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SUMMARY OF TRANSPONDER DATA JUNE 1977 THROUGH AUGUST 1978.(U)

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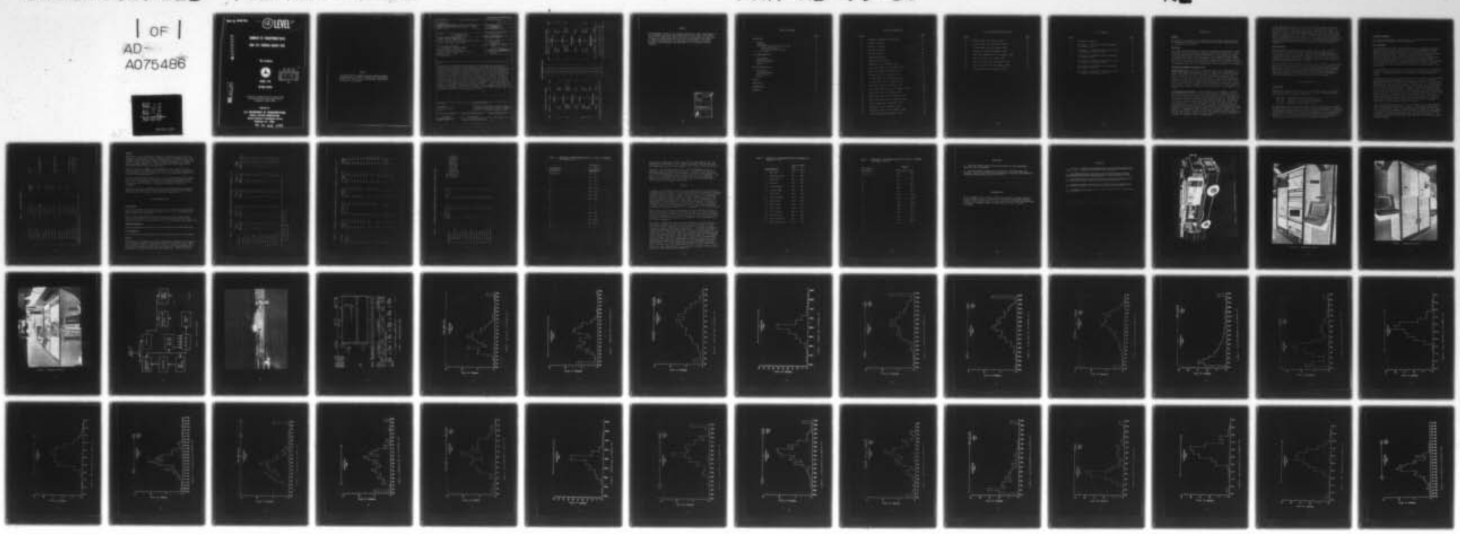

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Report No. FAA-RD-79-56

SUMMARY OF TRANSPONDER DATA

JUNE 1977 THROUGH AUGUST 1978

Max Greenberg

AUGUST 1979

INTERIM REPORT

Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.

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16. Abstract

The purpose of this effort was to determine the performance characteristics of transponders and digitized encoded altimeters in an operational environment in general aviation aircraft. A transponder performance analyzer (TPA) was developed at the National Aviation Facilities Experimental Center to measure performance parameters of transponders installed in aircraft. The TPA was installed in a bus for mobility and simulates an Air Traffic Control Beacon Interrogator (ATCBI) to facilitate measurement of 15 transponder parameters in 30 seconds. A standard gain horn is utilized to couple the signals between the TPA bus and the aircraft. Transponder data were collected at four different geographic locations resulting in more than 950 samples of general aviation transponders. Results show that 36 percent of the transponders met all measured parameters. It is concluded that this sample has established a significant data base. It is recommended that a study be conducted to determine the effects on the ATCRBS by individually varying each of the 15 parameters outside of their specification limits.

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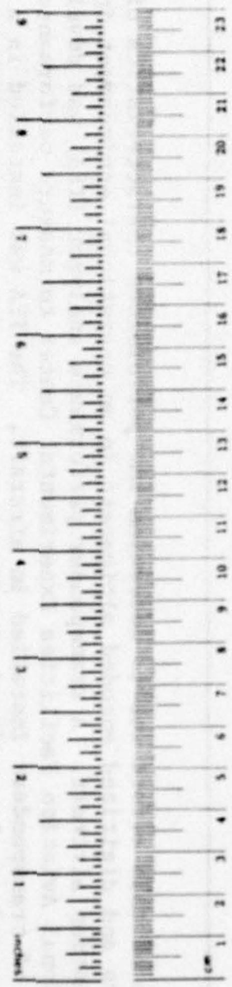
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

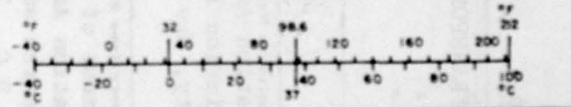
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2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

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

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



PREFACE

Acknowledgement is made to the following personnel for their participation in the transponder data collection efforts: Messrs. Oscar Adams, John Stanks, George Vento, Frank Rosati, Robert Mielicke, and Fred Siscoe for their roles in operating and maintaining the data collection equipment; John Roberts, Van Mason, and Stanley Scull for assisting in data reduction; and Mark Schoenthal, George Mahnken, and Vince Merel for the innovative software programs.

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INTRODUCTION

PURPOSE.

The purpose of this effort was to determine the performance characteristics of transponders and digitized encoded altimeters in general aviation aircraft in an operational environment.

BACKGROUND.

Operational field measurements on existing transponders would provide a significant data base for assessing and evaluating transponder problems in our present ATCRBS system and for future system planning. At the request of Airway Facilities Service (AAF) and Systems Research and Development Service (SRDS), the National Aviation Facility Experimental Center (NAFEC) was commissioned to provide data from general aviation aircraft transponders in calendar year 1977. This report is essentially the continuation of report No. FAA-RD-77-74, "Summary of Transponder Data, June 1975 through August 1976," dated June 1977 (reference 1).

TRANSPONDER PERFORMANCE ANALYZER (TPA).

GENERAL DESCRIPTION. The TPA is an automated mobile test system capable of testing many transponder parameters while the transponder is operating in the airspace environment (airborne), stopped on a ramp, or in a laboratory bench mode of operation. The TPA is fully self-contained and housed in a bus (figure 1) for mobility. The equipment consists of a modified UPX-14 beacon transmitter/receiver, directional horn antenna, voltage control (digital) PIN diodes, pulse mode generator (PMG), radio frequency (RF) control unit, reply processor, digital clock, computer buffer, minicomputer with magnetic tape and disk storage, a display terminal with hard copy printer, and other elements for timing, control, analog-to-digital (A/D) conversions, etc. (see figures 2, 3, and 4).

TPA OPERATION AND PROCEDURES. The minicomputer issues commands to the PMG, which establishes the pulse rate and spacing between interrogation pulses. The PMG also triggers the transmitter, which generates a low level of RF power. The control of the pulse rate and pulse spacing is utilized in measurement of transponder dead time, suppression time, decode accuracy, etc. The amplitude of the RF is controlled by the PIN diode modulators which feed the PMG and horn antenna which, in turn, transmits and receives all the RF pulses. The transponder reply is processed through the receiver intermediate frequency (IF) amplifiers and various circuits for measurement of pulse amplitude, width, spacing, etc., and then recorded on magnetic tape for data reduction and future analysis. A 100-megahertz (MHz) clock is used to measure the pulse width, spacing, and timing. A cathode ray tube (CRT) provides a visual output during the test, and a thermal printer provides a hard copy printout for immediate assessment. Figure 5 is the TPA block diagram.

In the ramp testing procedure, the TPA bus is located alongside the taxiway, and the aircraft under test is positioned over a reference mark (figure 6). The aircraft pilot is requested to turn on the transponder and squawk a specified code. The test takes approximately 30 seconds. When the aircraft transponder's antenna is over the calibrated reference mark, the free-space attenuation, horn antenna gain, cable losses, etc., are accounted for in measurements of transponder power and sensitivity. The computer software automatically controls interrogation, spacing, rate, etc., as 15 transponder characteristics are measured and recorded. These are also shown on the computer printout (figure 7).

DATA COLLECTION.

Transponder data recorded represents 2 calendar years of data collection, 1977 and 1978. During 1977, four air shows/fly-ins were selected for data collection: (1) the Reading Air Show, June 1977, Reading, Pennsylvania; (2) Transfair, August 1977, at NAFEC, Atlantic City, New Jersey; (3) the Confederate Air Show, October 1977, Harlingen, Texas; and (4) the AOPA Fly-In, October 1977, Opa-Locka, Florida. In addition to the above, data collected during the 1978 NAFEC Transfair are included.

The U.S. National Aviation Standard for the IFF Mark X (SIF)/Air Traffic Control Radar Beacon System Characteristics, 1010.51A, August 1971 (reference 2); The Radio Technical Commission for Aeronautics (RTCA), Document DO-150, "Minimum Performance Standards Airborne ATC Transponder Equipment" testing procedures, March 1972 (reference 3); and RTCA Document DO-144, "Minimum Operational Characteristics-Airborne ATC Transponder Systems," March 1970 (reference 4) were used to determine equipment characteristics for transponders.

1977 TRANSPONDER DATA

DATA SAMPLES.

This section contains a description of the measurements made on transponders installed in itinerant general aviation aircraft at the following geographic areas from air shows or fly-ins during 1977.

June 1977	Reading, Pennsylvania (Air Show)
Aug. 1977	Atlantic City, New Jersey (Transfair)
Oct. 1977	Harlingen, Texas (Confederate Air Show)
Oct. 1977	Opa-Locka, Florida (AOPA Fly-In)

More than 800 aircraft were interrogated in 1977 by the TPA bus at the various air shows and fly-ins. Of these, 753 were considered valid samples for compiling statistics. The invalid samples were due to the fact that some of the same aircraft appeared at another listed show or returned daily to the same show, creating duplicate data which were automatically discarded during data reduction. Another cause for invalid data was aircraft movement from the calibrated reference point before the data collection process was completed.

PARAMETERS MEASURED.

The parameters measured are listed in table 1. The results are compared with the established standards as defined in reference 2.

TEST PROCEDURES.

A very high frequency (VHF) communication frequency was assigned by frequency management prior to the air show/fly-in date. This information along with other general information about the TPA was utilized in Notices to Airmen (NOTAM's), Automatic Terminal Information Service (ATIS), brochures, and hand-outs for advance publicity. In addition, signs directed the aircraft towards the TPA bus testing area and parking facilities. Once communication was established, the volunteer pilot was guided by a member of the TPA team to a calibrated mark on the taxiway and advised to operate his transponder on a specified discrete code. When the personnel in the TPA bus detected reply signals from the transponder, they entered all the manual data via the CRT keyboard.

A CRT presentation is displayed for verification of test results. A hard copy printout is generated and the test data recorded on magnetic tape for future analysis. The transponder tests are accomplished within approximately 30 seconds.

A standard gain directional antenna (horn) is used to couple the signal between the aircraft transponder antenna and the TPA bus. The horn is Scientific Atlanta model 12-0.9. Calibration and dimensions for the horn are taken from NRL Report No. 4433. The nominal gain at 1.0 GHz is 13.7 dB. The E-plane and H-plane nominal bandwidths are 40° and 35°, respectively. The average height from ground to the general aviation transponder antennas are about 30 inches and the horn is set at that height. A coupling factor due to height variation is taken into consideration as part of the measurement tolerance (reference 5, pages 48 and 49). The distance of 50 feet between horn and aircraft transponder antenna was used for separation and clearance purposes and is taken into account during calibration. Calibration to the TPA electronics utilizes the state-of-the-art test equipment and a reference transponder. The reference transponder is measured for 15 parameters directly by the TPA equipment (bench test), and the parameter values are recorded.

The reference transponder is then placed 50 feet away (with a large aluminum plate approximately 3 square feet, to support an IFP quarter-wave antenna or "stub" in the center). When the transponder is interrogated, the TPA equipment, would then be readjusted by offset voltages to produce the same readings as previously recorded from the bench test. This would allow for free-space attenuation, cable losses, power level settings, gain of the horn, etc. If a different distance is required, new offset voltages are required to produce the same readings.

TABLE 1. MEASUREMENT PARAMETERS

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

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

RESULTS.

Measurements of the 15 parameters from all 753 samples obtained in 1977 were compared to the standards. Table 2 indicates these 15 characteristics at the individual shows and fly-ins as well as composite data for 1977. A measurement tolerance is also indicated to allow for possible measurement error and/or antenna coupling (reference 5). These are taken into consideration in the calculation of power output and sensitivity.

Table 3 shows the percentages of transponders which met some ("N") of the standards, where the parameter "N" varies from 1 to 15. Figures 8 through 19 are the composite data (753 samples) for each of the individual parameters for a total of 11,295 measurements.

It can be seen from table 3 that 258 out of 753 transponders met all 15 parameters, which is approximately 34 percent, 59 percent of transponders tested met 14 out of 15 parameters, 77 percent of transponders tested met 13 out of 15 parameters, and 87 percent of transponders tested met 12 out of 15 parameters.

From table 2 one can see parameters with the lowest percentage of meeting the specifications; namely, reply power, sensitivity, and mode C decode accuracy, at 83.3 percent, 77.7 percent, and 81.4 percent, respectively.

1978 TRANSPONDER DATA

DATA SAMPLES.

This section contains essentially the same type of transponder data previously described under 1977 transponder data except that it is for 1978 Transfair at NAFEC, Atlantic City, New Jersey.

More than 250 itinerant general aviation aircraft were interrogated by the TPA bus at Transfair 1978. Of these, 212 were valid samples, with invalid samples due basically to the same reasons for 1977 data; namely, duplications, etc.

PARAMETERS MEASURED.

Parameters measured were the same as the 1977 parameters previously mentioned.

TEST PROCEDURES.

Test procedures were the same as the 1977 test procedures previously mentioned.

RESULTS.

Measurements of 15 parameters for the 212 samples were compared to the standards. Table 4 indicates these 15 characteristics recorded at Transfair 1978. Again, the measurement tolerance is indicated to allow for possible measurement error and/or antenna coupling variables which were taken into consideration during measurement of transponder power output and sensitivity. Table 5 shows the

TABLE 2. PERCENTAGE OF TRANSPONDERS MEETING STANDARDS (753 SAMPLES, 1977)

Characteristics	Reading, Pa. (96) Meas. Toler.,%	Reading, Pa. (96) Spec. %	Atlantic City, N.J. (259) Meas. Toler.,%	Atlantic City, N.J. (259) Spec. %	Harlingen, Tx. (135) Meas. Toler.,%	Harlingen, Tx. (135) Spec. %	Opa-Locka, Fla. (263) Meas. Toler.,%	Opa-Locka, Fla. (263) Spec. %	Composite (753) Meas. Toler.,%	Composite (753) No.	Composite (753) Spec. %
1. Dead Time	—	99.0	—	98.1	—	98.5	—	96.6	—	736	97.7
2. Suppression Time	—	88.6	—	85.3	—	97.8	—	92.8	—	682	90.6
3. Reply Power	22.5	79.2	22.7	86.5	19.1	74.8	24.8	85.9	22.3	627	83.3
4. Frequency	—	91.7	—	93.1	—	97.0	—	95.4	—	711	94.4
5. F_2 Pulse Width	4.0	87.5	8.3	83.0	3.1	88.9	4.5	92.8	5.3	663	88.0
6. F_1 Pulse Width	4.0	85.4	6.7	79.0	4.5	88.1	5.7	92.0	5.4	650	86.3
7. Sensitivity	17.4	67.7	24.6	78.4	24.5	77.8	28.8	80.6	25.0	585	77.7
8. Delay Time Diff.	3.0	94.8	1.3	92.3	1.4	94.1	3.8	92.4	2.6	700	93.0
9. Reply Jitter	4.0	90.6	3.5	96.1	1.5	92.6	2.6	93.2	2.9	706	93.8
10. Mode A Delay	—	99.0	—	93.1	—	95.6	—	96.6	—	727	96.6
11. Mode C Delay	—	99.0	—	95.0	—	93.3	—	97.7	—	724	95.1
12. F_1 F_2 Spacing	3.0	85.4	8.9	87.6	4.6	93.3	4.1	89.0	5.5	669	88.8
13. SLS Decode Acc.	—	85.4	—	90.0	—	91.1	—	91.3	—	678	90.0
14. Mode A Decode Acc.	—	77.1	—	86.5	—	88.9	—	95.1	—	668	88.7
15. Mode C Decode Acc.	—	85.4	—	78.0	—	76.3	—	85.9	—	613	81.4

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

Under spec. % the measurement tolerance % is included.

— Zero measurement tolerance.

