NTIA-Report-80-43

# Measurement of the Effect of Vehicle Ignition Noise on Land-Mobile Voice Channels

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**U.S. DEPARTMENT OF COMMERCE**
Philip M. Klutznick, Secretary

Henry Geller, Assistant Secretary
for Communications and Information

June 1980

# PREFACE

This work was done by U. S. Department of Commerce, National Telecommunications and Information Administration, Institute for Telecommunication Sciences, for the Motor Vehicle Manufacturers Association of the United States, Inc., Detroit, Michigan 48202.

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# MEASUREMENT OF THE EFFECT OF VEHICLE IGNITION NOISE ON LAND-MOBILE VOICE CHANNELS

W. J. Hartman*

Measurements of the voice intelligibility over land-mobile systems in the presence of vehicle noise are presented. These are compared with several statistical noise parameters obtained from measured amplitude probability distributions.

Key words: Impulse noise, intelligibility, scoring, vehicle noise.

## 1. INTRODUCTION

Tests were run during April 1979, at the GM proving ground near Milford, Michigan, to determine the effects of automotive ignition noise on the voice channel performance of land-mobile radios. The Institute for Telecommunication Sciences (ITS) participated in these tests by measuring the amplitude probability distribution (APD) of the noise and making voice recordings for later scoring. The voice intelligibility scoring was done both subjectively (listener panel) and objectively (Gamauf and Hartman, 1977). The results of these tests are presented here.

From the APD, the statistical moments can be obtained and compared with the voice scoring. Here, we calculate the average V(AVG), the root mean square V(RMS), and the difference $V_d$ = V(RMS) - V(AVG) for comparison.

## 2. TEST PROCEDURES

The vehicles, antennas, cables, and receivers were provided by The Motor Vehicle Manufacturers Association (MVMA). A total of 10 test conditions were used, and these are described in Table 1. The placement of the vehicles is shown in Figure 1. When a super noise vehicle (SNV) was used, it was placed in position 1, except for the test condition #9, when it was placed in position 4. The receiving antenna was located on the trunk of the test car. The antenna cable was run into a building used for the test equipment. The APD tests used the output from the antenna cable as an input signal.

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Table 1. 1979 MVMA Tests
Test Schedule

| Test No. | Frequency | Vehicles | Signal Level (dBm) |
|---|---|---|---|
| 1 | 50 MHz | 1 SAE | -108 |
| 2 | 50 MHz | 1 SNV | -108 |
| 3 | 50 MHz | " | -98 |
| 4 | 50 MHz | None | -108 |
| 5 | 29 MHz | " | -101 |
| 6 | 50 MHz | 6 SAE | -108 |
| 7 | 29 MHz | 12 SAE | -101 |
| 8 | 50 MHz | 12 SAE | -108 |
| 9 | 50 MHz | 11 SAE+SNV | -108 |
| 10 | 147 MHz | 12 SAE | -113 |

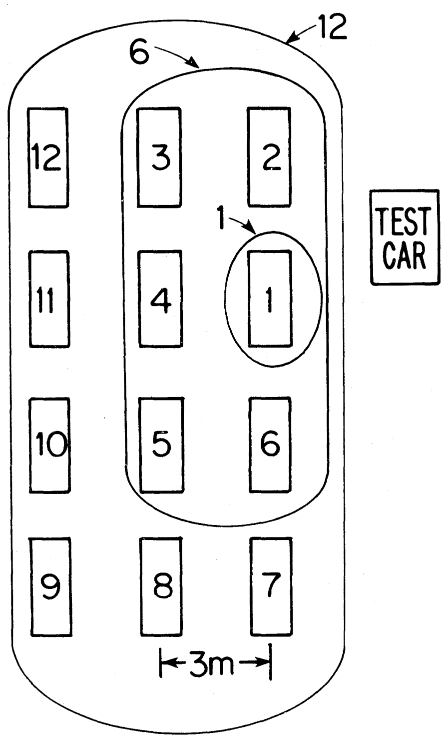


Figure 1. The location of vehicles for the 1979 MVMA tests.

