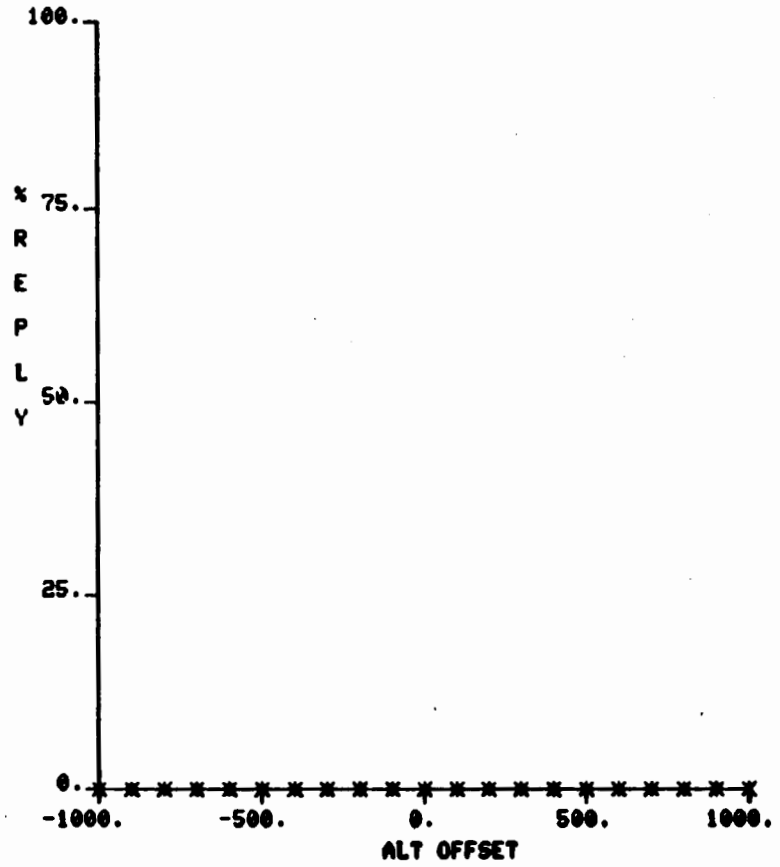


FIGURE B-19. MTPA TEST 5 SUMMARY SHEET (POWER) (SHEET 2 OF 2)

N6024K$2 1.5 FT -49 DB

MODE C ALTITUDE VERIFICATION - 99



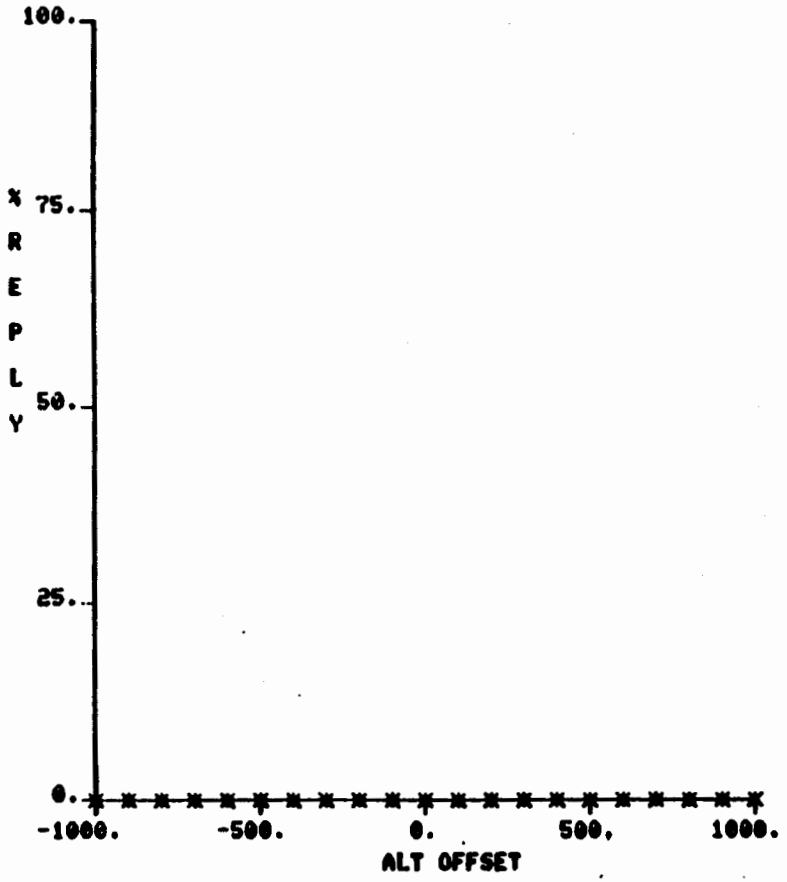
STANDARD TRANSPONDER = 900. FEET 100. % VALID REPLY

TEST TRANSPONDER = 0. FEET 0. % VALID REPLY

0. REPLY 0. % BRACKET REPLY

FIGURE B-20. MTPA TEST 99 SUMMARY SHEET (2nd RUN) (SHEET 1 OF 2)

24K NO POWER SEN. #1 1.5 FT -49 DB
MODE C ALTITUDE VERIFICATION - 99



STANDARD TRANSPONDER = 900. FEET 100. % VALID REPLY
TEST TRANSPONDER = 0. FEET 0. % VALID REPLY
0. REPLY 0. % BRACKET REPLY

FIGURE B-20. MTPA TEST 99 SUMMARY SHEET (2nd RUN) (SHEET 2 OF 2)