TABLE 3. PERCENTAGE OF TRANSPONDERS MEETING "N" OF THE 15 STANDARDS (753 SAMPLES, 1977)

"N" Standards	Reading, Pa. (96)		Atlantic City, N.J. (259)		Harlingen, Tx. (135)		Opa-Locka, Fla. (263)		Composite (753)	
out of 15	"N"	%	"N"	%	"N"	%	"N"	%	"N"	%
15 out of 15	24	25.0	76	29.3	47	34.8	111	42.2	258	34.3
14	45	46.9	145	55.9	80	59.2	178	67.7	448	59.5
13	68	70.9	191	73.7	101	74.8	224	85.2	584	77.6
12	79	82.4	217	83.7	118	87.4	244	92.8	658	87.4
11	89	92.8	238	91.8	132	97.8	253	96.2	712	94.6
10	94	98.0	246	94.9	—	—	259	98.5	731	97.1
9	—	—	252	97.2	—	—	260	98.9	738	98.03
8	95	99.0	255	98.4	134	99.3	—	—	744	98.08
7	—	—	257	99.2	—	—	262	99.6	748	98.83
6	—	—	258	99.6	135	100	—	—	750	99.36
5	96	100	—	—	—	—	263	100	752	99.90
4	—	—	—	—	—	—	—	—	—	—
3	—	—	—	—	—	—	—	—	—	—
2	—	—	259	100	—	—	—	—	753	100
1	—	—	—	—	—	—	—	—	—	—
0	—	—	—	—	—	—	—	—	—	—

TABLE 4. PERCENTAGE OF TRANSPONDERS MEETING STANDARDS (212 SAMPLES, 1978)

Characteristics	Atlantic City, N.J. (212) Meas.* Toler.%	Spec %	Passed "N"	Failed "N"
1. Dead Time	—	97.2	206	6
2. Suppression Time	—	97.6	207	5
3. Reply Power	24.0	82.5	175	37
4. Frequency	—	85.8	182	30
5. F_2 Pulse Width	4.1	93.9	199	13
6. F_1 Pulse Width	2.2	91.5	194	18
7. Sensitivity	20.5	79.7	169	43
8. Delay Time Diff.	1.3	92.5	196	16
9. Reply Jitter	6.8	93.4	198	14
10. Mode A Delay	—	93.9	199	13
11. Mode C Delay	—	94.3	200	12
12. F_1 F_2 Spacing	5.1	88.7	188	24
13. SLS Decode Acc.	—	90.1	191	21
14. Mode A Decode Acc.	—	91.0	193	19
15. Mode C Decode Acc.	—	85.4	181	31

Remarks

* Measurement tolerance provides for measurement error and/or antenna coupling factor including variations due to antenna height, lobing, reflections, etc. Under spec.% the measurement tolerance % is included.

TABLE 5. PERCENTAGE OF TRANSPONDERS MEETING "N" OF THE 15 STANDARDS (212 SAMPLES 1978)

"N" Standards Out of 15	Atlantic City (212) "N" Transpond.	Percent
15 out of 15	89	42
14	141	66.5
13	175	82.5
12	193	91.0
11	197	92.9
10	203	95.7
9	205	96.6
8	209	98.5
7	--	--
6	--	--
5	--	--
4	210	99.0
3	211	99.5
2	212	100.0
1	212	100.0
0	--	--

percentage of transponders which met some ("N") of the standards, where the parameter "N" varies from 1 to 15. Figures 20 through 31 are the data from 212 transponders for each of the parameters for a total of 3,180 measurements.

From table 5, it can be seen that 89 out of 212 transponders met all 15 parameters, which is approximately 42 percent. Approximately 66 percent of the transponders met 14 out of 15 parameters, 82 percent of the transponders met 13 out of 15 parameters, and 91 percent met 12 out of 15 parameters. From table 4, one can also see that the parameters with the lowest percentage meeting the specification once again include reply power and sensitivity at 82.5 percent and 79.7 percent, respectively.

ANALYSIS

The number of data samples collected for this reporting effort was 965, which is approximately 1.0 percent of the estimated 100,000-plus transponders installed in general aviation aircraft. Whereas transponder data collected in FAA-RD-77-74 (1975/76) (reference 1) did not cover a sufficient number of 15 transponder-parameter samples, it would be difficult to show a trend statistically. However, a significant difference was found; namely, in the 1977/78 data, 348 transponders out of 965 meet all 15 parameters, approximately 36 percent, as compared to the 1975/76 results of only 13 percent. This may be attributed to larger sample size and implementation of solid state design transponders. The number of transponders tested for all 15 parameters in 1975/76 was only 56.

Table 6 shows the percentage of transponders meeting standards, and table 7 shows the percentage of transponders meeting at least "N" of the 15 standards for 1977 and 1978. From table 7, it can be seen that approximately 61 percent of the 965 transponders met 14 of the 15 parameters, 78 percent of the transponders met 13 of the 15 parameters, and 88 percent of the transponders met 12 of the 15 parameters.

The two most commonly out-of-specification parameters are reply power and sensitivity, and these are also the two most difficult parameters to measure. This is due to variables such as, ground effect, antenna coupling/orientation (lobing, reflections, shielding, etc.). Therefore, an additional 3 dB was allowed under the heading, Meas. Toler. %, in tables 2 and 4 and figures 10, 14, 22, and 26 for reply power and sensitivity measurements. This 3 dB or grey area, where Meas. Toler. % is indicated, show a greater percentage in tolerance than those for pulse width, jitter, delay, etc. An example, in table 2 under composite for reply power, it shows that 83.3 percent met the specification out of 753 transponders of which 22.3 percent were in this grey area, as indicated under Meas. Toler. %. The same applies for sensitivity, wherein 77.7 percent met the specification, of which 25.0 percent were in the grey area. Where measurement tolerance for pulse width, jitter, delay, etc., are relatively small due to electronic equipment and test equipment error, these tolerances are negligible.

TABLE 6. PERCENTAGE OF TRANSPONDERS MEETING STANDARDS (965 SAMPLES, 1977/78)

	Characteristics	Composite (965) Spec. %	"N"
1	Dead Time	97.6	942
2	Suppression Time	92.1	889
3	Reply Power	83.1	802
4	Frequency	92.5	893
5	F_2 Pulse Width	89.3	862
6	F_1 Pulse Width	87.5	844
7	Sensitivity	78.1	754
8	Delay Time Diff.	92.8	896
9	Reply Jitter	93.7	904
10	Mode A Delay	96.0	926
11	Mode C Delay	95.8	924
12	F_1 F_2 Spacing	88.8	857
13	SLS Decode Acc.	90.1	869
14	Mode A Decode Acc.	89.2	861
15	Mode C Decode Acc.	82.3	794

TABLE 7. PERCENTAGE OF TRANSPONDERS MEETING "N" OF THE 15 STANDARDS (965 SAMPLES, 1977/78)

"N" Standards Out of 15	Composite (965) "N"	Composite (965) %
15 out of 15	348	36.1
14	590	61.2
13	760	78.8
12	852	88.3
11	910	94.3
10	935	96.9
9	944	97.83
8	954	98.87
7	958	99.28
6	960	99.49
5	962	99.7
4	963	99.8
3	964	99.9
2	965	100.0
1	--	--

CONCLUSIONS

1. Test data results indicate that only 36 percent of the transponders tested met all 15 parameters.

2. The data provide a significant data base for future comparisons and analysis. This data base represents approximately 1 percent of all registered transponder-equipped general aviation aircraft.

RECOMMENDATION

It is recommended that a study be conducted to determine the impact upon the National Airspace System of varying the 15 individual transponder parameters outside of their specification. If these effects can be defined and quantified, transponder requirements (specifications) may be modified or amended accordingly.

REFERENCES

1. Hetrich, G., Summary of Transponder Data, June 1975 through August 1976, Federal Aviation Administration, FAA-RD-77-74, June 1977.

2. U.S. National Aviation Standard For The IFF Mark X(SIF)/Air Traffic Control Radar Beacon System Characteristics, No. 1010.51A August 3, 1971.

3. Minimum Performance Standards Airborne ATC Transponder Equipment, Radio Technical Commission for Aeronautics, DO-150, March 17, 1972.

4. Minimum Operational Characteristics--Airborne ATC Transponder Systems, Radio Technical Commission for Aeronautics, DO-144, March 12, 1970.