For the tests at 50 MHz, this signal was first passed through a tunable bandpass filter [Texscan 5 VF 48195-5-CC][1], then through a fixed (40 dB) gain broadband amplifier [ENI 411 LA], and into an HP 8558B spectrum analyzer. The 21.4 MHz output of the spectrum analyzer was then used as input to the noise measuring system, the DM 3[2]. For the 29 MHz and the 147 MHz tests a bandpass filter was not available, but the rest of the test configuration remained the same.

The DM 3, which was built by the Institute for Telecommunication Sciences for the Air Force, uses an envelope detector to detect the IF output voltage, and quantizes the output of the detector into 15 discrete levels spaced 6 dB apart. The count at each level divided by the total count gives the percentage of time that the envelope exceeds that level. An internal calibration is available for setting the 6 dB steps.

An external calibration was made using a sine wave from a signal generator. This signal was substituted at the input to the filter, or the amplifier as appropriate. This technique allows the calculation of input noise levels and serves as a check on the internal calibration.

The DM 3 has a bandwidth of approximately 1 MHz. The spectrum analyzer was used to select the narrow band mode, 30 kHz, for the measurements.

For the voice measurements, the phonetically balanced (PB) word lists were played from a master tape on a 1/2-inch recorder. This signal was used to modulate the transmitter. The audio output of the receiver was recorded on a second identical recorder. The master tape had 8 50-word PB word groups. For the 10 tests, two word groups were repeated once and six word groups were used only once.

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1. "Certain commercial equipment, instruments, or materials are identified in this paper to adequately specify the experimental procedure. In no case does such identification imply recommendation or endorsement by the National Telecommunications and Information Administration, nor does it imply that the material or equipment identified is necessarily the best available for the purpose."

2. Robert Matheson described the DM 3 in an unpublished draft, "An Instrument to Measure the Amplitude Probability Distribution of EM Noise.

## 3. TEST RESULTS

The voice tapes were copied, edited, and sent to the U.S. Army Electronic Proving Ground, Ft. Huachuca, Arizona, for subjective scoring by listener panels. The tapes were also scored objectively using a modification of the methods developed by Gamauf and Hartman (1977). The subjective and objective articulation scores (AS) for 10 tests are given in Table 2.

The objective scores are plotted against the subjective scores in Figure 2. The straight line would represent perfect agreement. The correlation coefficient between the objective and subjective scores is .88.

The calculation of the objective score requires alining the digitized samples of the master tape with the samples from the tapes with the noise added. In the earlier study, [Gamauf and Hartman, 1977] this was done using software. For this study a newly developed hardware alinement procedure was used, greatly decreasing the cost of obtaining the objective scores.

The APD's are given in the Appendix. The statistical parameters V(average), V(RMS) and $V_d$ = V(RMS) - V(average) calculated from the APD's are given in Table 3.

Table 2. Voice Scores

| Test No. | Word Group | Subjective AS | Objective AS |
|---|---|---|---|
| 1 | 361 | 72.5 | 73.3 |
| 2 | 312 | 72.7 | 71.7 |
| 3 | 291 | 84.7 | 81.1 |
| 4 | 265 | 80.2 | 76.4 |
| 5 | 291 | 92.7 | 88.5 |
| 6 | 275 | 69.7 | 71.0 |
| 7 | 312 | 78.5 | 68.1 |
| 8 | 305 | 68.2 | 69.8 |
| 9 | 214 | 75.5 | 66.7 |
| 10 | 265 | 57.7 | 61.0 |