5. Transponder Test Program, Federal Aviation Administration, FAA-RD-72-30, April 12, 1972.

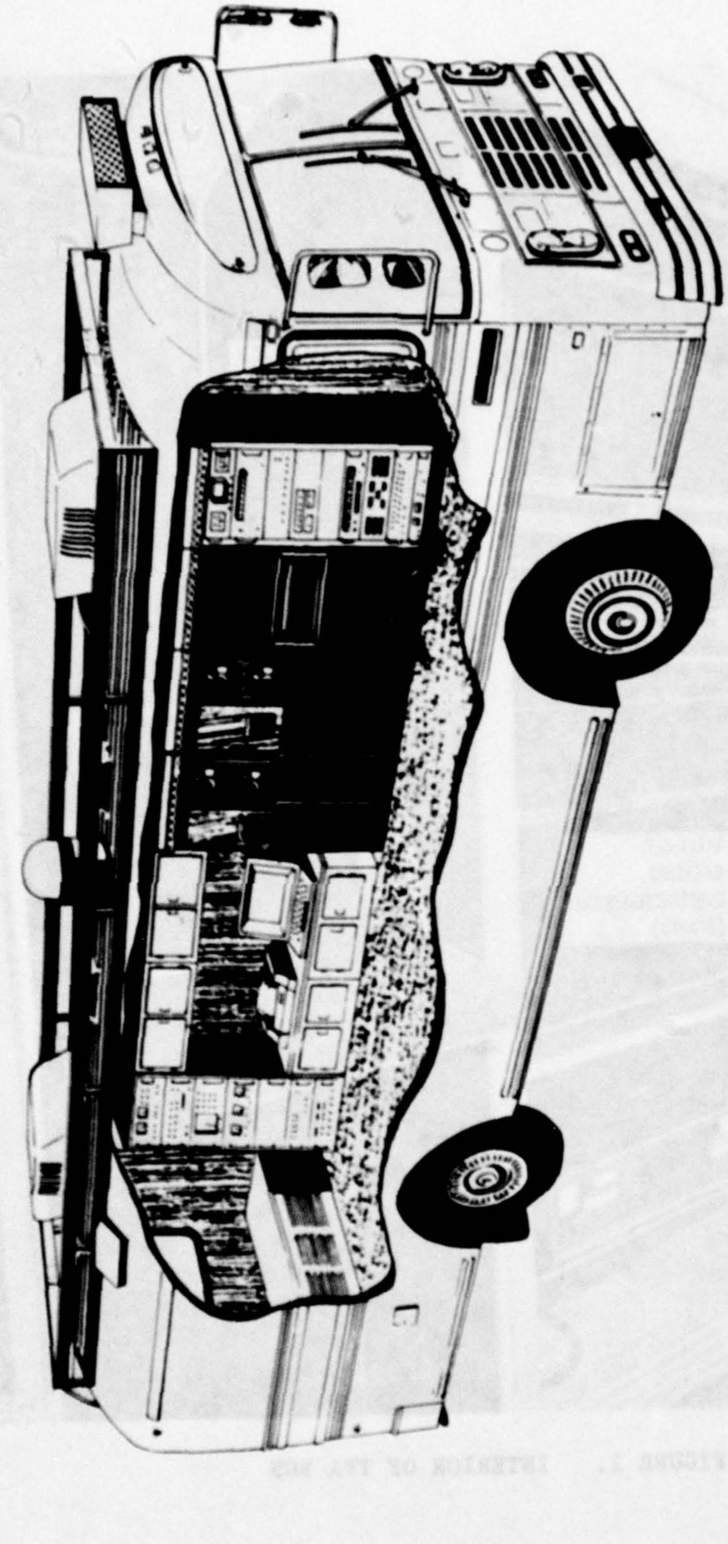


FIGURE 1. TRANSPONDER PERFORMANCE ANALYZER BUS

FIGURE 2. INTERIOR OF TPA BUS

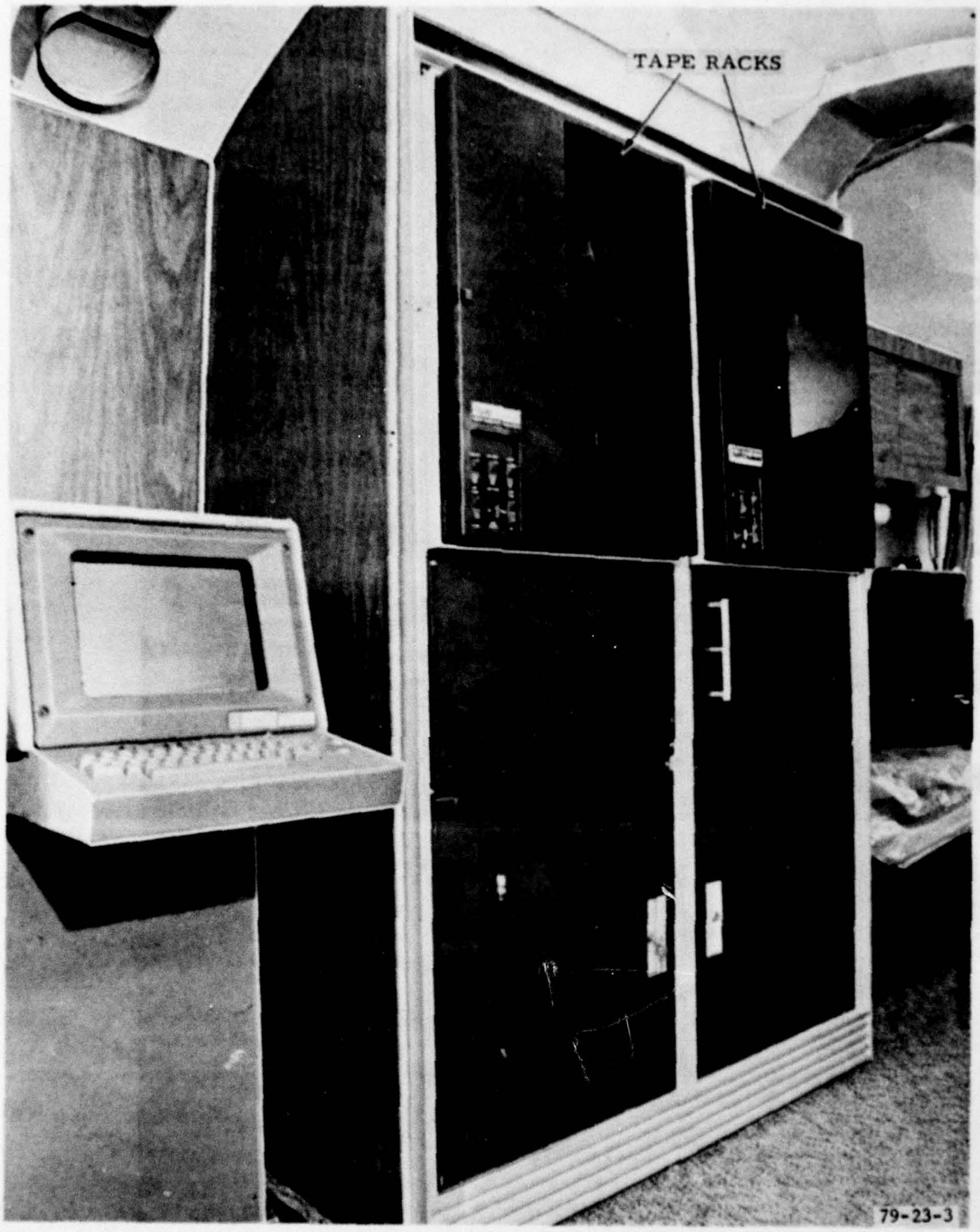


FIGURE 3. INTERIOR OF TPA BUS

FIGURE 4. INTERIOR OF TPA BUS

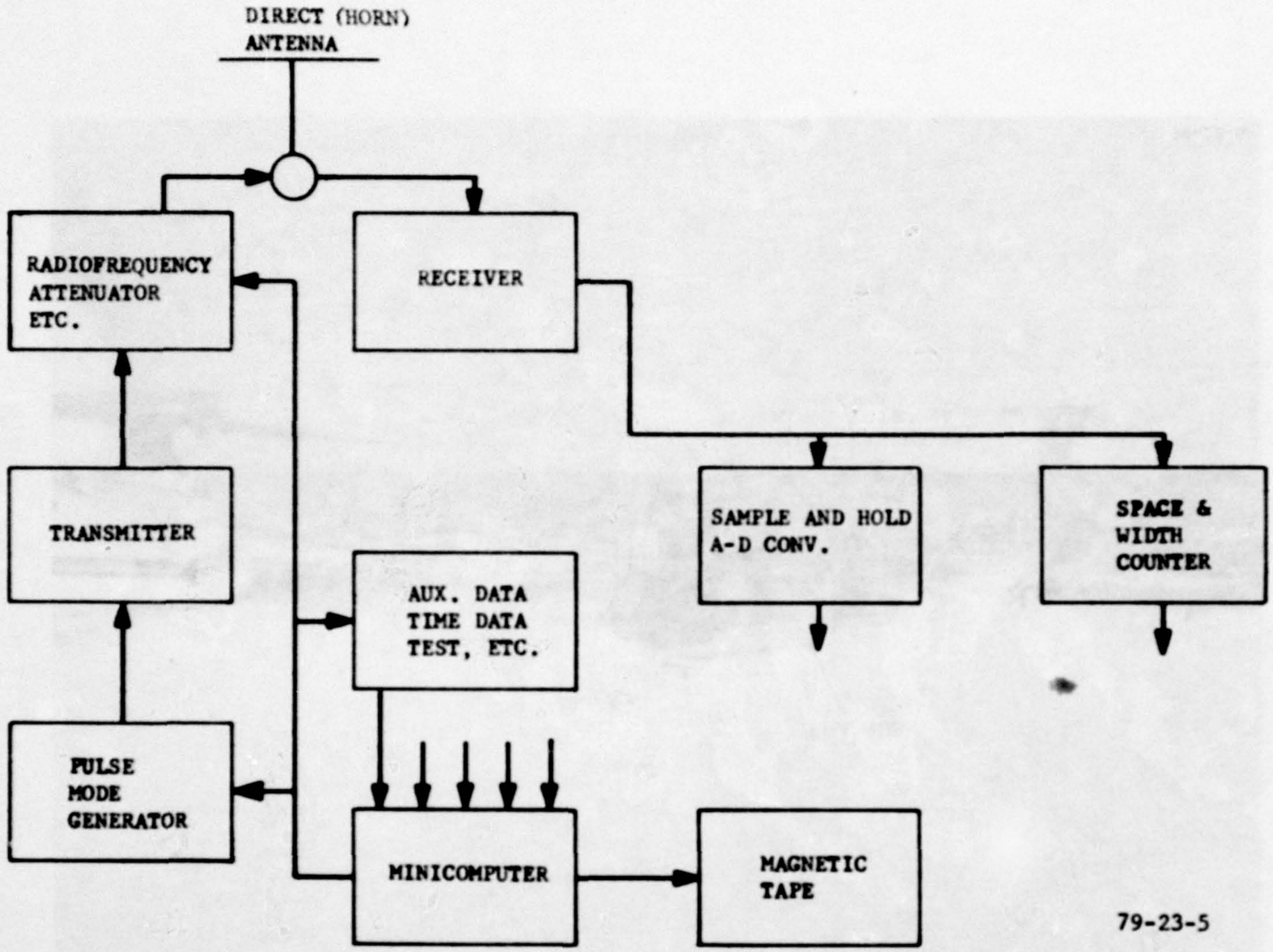
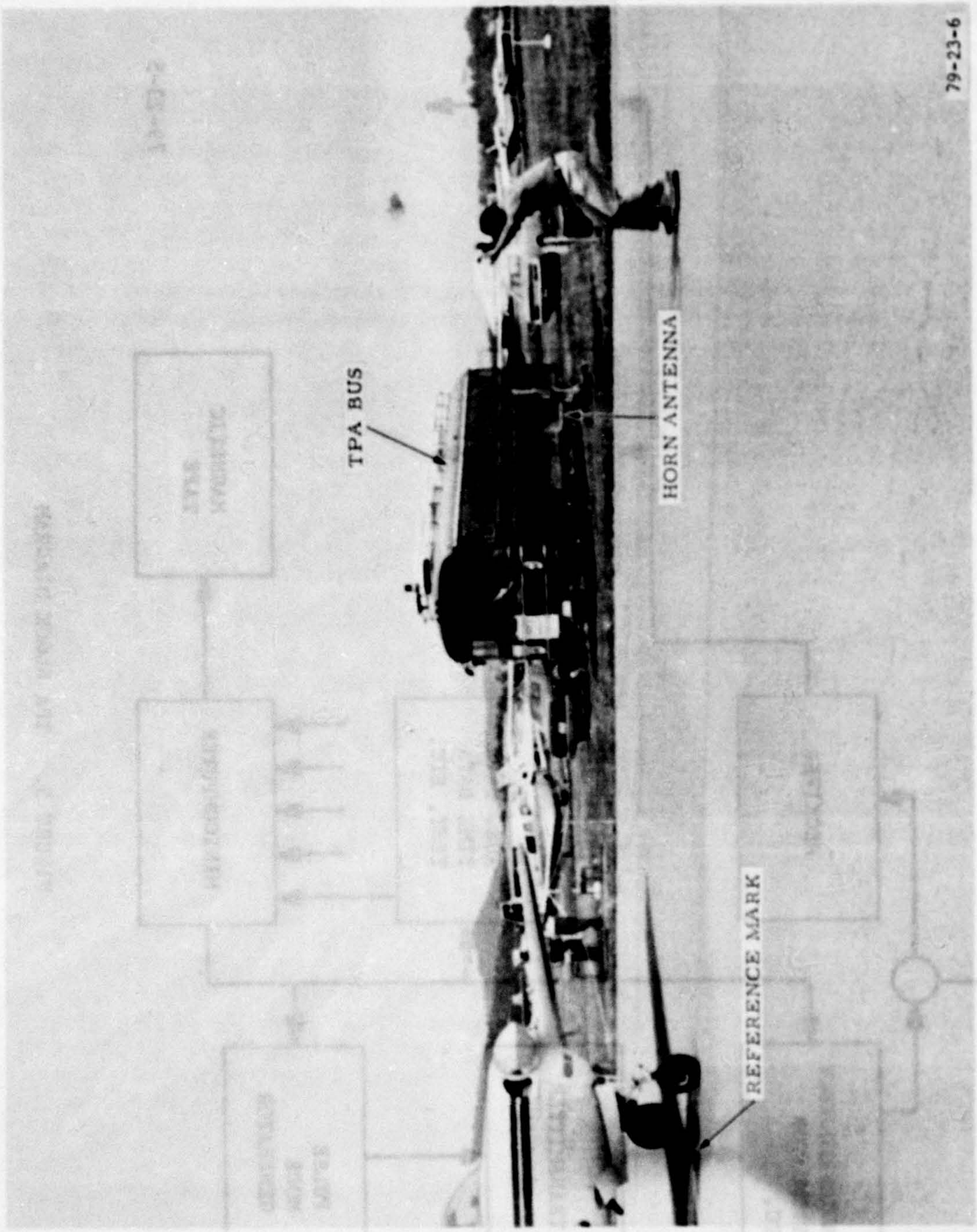
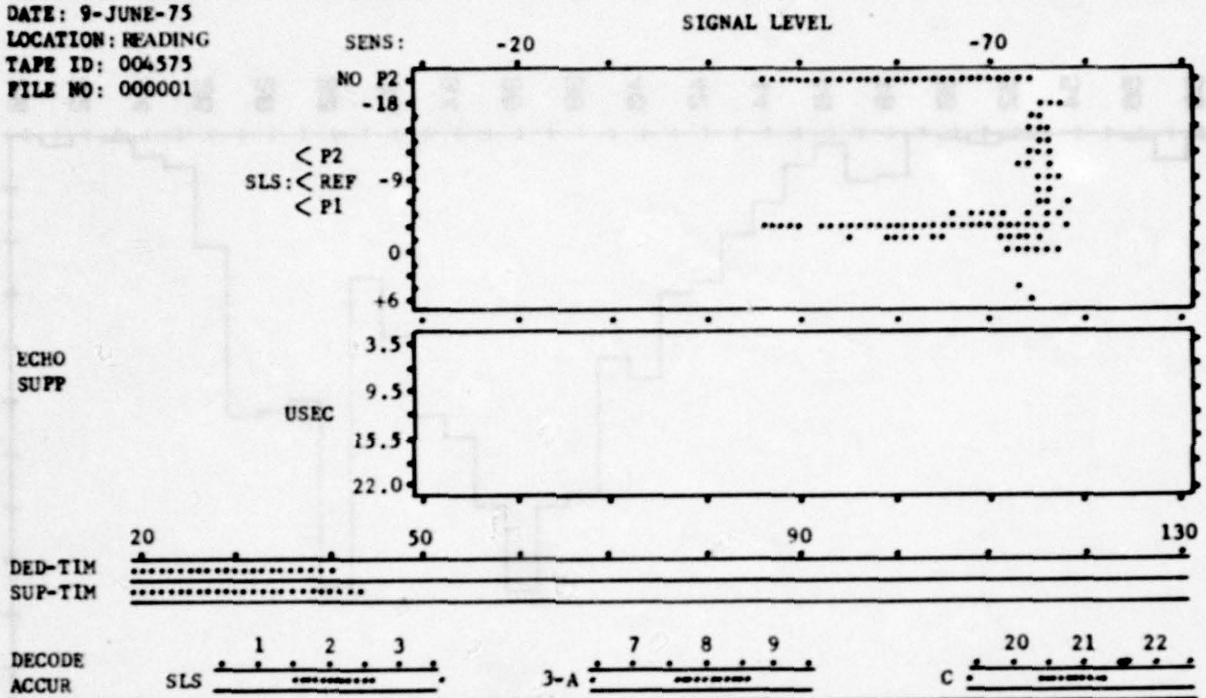


FIGURE 5. TPA BLOCK DIAGRAM


TPA BUS
HORN ANTENNA
REFERENCE MARK
79-23-6

A-C ID. N56313	A-C TYPE	CODE:7777	FREQ: 1090 MHZ
TEST NO. 27.0	XPNDR TYPE	ALT: 0	POWER DBM

DATE: 9-JUNE-75
LOCATION: READING
TAPE ID: 004575
FILE NO: 000001



F1-F2 SPACING:	20.27 USEC.	WIDTH:	470, 460 NS.	PWR OUT:	41.3, 40.6 DBM
DELAY TIME:	MODE 3-A: 3.10 USEC.	MODE C:	2.85 USEC	JITTER:	190 NSEC

AVERAGE CODE PULSE SPACING IN NANOSECONDS

	ACT		ACT		ACT		ACT		ACT		ACT
A1:	28500K	A2:	57200K	A4:	86300K	B1:	116100K	B2:	144200K	B4:	173300K
C1:	14000K	C2:	42900K	C4:	71600K	D1:	129800K	D2:	158800K	D4:	187700K

COMMENTS:

-------COURTESY OF NAFEC., ATLANTIC CITY, N.J.------- 76-37-1

FIGURE 7. COMPUTER PRINTOUT SAMPLE

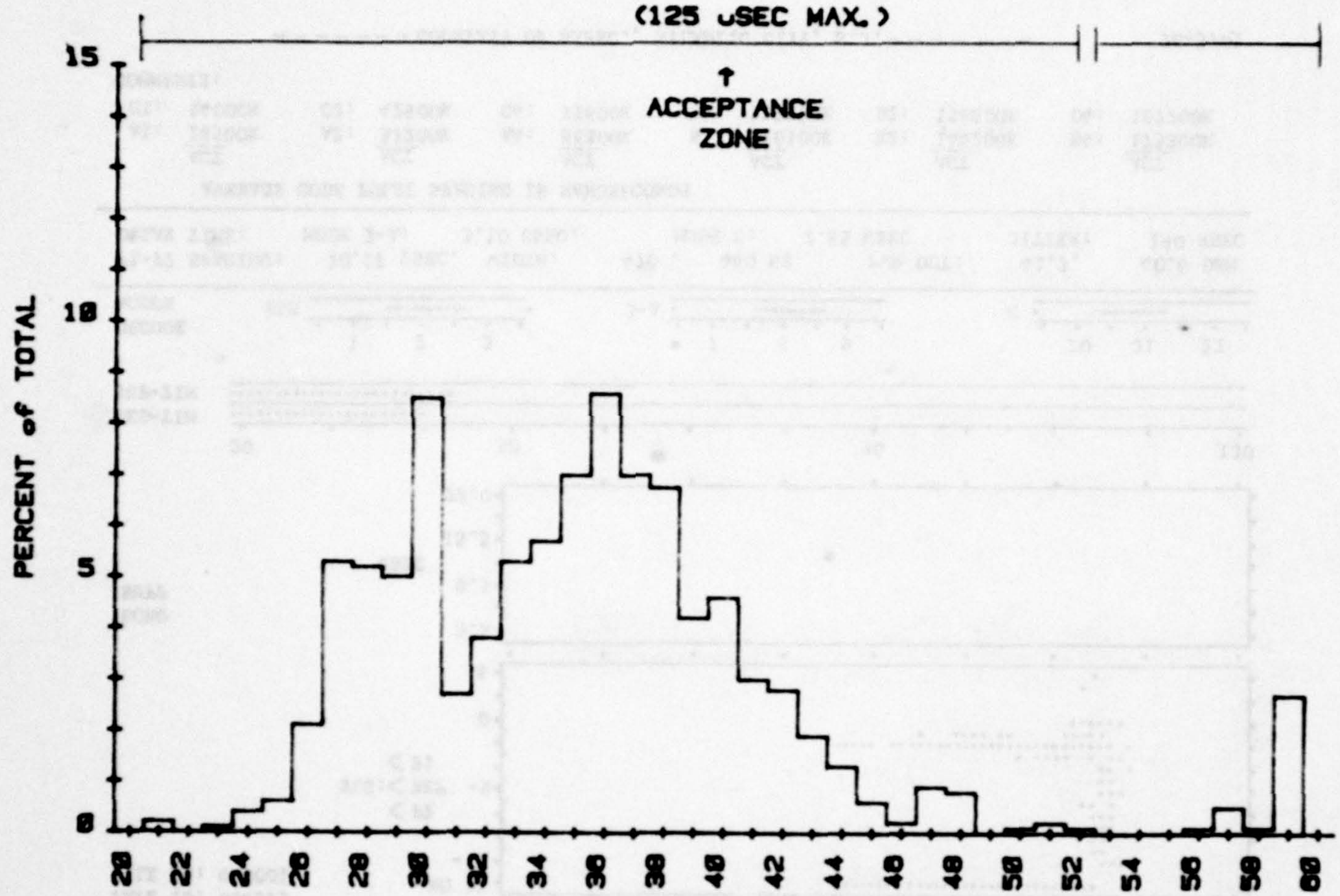


FIGURE 8. DEAD TIME (μs) (753 SAMPLES, 1977)

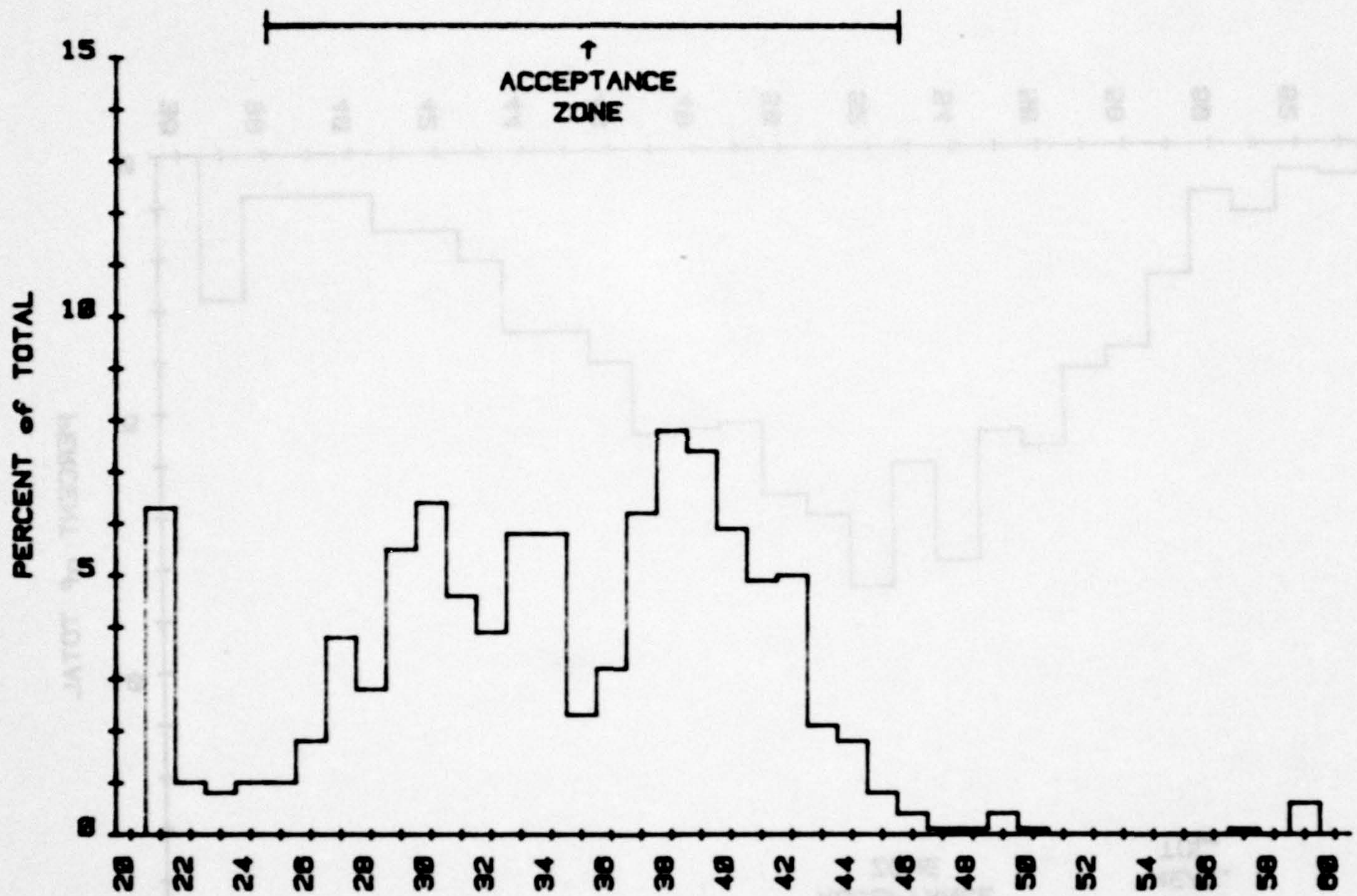


FIGURE 9. SUPPRESSION TIME (μs) (753 SAMPLES, 1977)

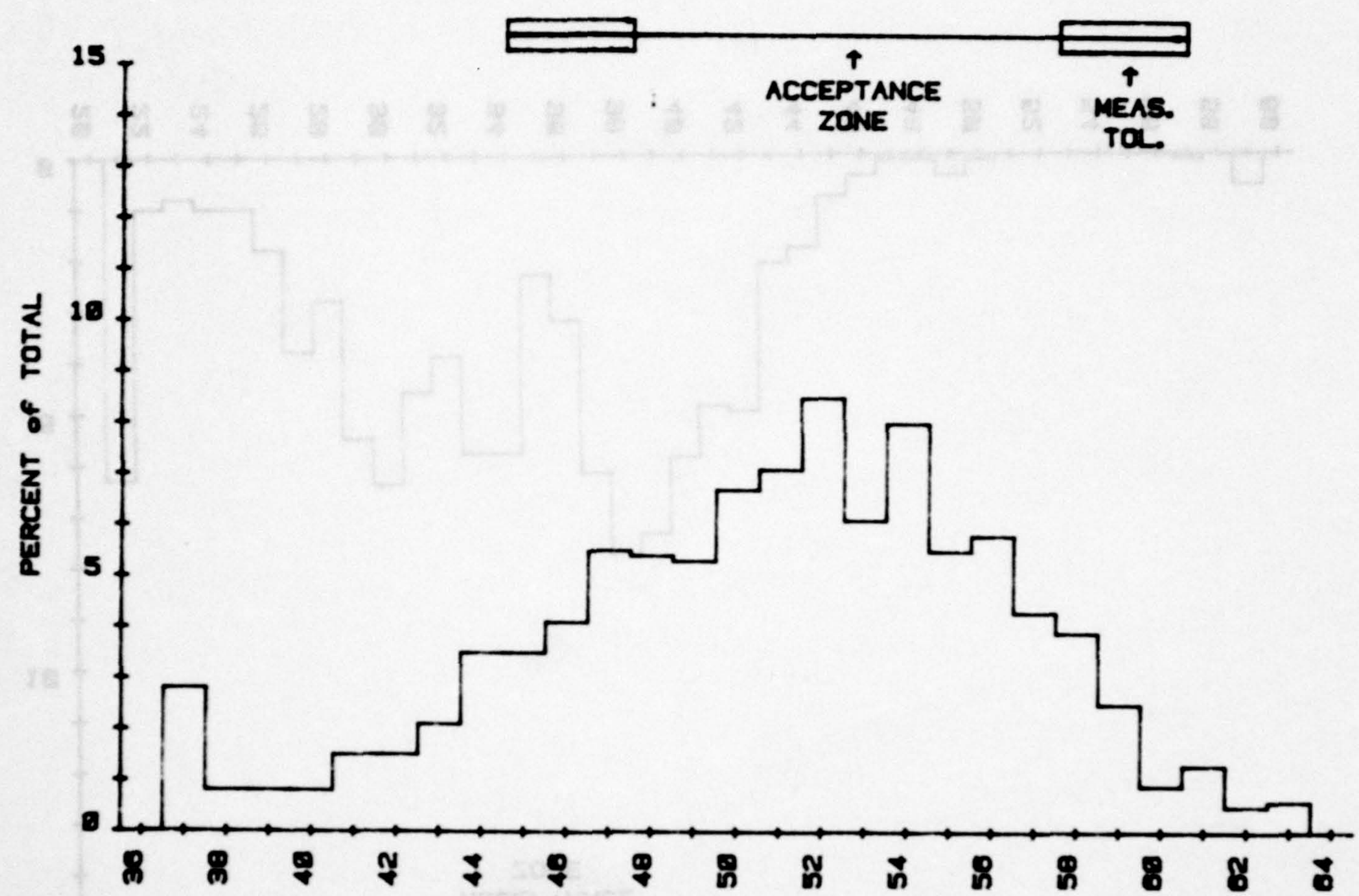


FIGURE 10. REPLY POWER (dBm) (753 SAMPLES, 1977)

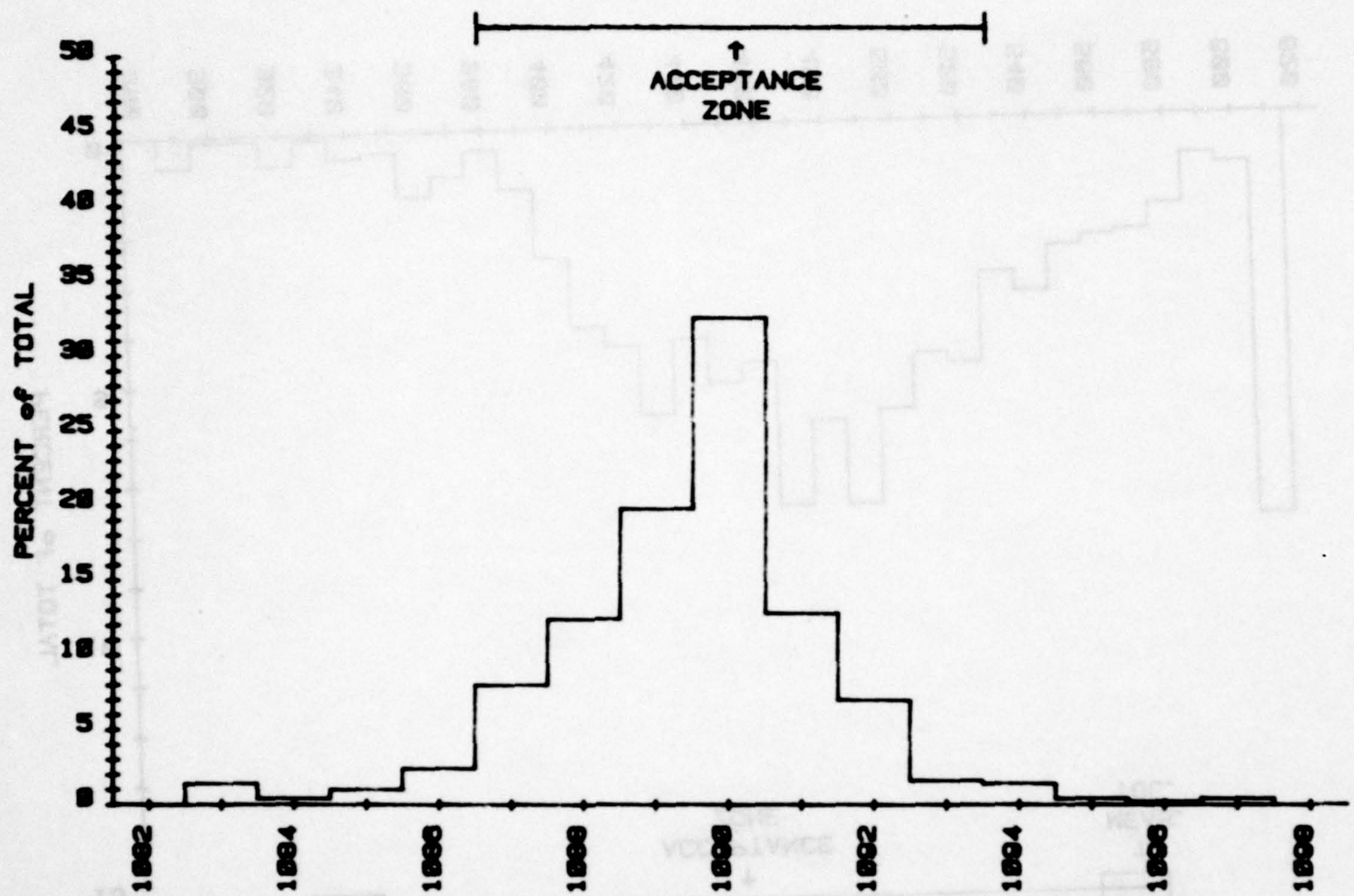


FIGURE 11. FREQUENCY (MHz) (753 SAMPLES, 1977)

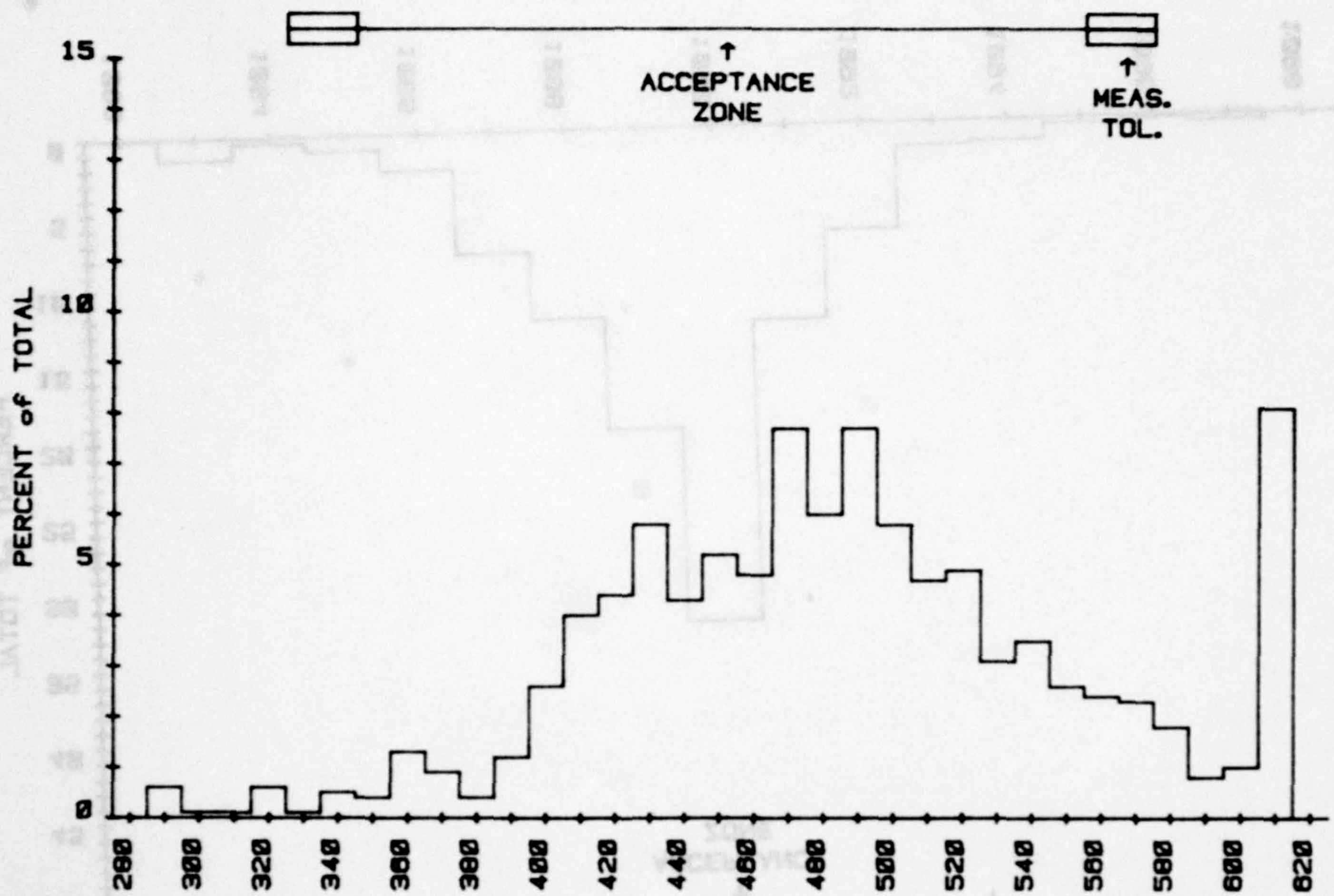


FIGURE 12. F_2 PULSE WIDTH (ns) (753 SAMPLES, 1977)

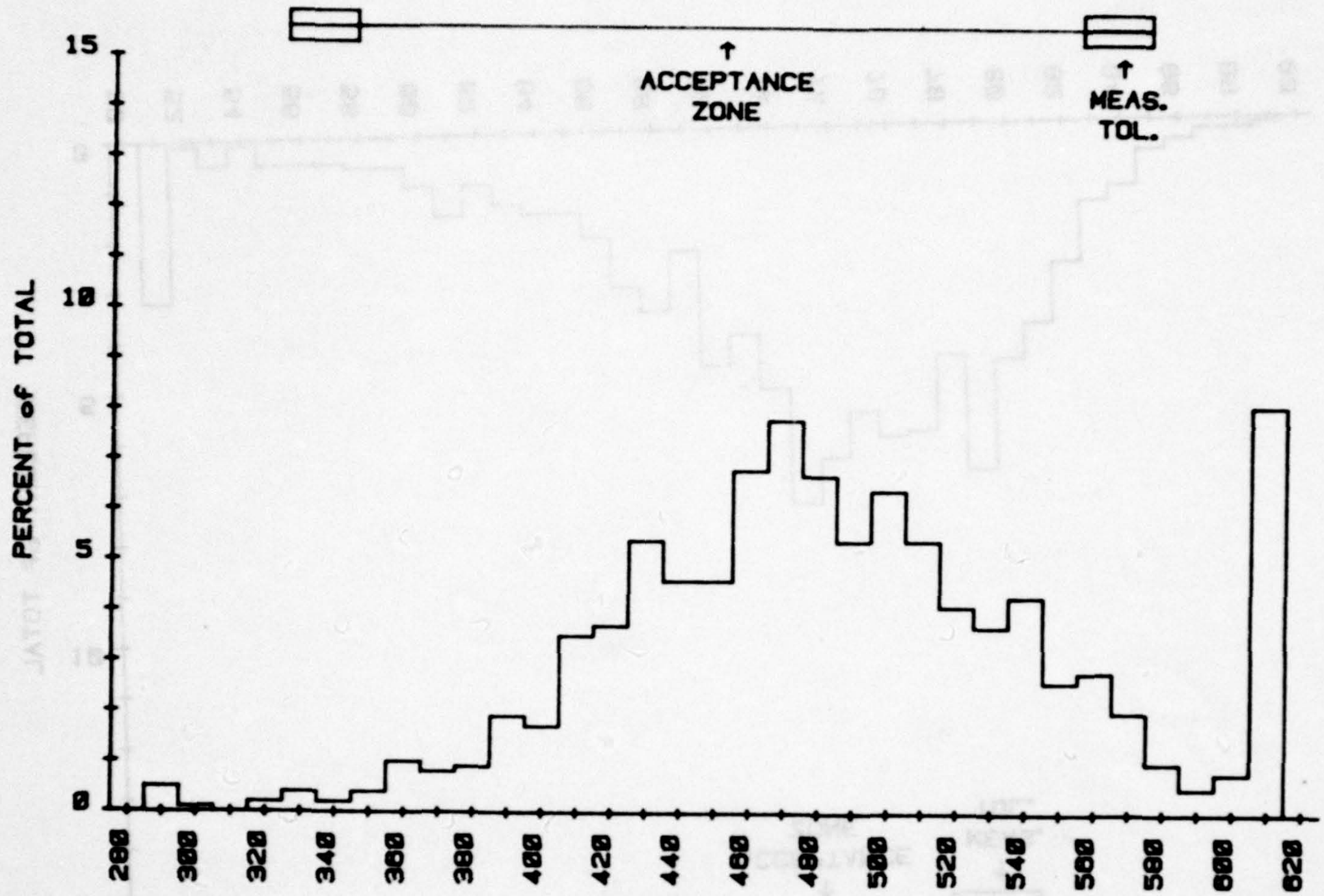


FIGURE 13. F_1 PULSE WIDTH (ns) (753 SAMPLES, 1977)