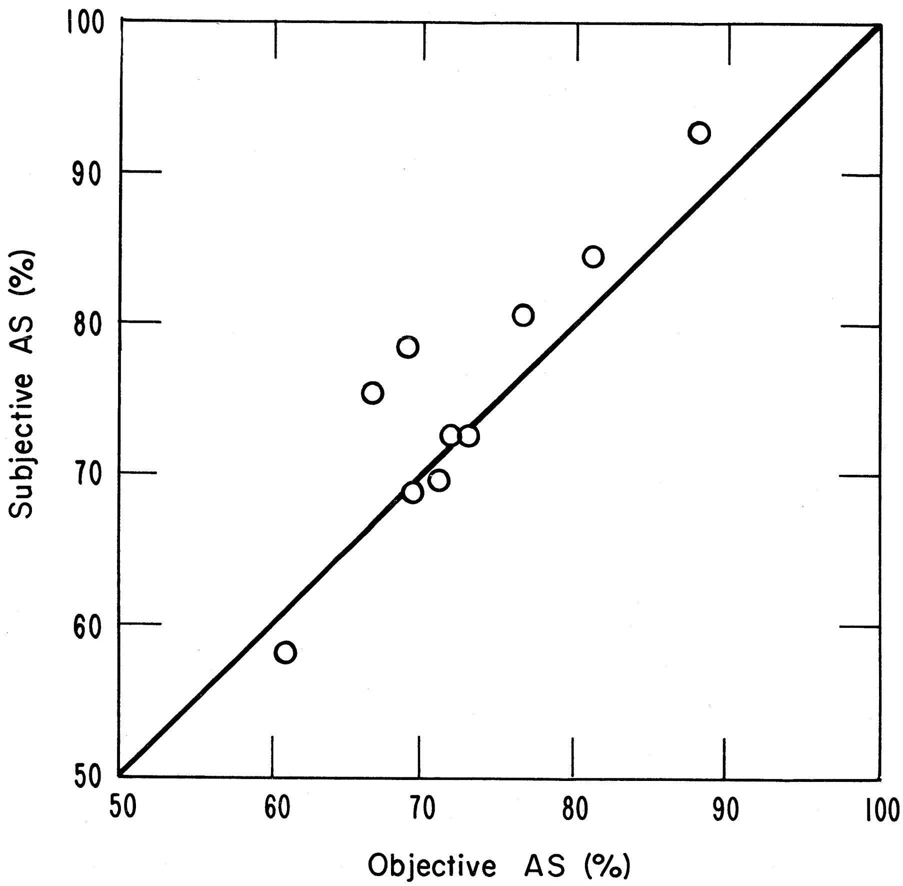


Figure 2. Comparison of the subjective articulation scores (AS) with the objective scores. The straight line would be perfect agreement.

Table 3. Statistical Noise Parameters

| | Test # | Figure # | V(RMS) dBm | V(AVG) dBm | $V_d$ dB |
|---|---|---|---|---|---|
| | | | 30 kHz Bandwidth | | |
| | 1 | A1 | -120.6 | -122.2 | 1.6 |
| * | 2,3 | A2 | -100.6 | -119.9 | 19.3 |
| | 4 | A3 | -120.4 | -121.8 | 1.4 |
| | 5 | A4 | -118.3 | -119.7 | 1.4 |
| | 6 | A5 | -119.9 | -121.6 | 1.7 |
| | 7 | A6 | -117.4 | -119.0 | 1.6 |
| | 8 | A7 | -119.7 | -121.5 | 1.8 |
| | 9 | A8 | -120.9 | -120.4 | 17.5 |
| | 10 | A9 | -118.1 | -119.4 | 1.3 |
| | Calib. | A10 | -121.0 | -122.4 | 1.4 |

*The noise was the same for test 2 and 3.

## 4. DISCUSSION OF RESULTS

Table 4 contains the statistical parameters together with the articulation scores for easy comparison. As noted in the previous section, the correlation between the articulation scores is .88.