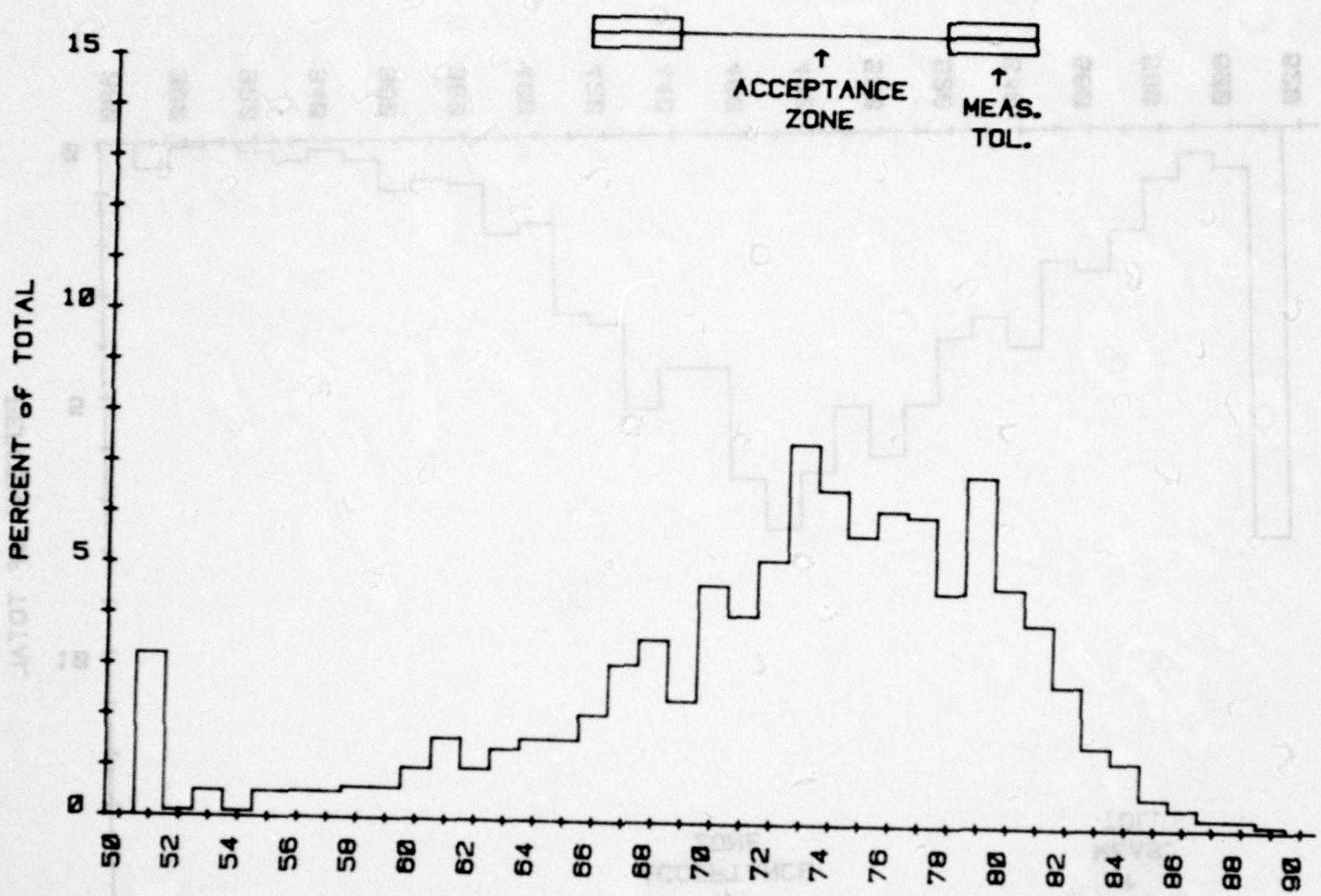


FIGURE 14. SENSITIVITY (-dBm) (753 SAMPLES, 1977)

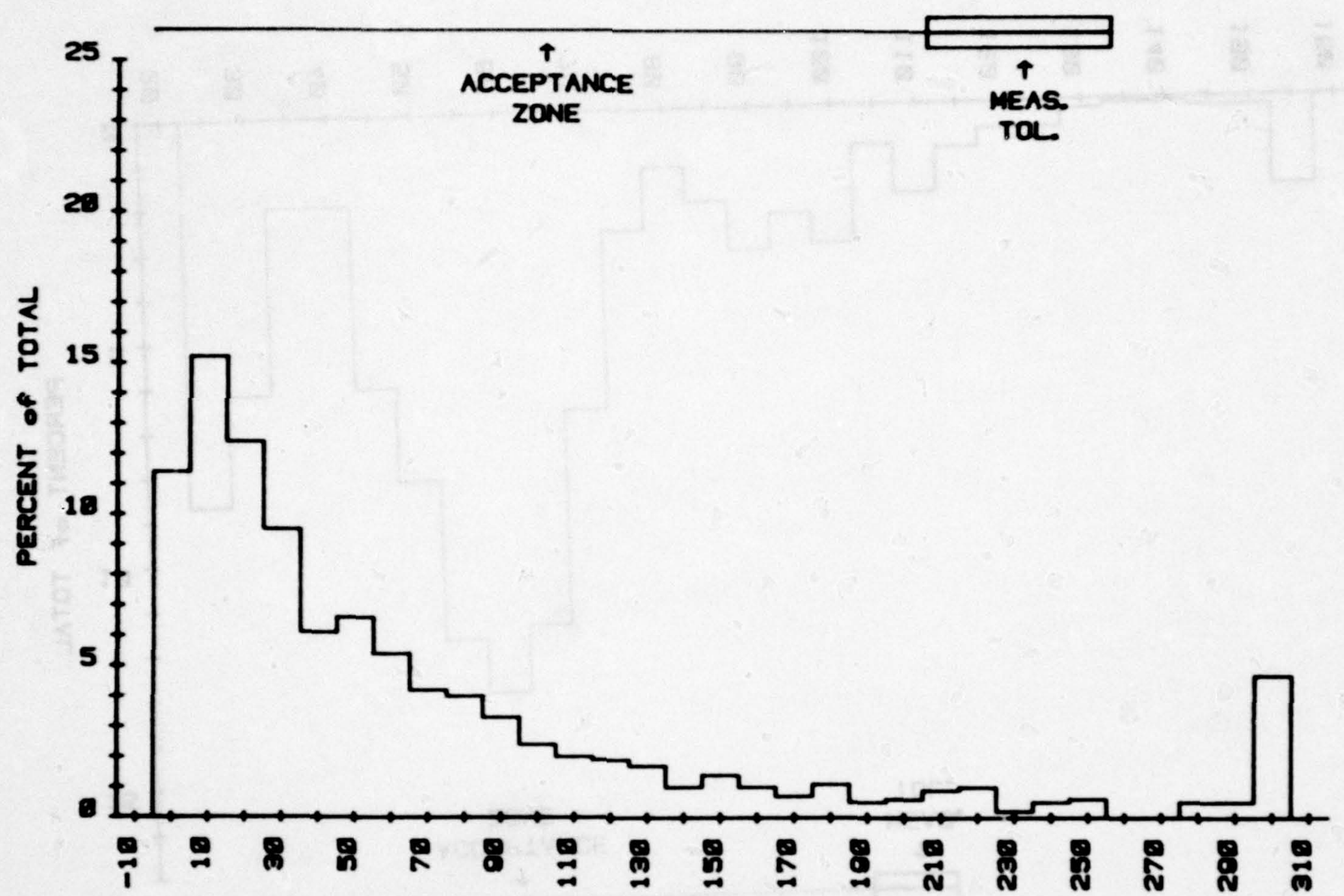


FIGURE 15. DELAY TIME DIFFERENCE (ns) (753 SAMPLES, 1977)

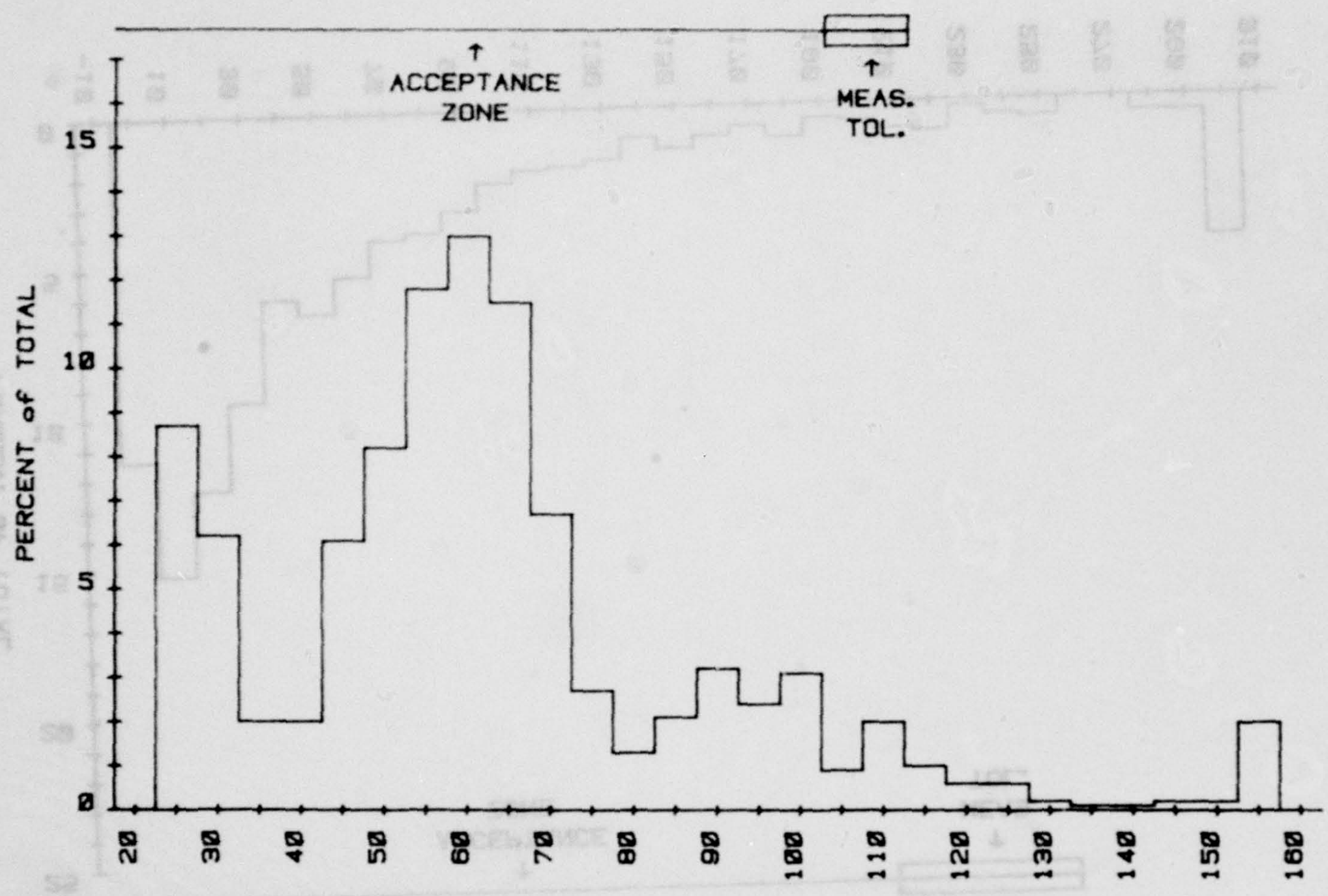


FIGURE 16. REPLY JITTER (ns) (753 SAMPLES, 1977)

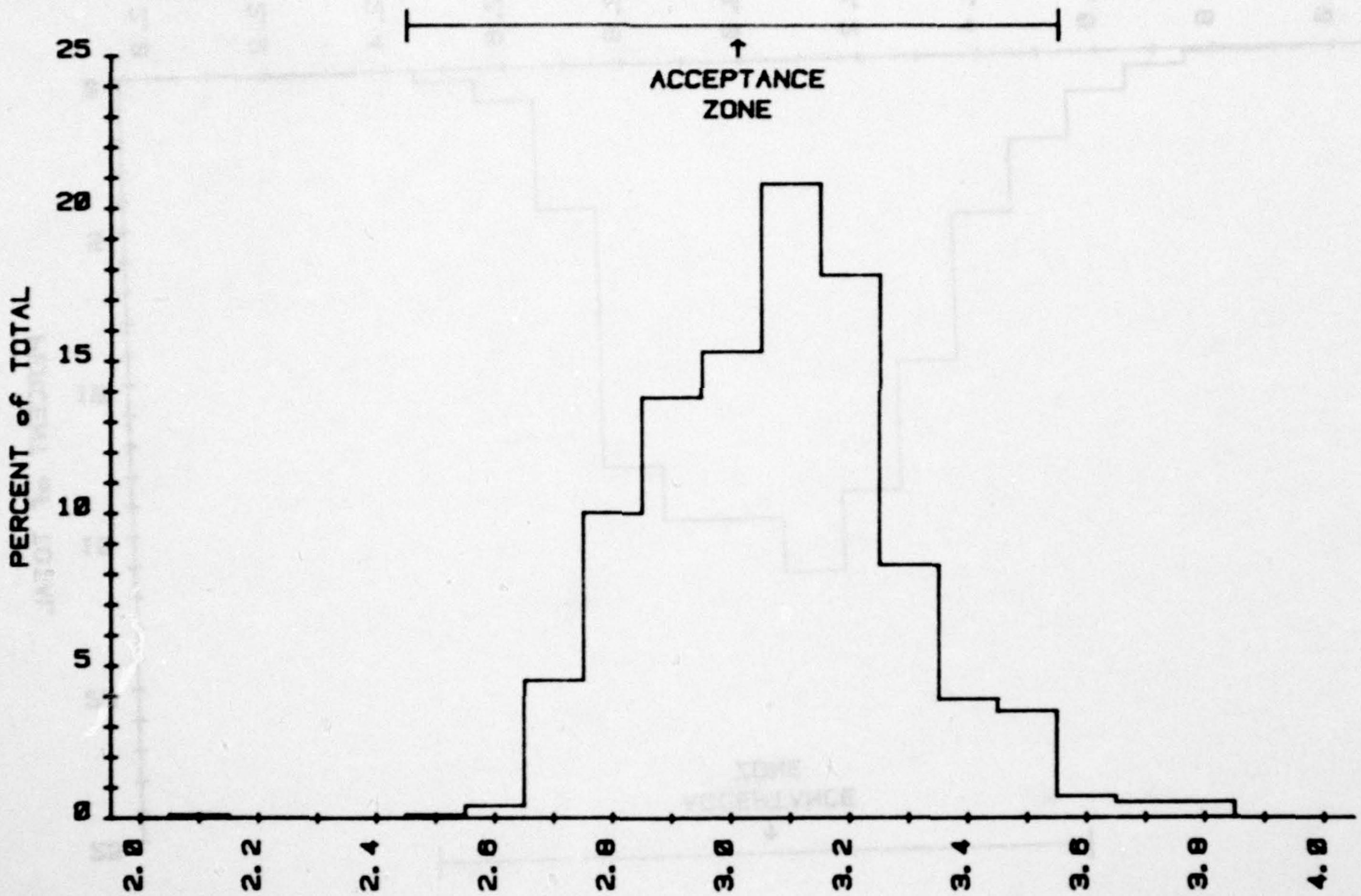


FIGURE 17. MODE A TIME DELAY (μs) (753 SAMPLES, 1977)

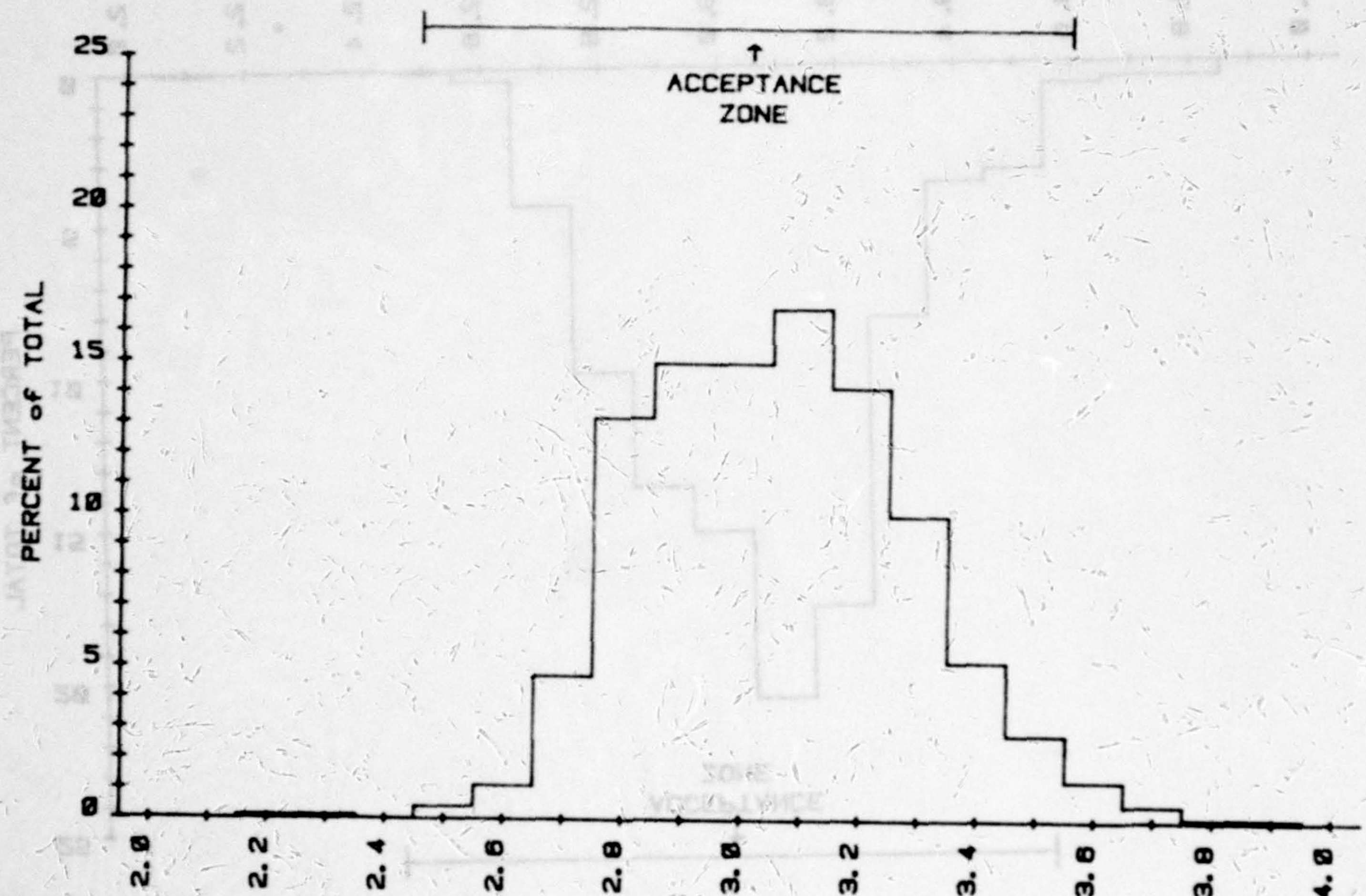


FIGURE 18. MODE C TIME DELAY (μs) (753 SAMPLES, 1977)

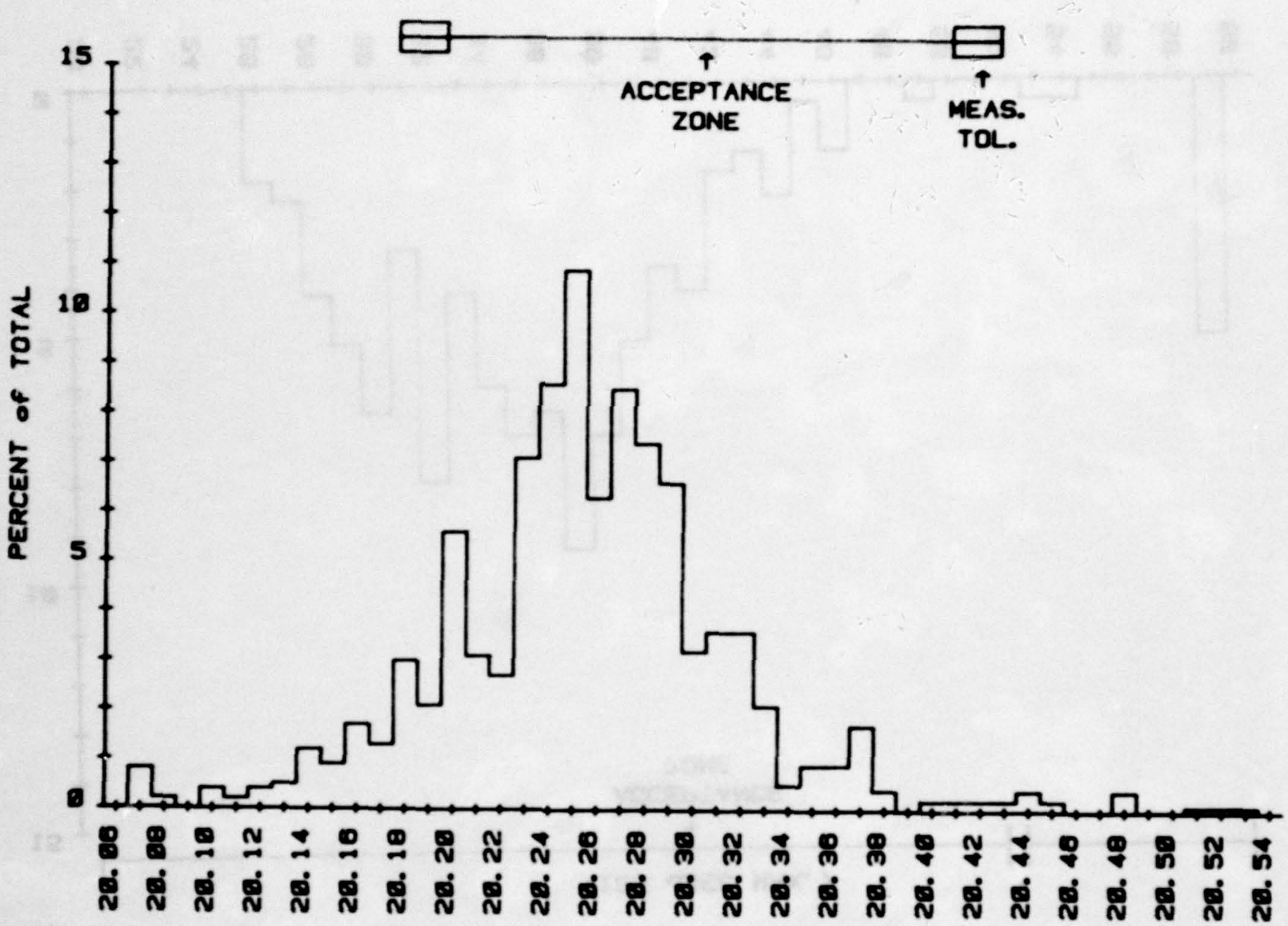


FIGURE 19. F_1 F_2 SPACING (μs) (753 SAMPLES, 1977)

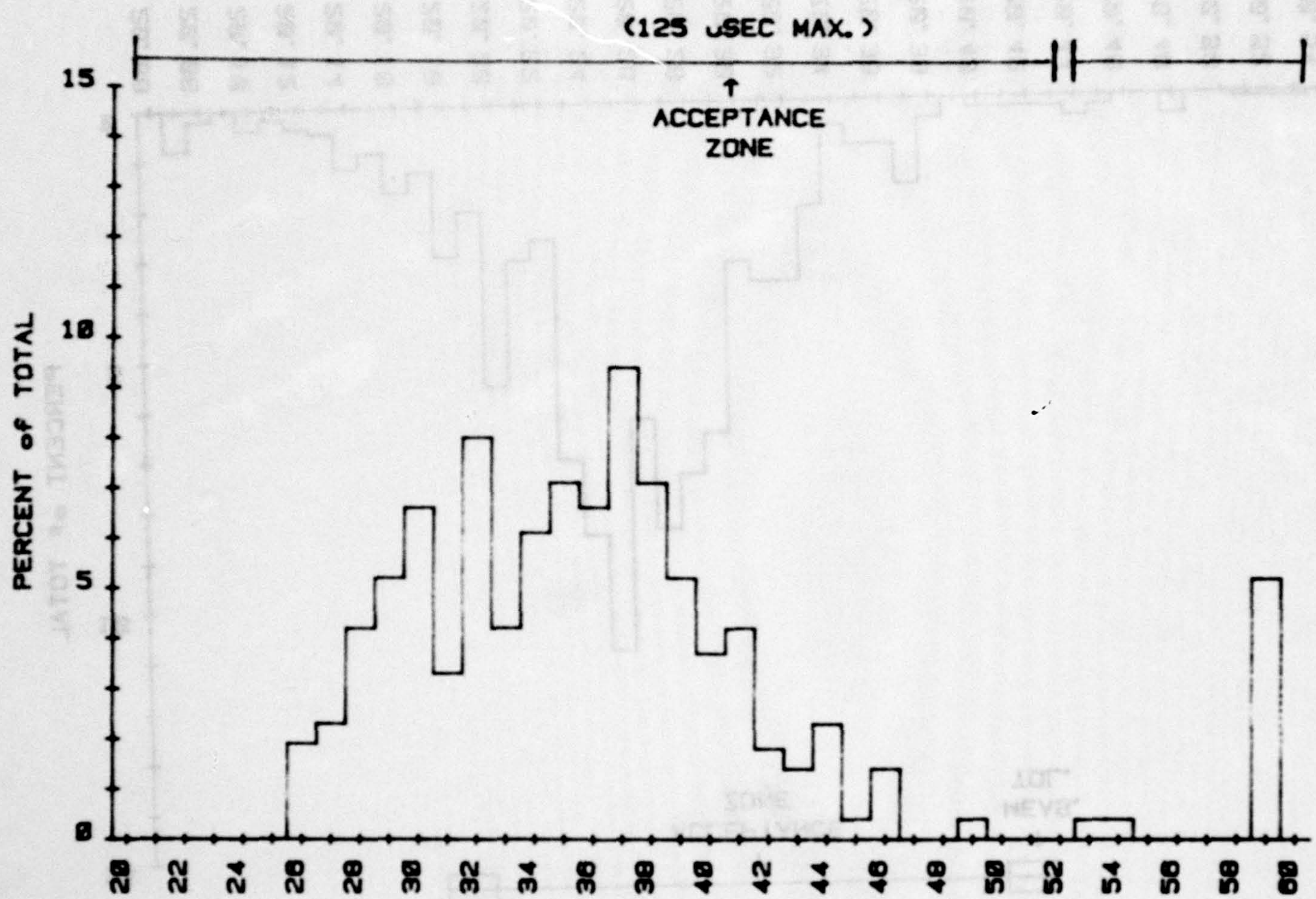


FIGURE 20. DEAD TIME (μs) (212 SAMPLES, 1978)

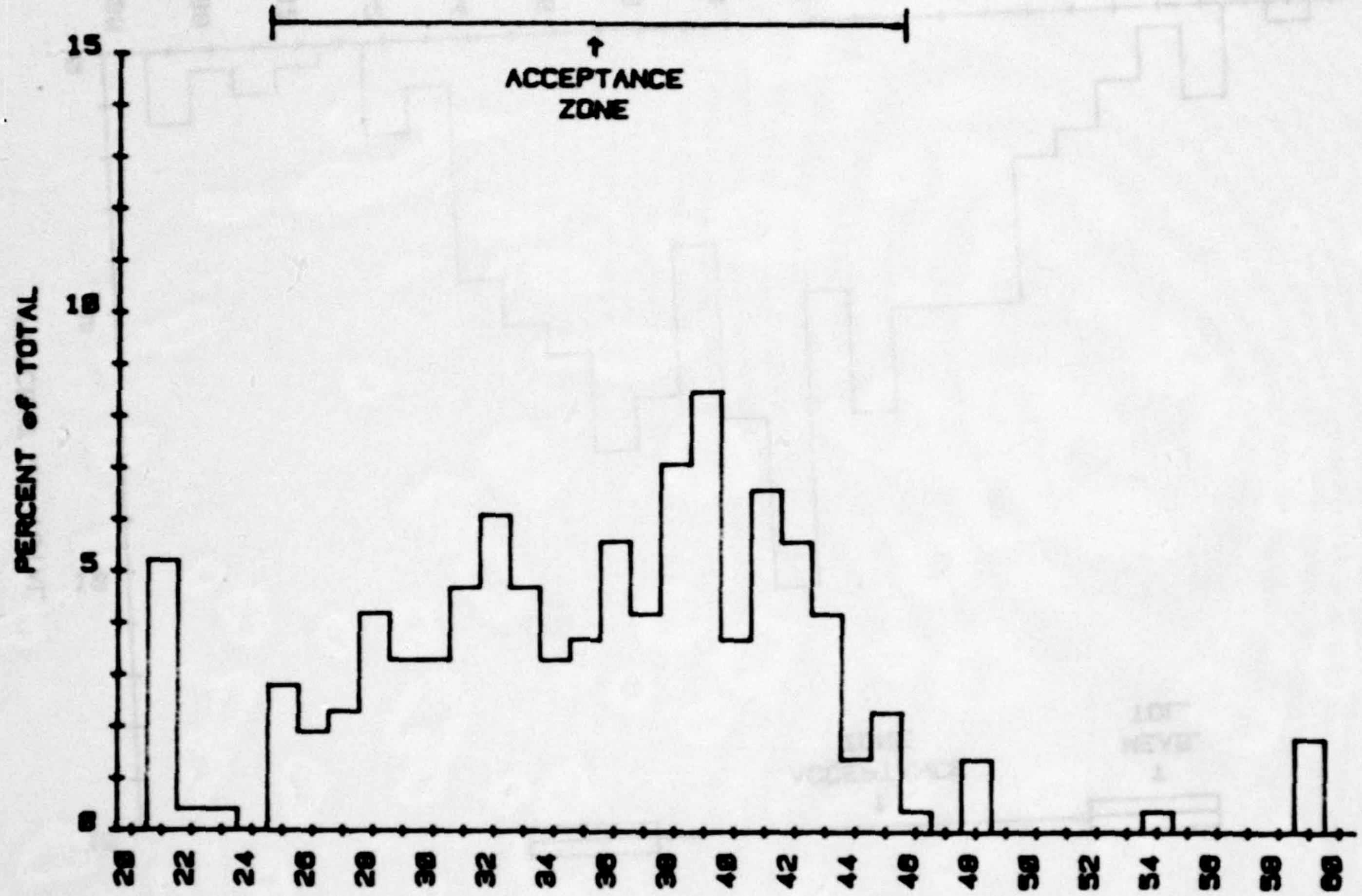


FIGURE 21. SUPPRESSION TIME (μs) (212 SAMPLES, 1978)

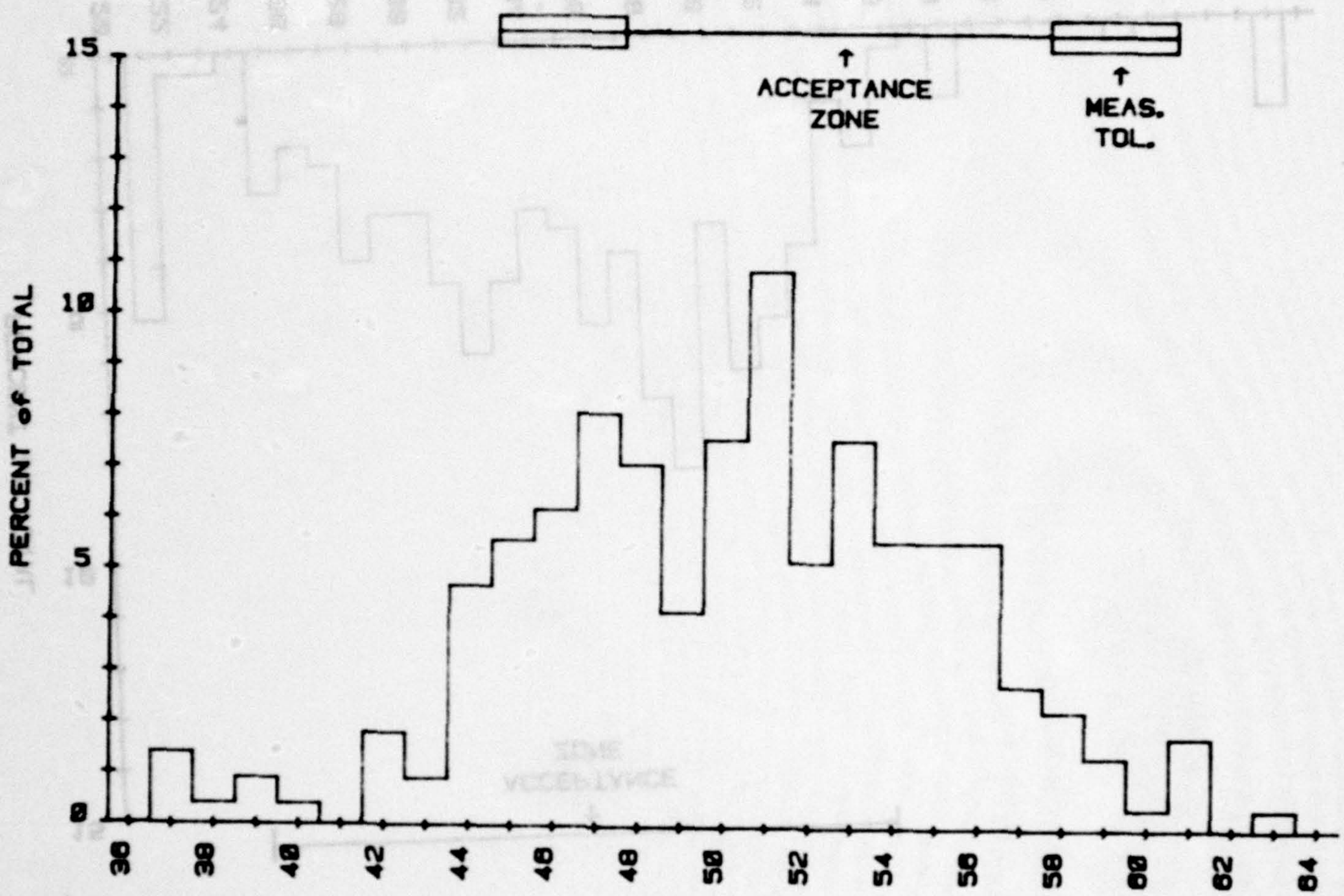


FIGURE 22. REPLY POWER (dBm) (212 Samples, 1978)