It is instructive to compare the noise parameters with the subjective scores to determine if any of these are good predictors. Several of the tests at 50 MHz allow a comparison of results because the same frequency and input signal level are used. Referring to Table 1, we would expect the following ordering (on the basis of the test condition) of the AS from best score to worst score; #4(no vehicles) #1(1 SAE), #6(6 SAE), #8(12 SAE), #9(11 SAE & 1 SNV). The subjective articulation scores are ordered 4, 9, 1, 6, and 8, and the objective scores are ordered 4, 1, 6, 8, and 9. Consequently, the subjective score for test 9 appears inconsistent. For the five similar tests 1, 4, 6, 8, and 9, the correlations are given in Table 5. The four tests, 4, 1, 6, and 8 with respectively 0, 1, 6, and 12 SAE vehicles show decreasing intelligibility (80.2%, 72.5%, 69.7%, and 68.2%) as expected, with the

Table 4. Tabulation for Comparison of the Noise Statistical Parameters with the Articulation Scores.

| Test No. | V(RMS) dBm | $V_d$ dB | Signal Level (dBm) | Subjective AS | Objective AS | Vehicles |
|---|---|---|---|---|---|---|
| 1 | -120.6 | 1.6 | -108 | 72.5 | 73.3 | 1 SAE |
| 2 | -100.6 | 19.3 | -108 | 72.7 | 71.7 | 1 SNV |
| 3 | -100.6 | 19.3 | -98 | 84.7 | 81.1 | " |
| 4 | -120.4 | 1.4 | -108 | 80.2 | 76.4 | NONE |
| 5 | -118.3 | 1.4 | -101 | 92.7 | 88.5 | " |
| 6 | -119.9 | 1.7 | -108 | 69.7 | 71.0 | 6 SAE |
| 7 | -117.4 | 1.6 | -101 | 78.5 | 68.1 | 12 SAE |
| 8 | -119.7 | 1.8 | -108 | 68.2 | 69.8 | 12 SAE |
| 9 | -102.9 | 17.5 | -108 | 75.5 | 66.7 | 11 SAE+SNV |
| 10 | | | -113 | 57.7 | 61.0 | 12 SAE |

Table 5. Correlation Coefficients for Tests 1, 4, 6, 8, and 9 Between the Statistical Noise Parameters and the Voice Scores

| | V(RMS) | V(AVG) | $V_d$ |
|---|---|---|---|
| Subjective score | -.19 | .10 | .25 |
| Objective score | -.75 | .03 | -.74 |

largest change observed between no vehicles and 1 vehicle. None of the statistical noise parameters appear to be a good predictor of the subjective AS although V(RMS) exhibits some correlation with the objective AS (significant at the 5% level).

The tests using a SNV, are more difficult to interpret. Previous results (Spaulding, 1976) indicate that impulsive noise is less harmful than Gaussian noise to voice intelligibility for the same values of V(RMS). However, comparing tests 1 and 2, and 8 and 9, we see that V(RMS) for the replacement of an SAE vehicle with an SNV produces a much larger V(RMS). It should be noted that for both pairs the subjective scores are higher when the SAE vehicle is replaced by an SNV, while the objective scores are lower in both cases.

## 5. REFERENCES

Gamauf, K. J., and W. J. Hartman (1977), Objective measurement of voice channel intelligibility, FAA Report No. FAA-RD-77-153, October.

Spaulding, A. D. (1976), Man-made noise: The problem and recommended steps toward solution, Office of Telecommunications Report OT 76-85. (NTIS Access No. PB 253 745/AS).

# APPENDIX AMPLITUDE PROBABILITY DISTRIBUTIONS

Figures A1 through A10 show the APD's for the test conditions 1-10 and one of the calibration runs, respectively. The sharp rise at the lower percentages in Figures A2 and A8 is typical of impulse noise. Each of these curves is normalized to the V(RMS) for that test condition and this V(RMS) is given in the figure caption. Note that tests 2 and 3 had the same noise condition.