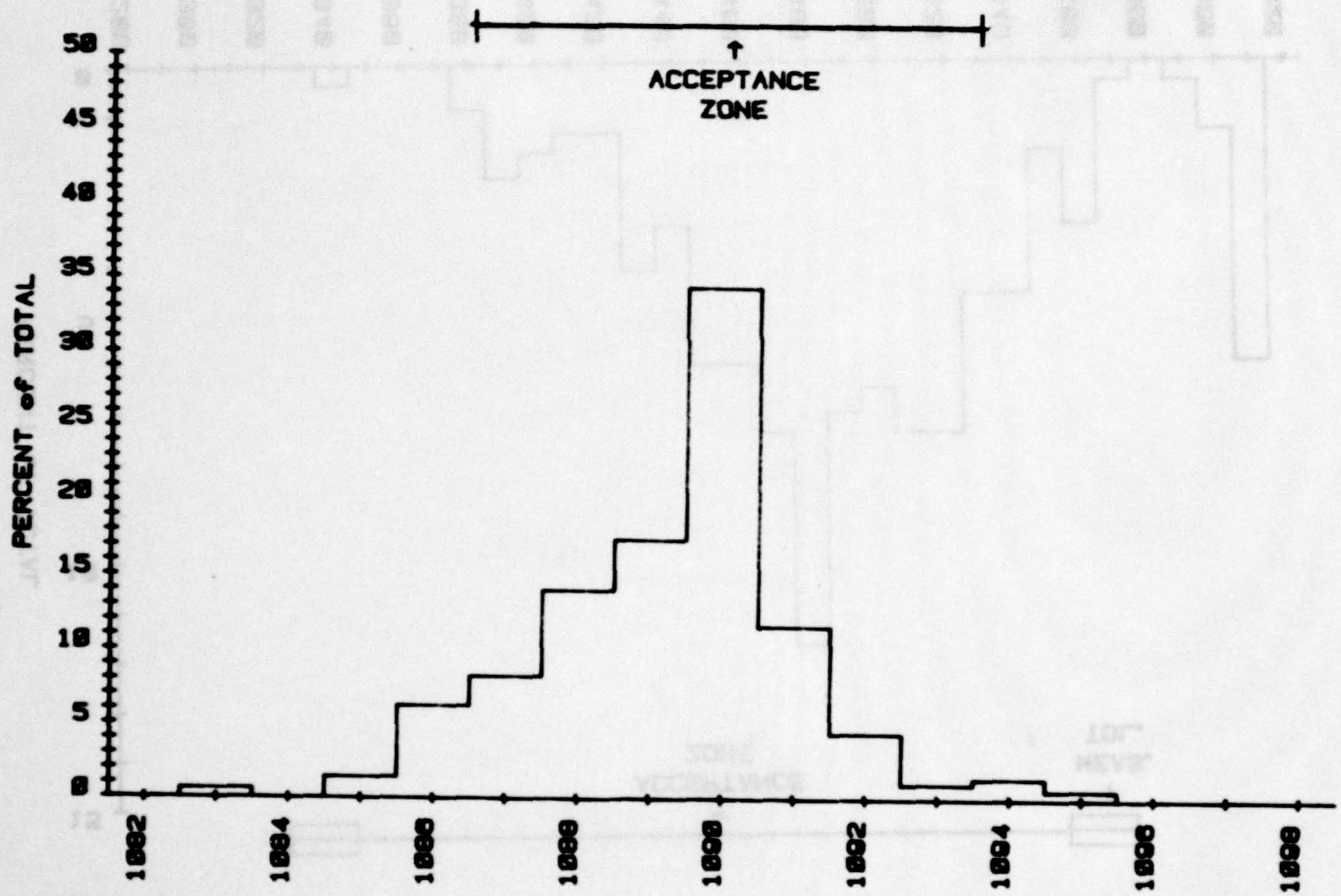


FIGURE 23. FREQUENCY (MHz) (212 SAMPLES, 1978)

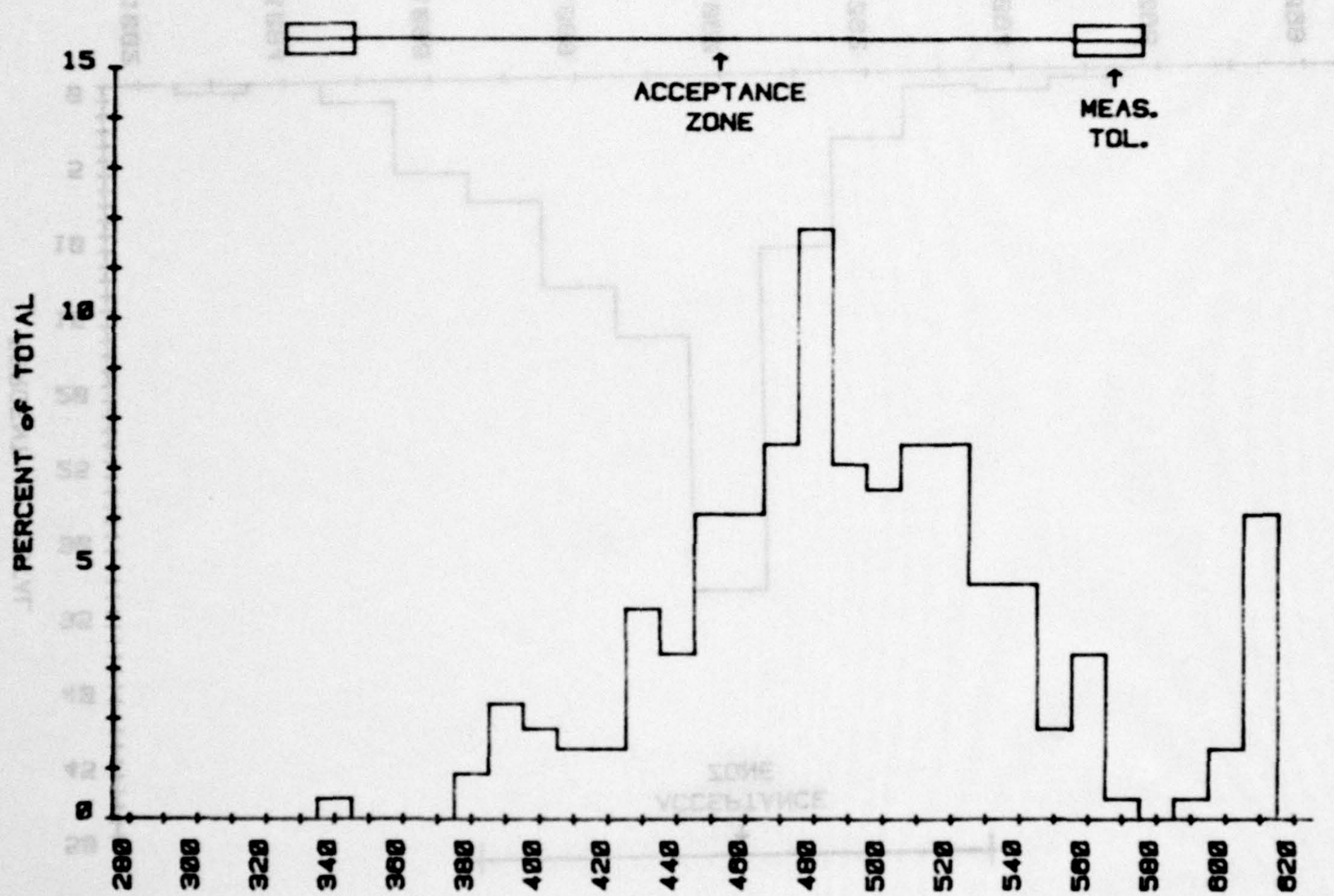


FIGURE 24. F_2 PULSE WIDTH (μs) (212 SAMPLES, 1978)

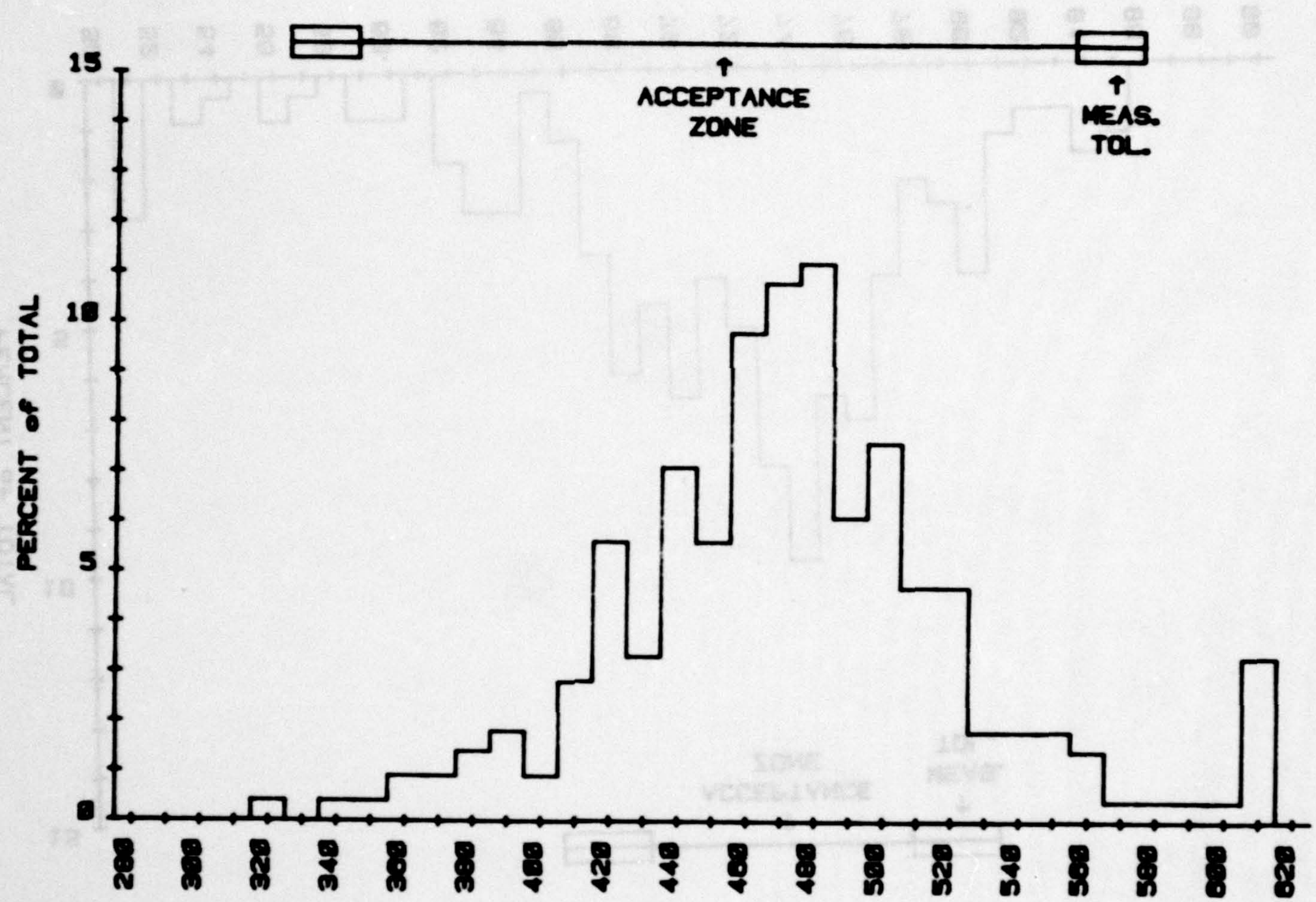


FIGURE 25. F_1 PULSE WIDTH (ns) (212 SAMPLES, 1978)

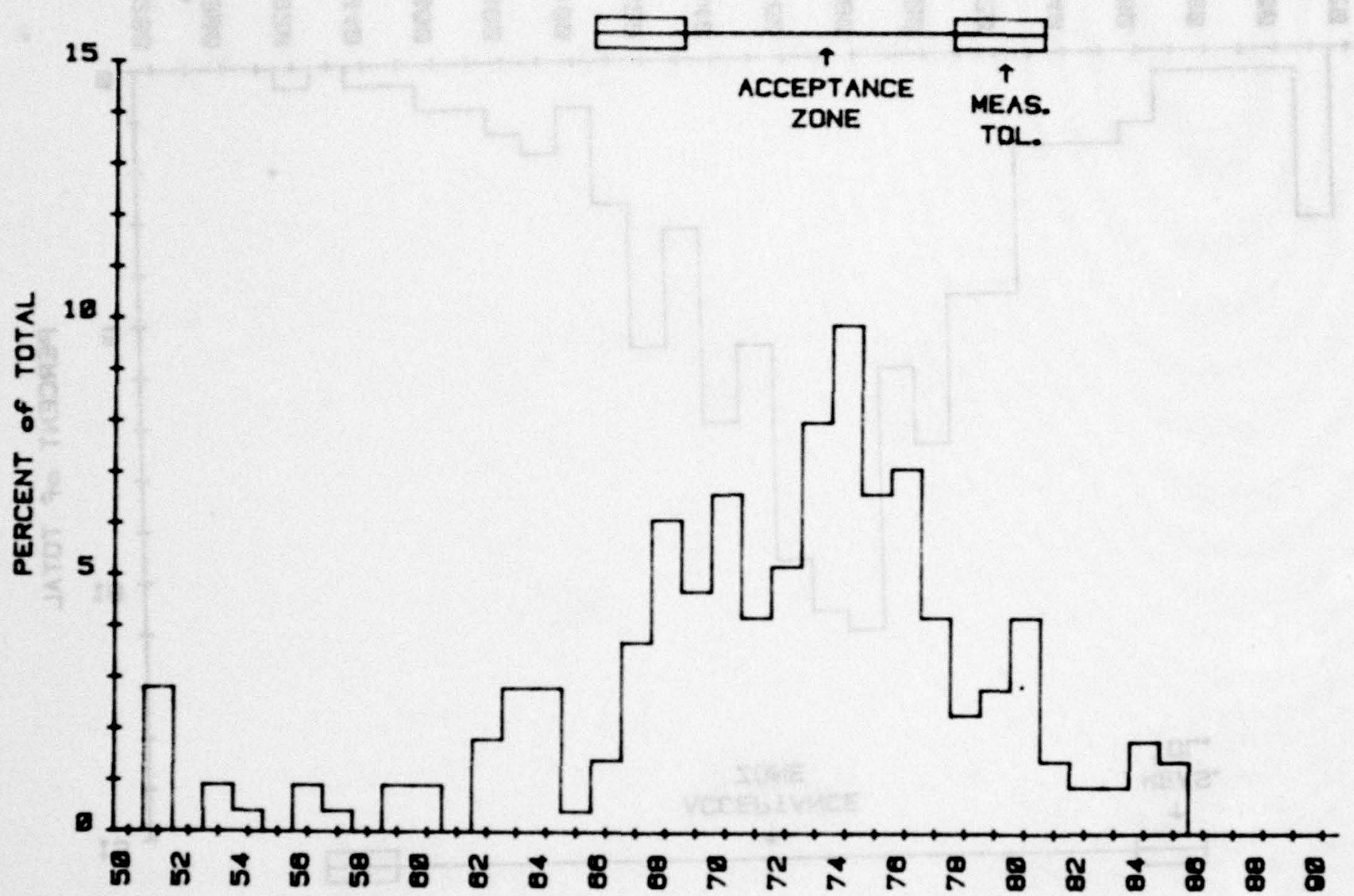


FIGURE 26. SENSITIVITY (-dBm) (212 SAMPLES, 1978)

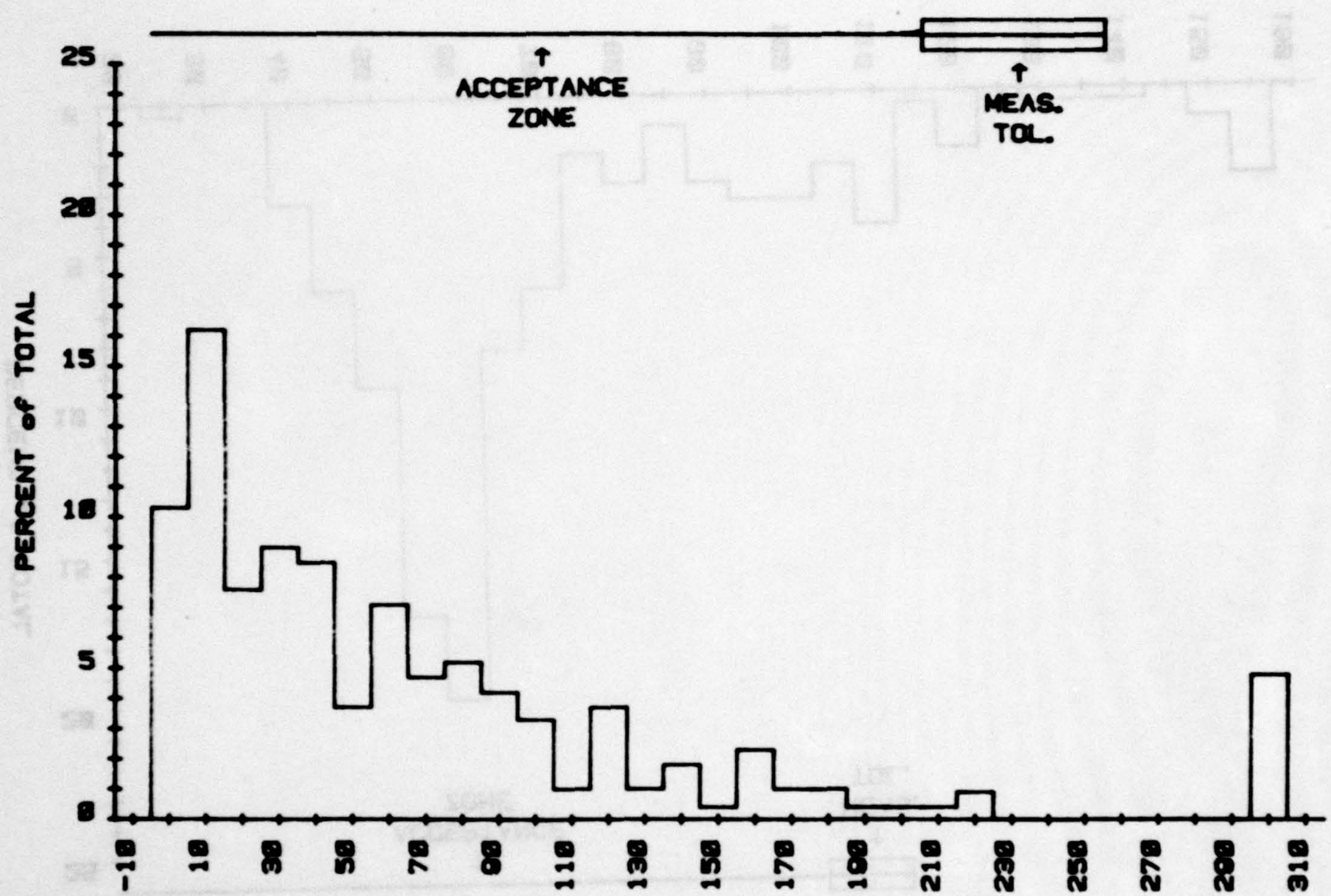


FIGURE 27. DELAY TIME DIFFERENCE (ns) (212 SAMPLES, 1978)