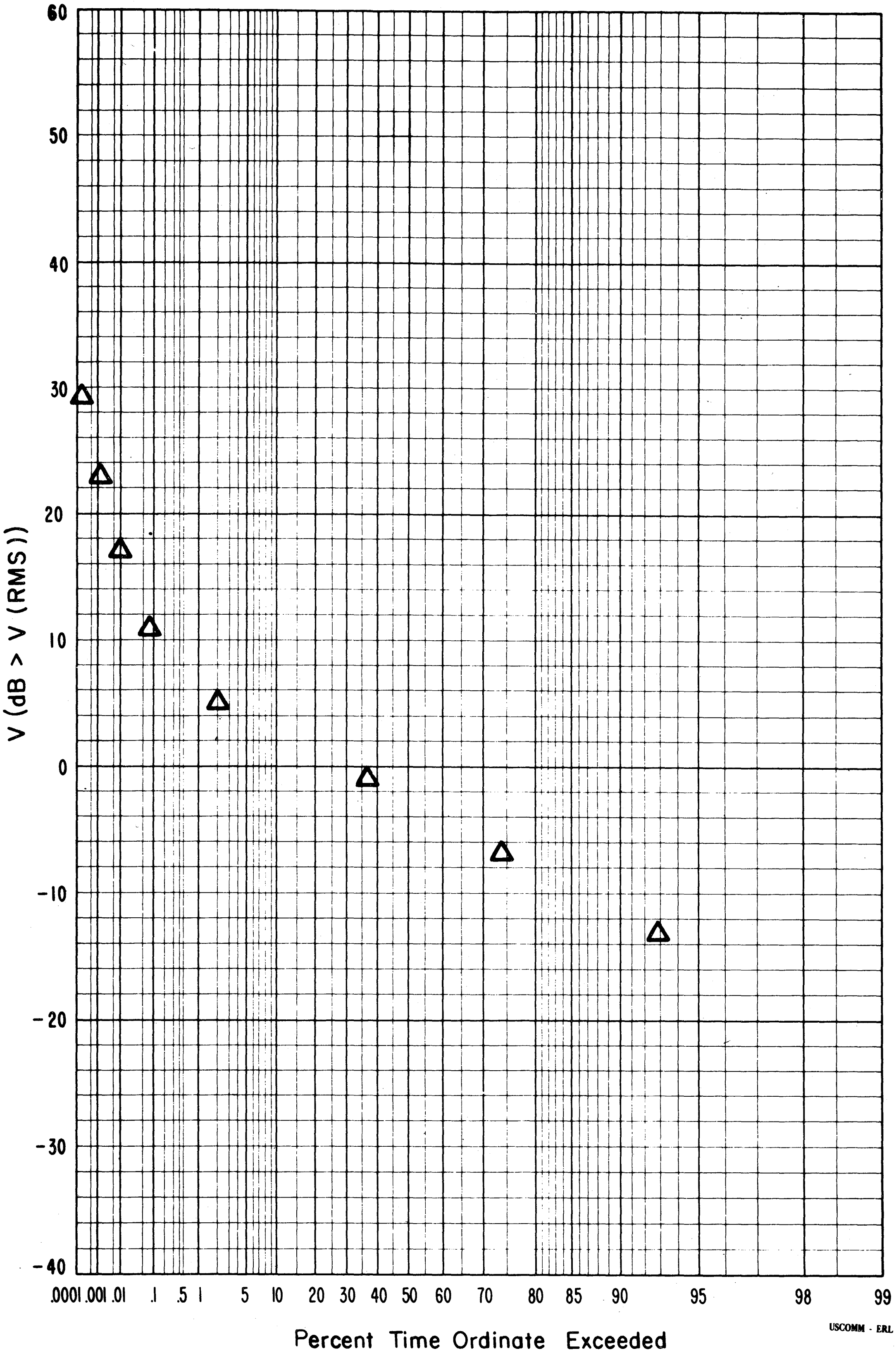


Figure A1. The APD's for test 1 at 50 MHz with 1 SAE vehicle.
V(RMS) = -120.6 dBm.

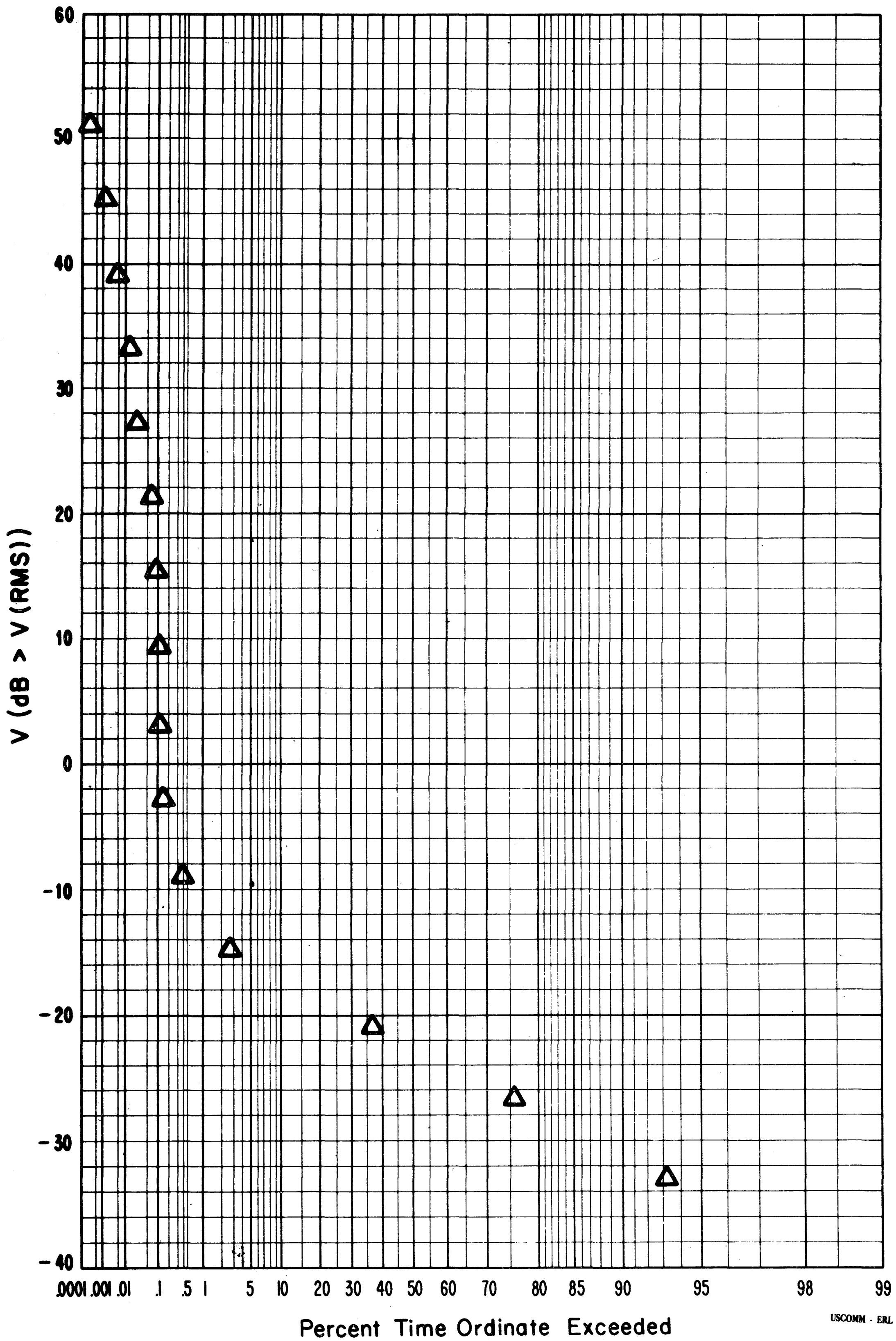


Figure A2. The APD's for tests 2 and 3 at 50 MHz with 1 super noisy vehicle. V(RMS) = -100.6 dBm.