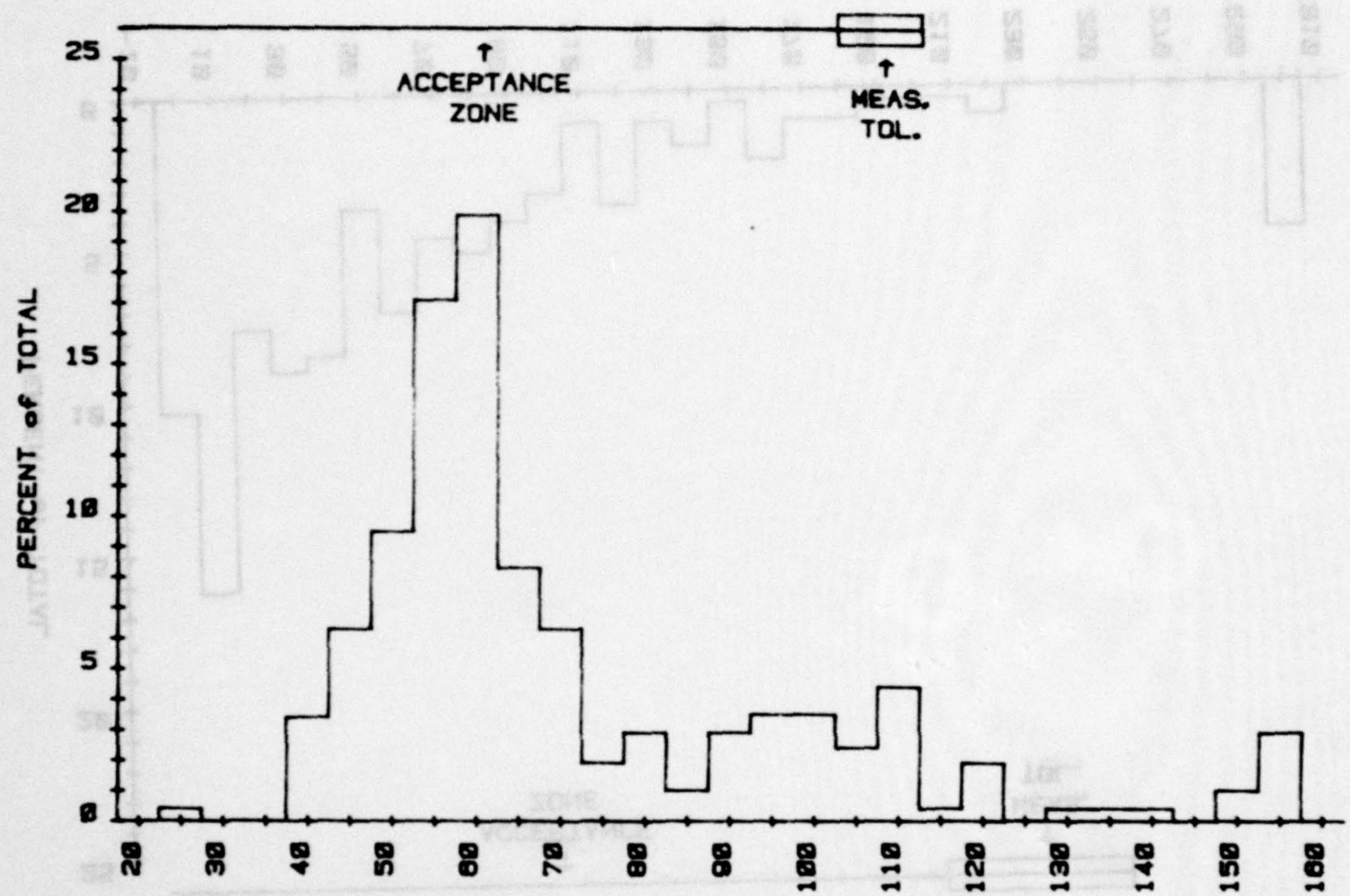


FIGURE 28. REPLY JITTER (ns) SAMPLES, 1978)

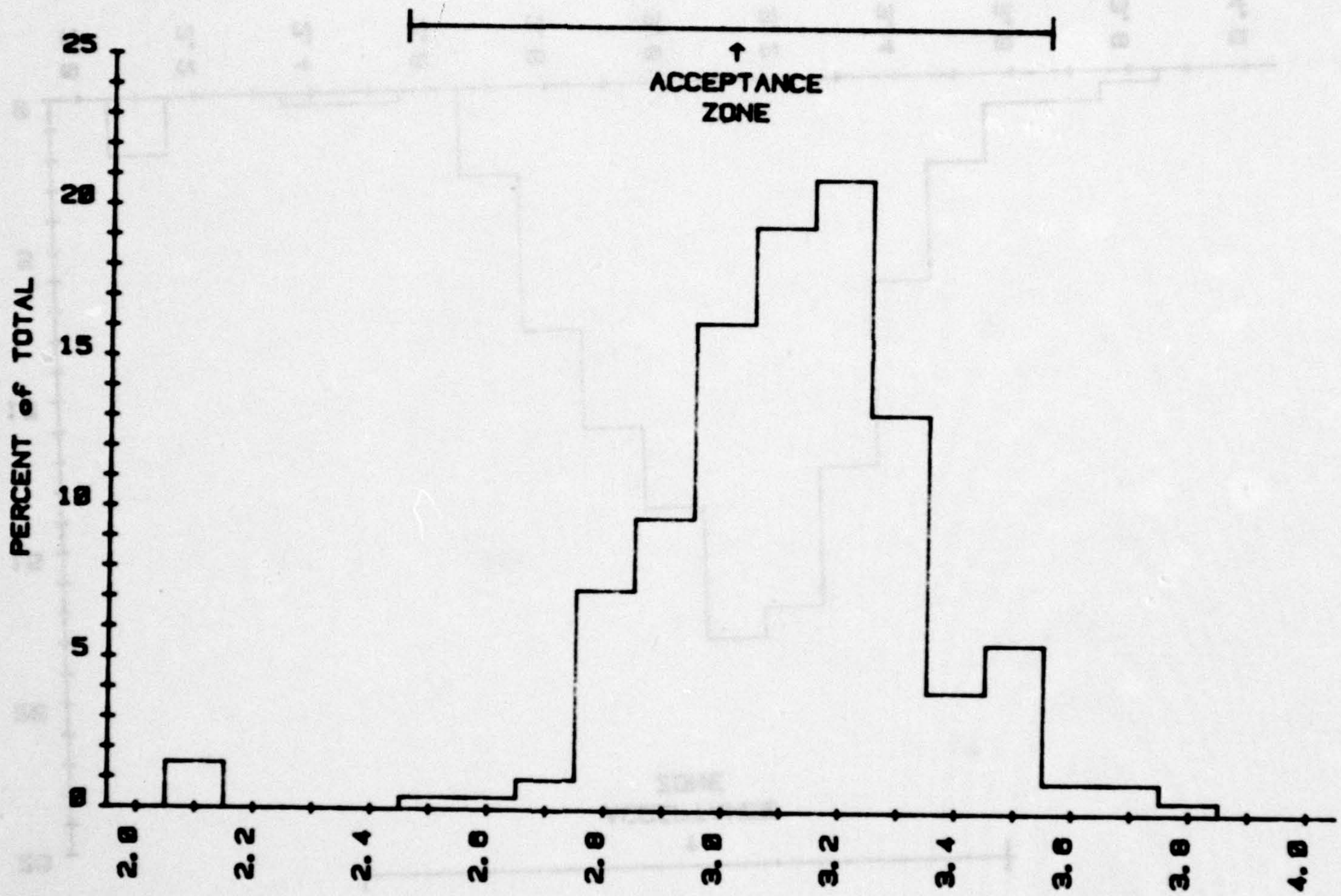


FIGURE 29. MODE A TIME DELAY (μs) (212 SAMPLES, 1978)

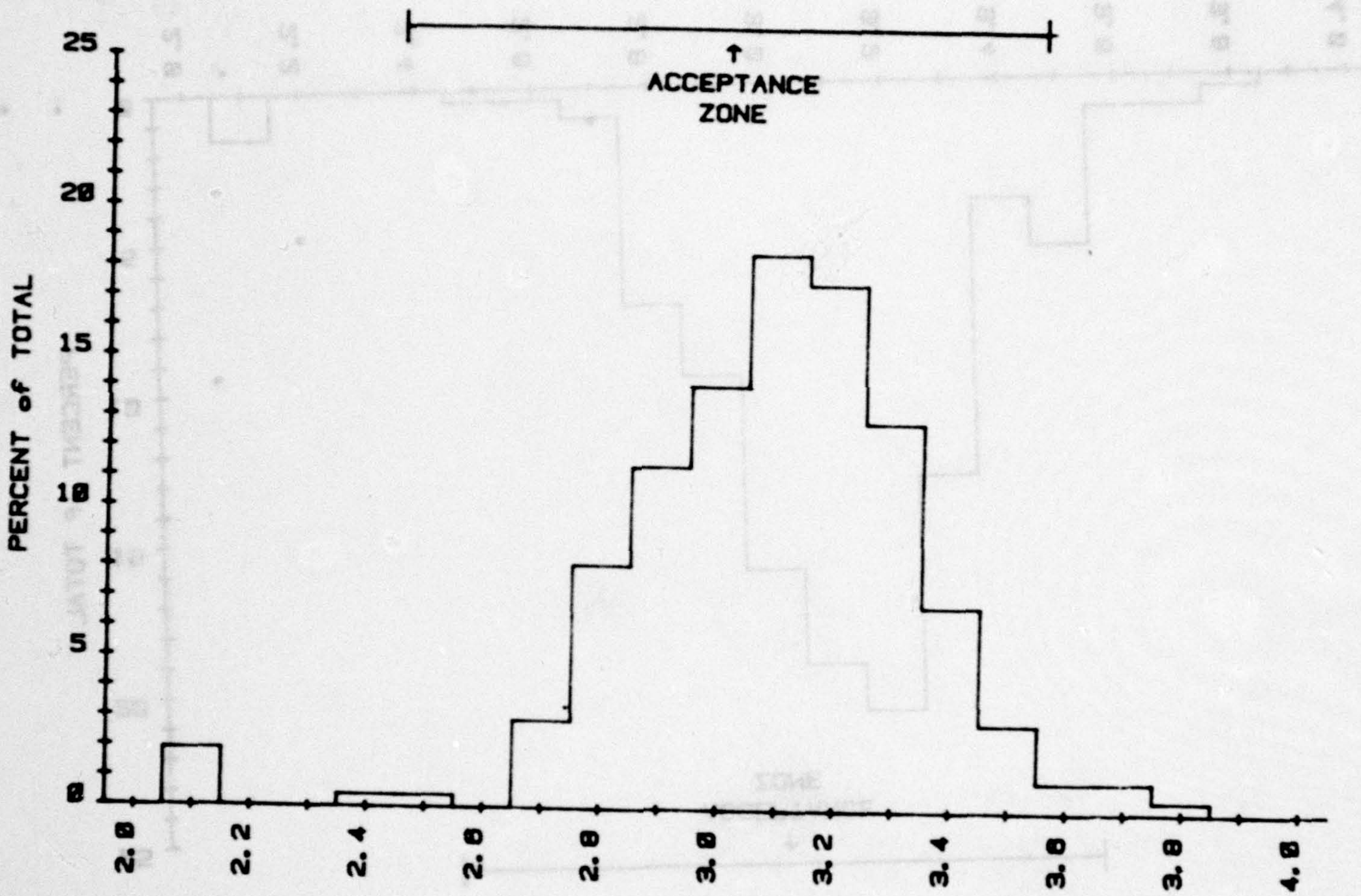


FIGURE 30. MODE C TIME DELAY (μs) (212 SAMPLES, 1978)

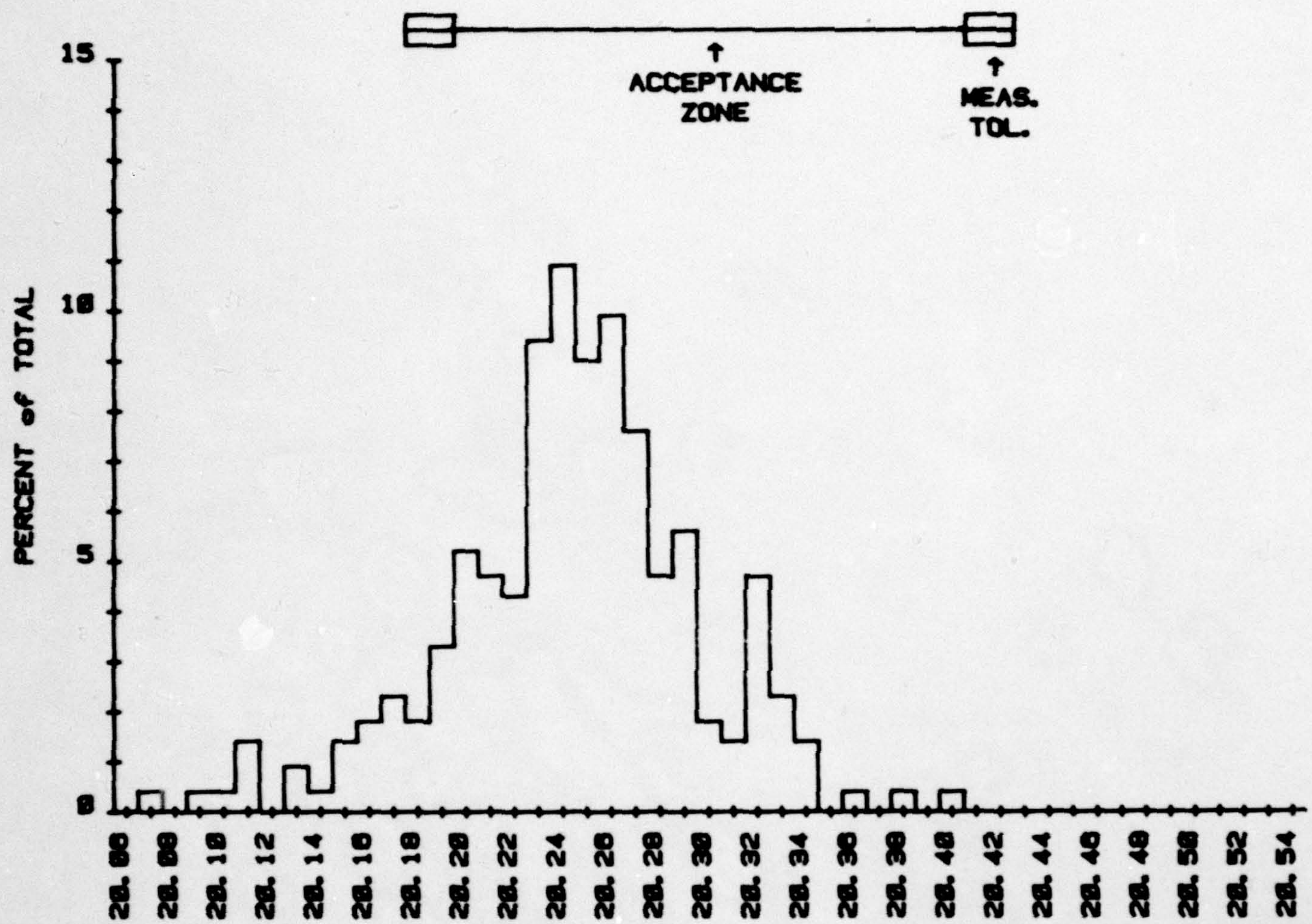


FIGURE 31. F_1F_2 SPACING (μs) (212 SAMPLES, 1978)