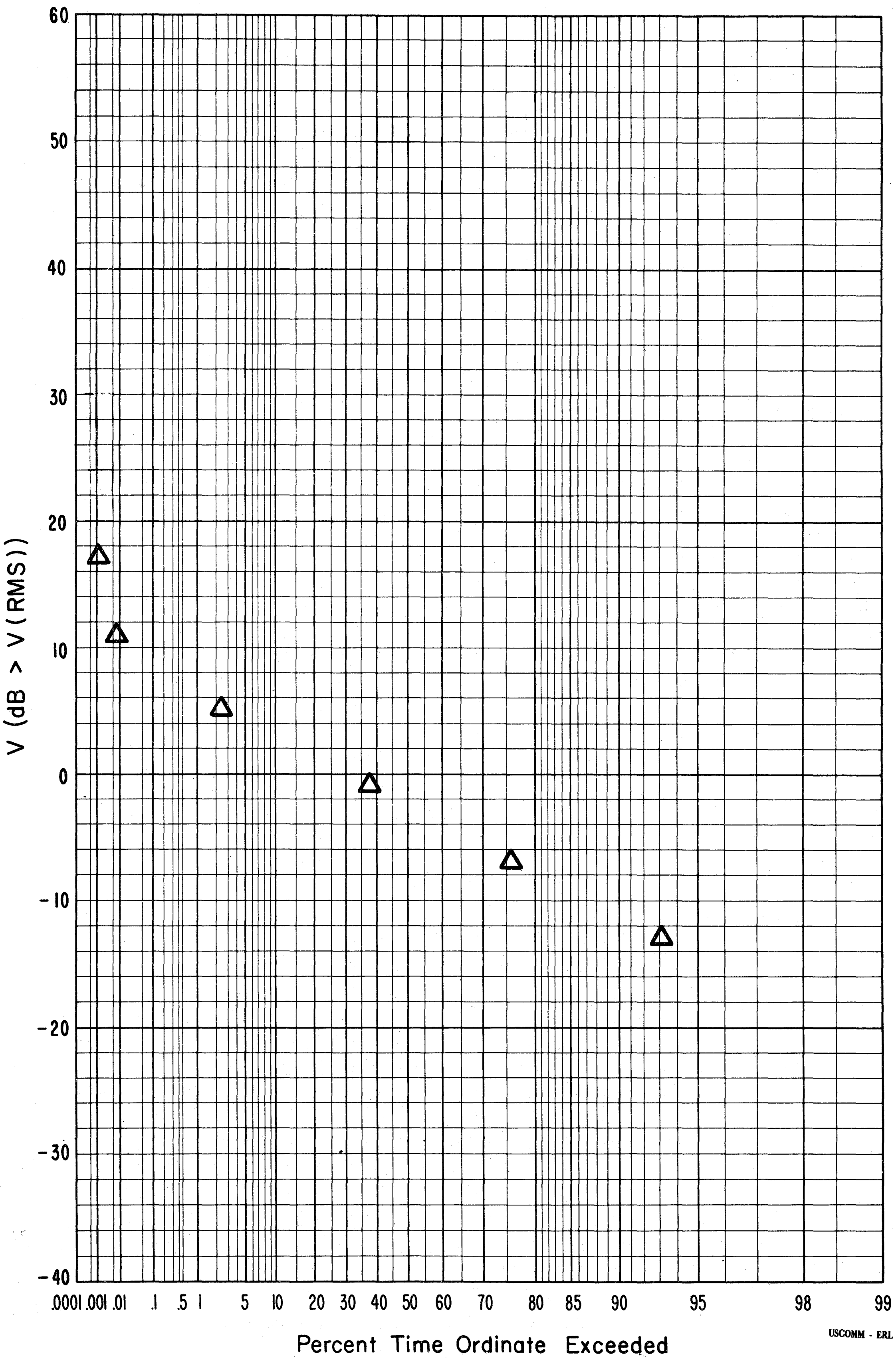


Figure A3. The APD for test 4 at 50 MHz with no vehicles.
V(RMS) = -120.4 dBm.

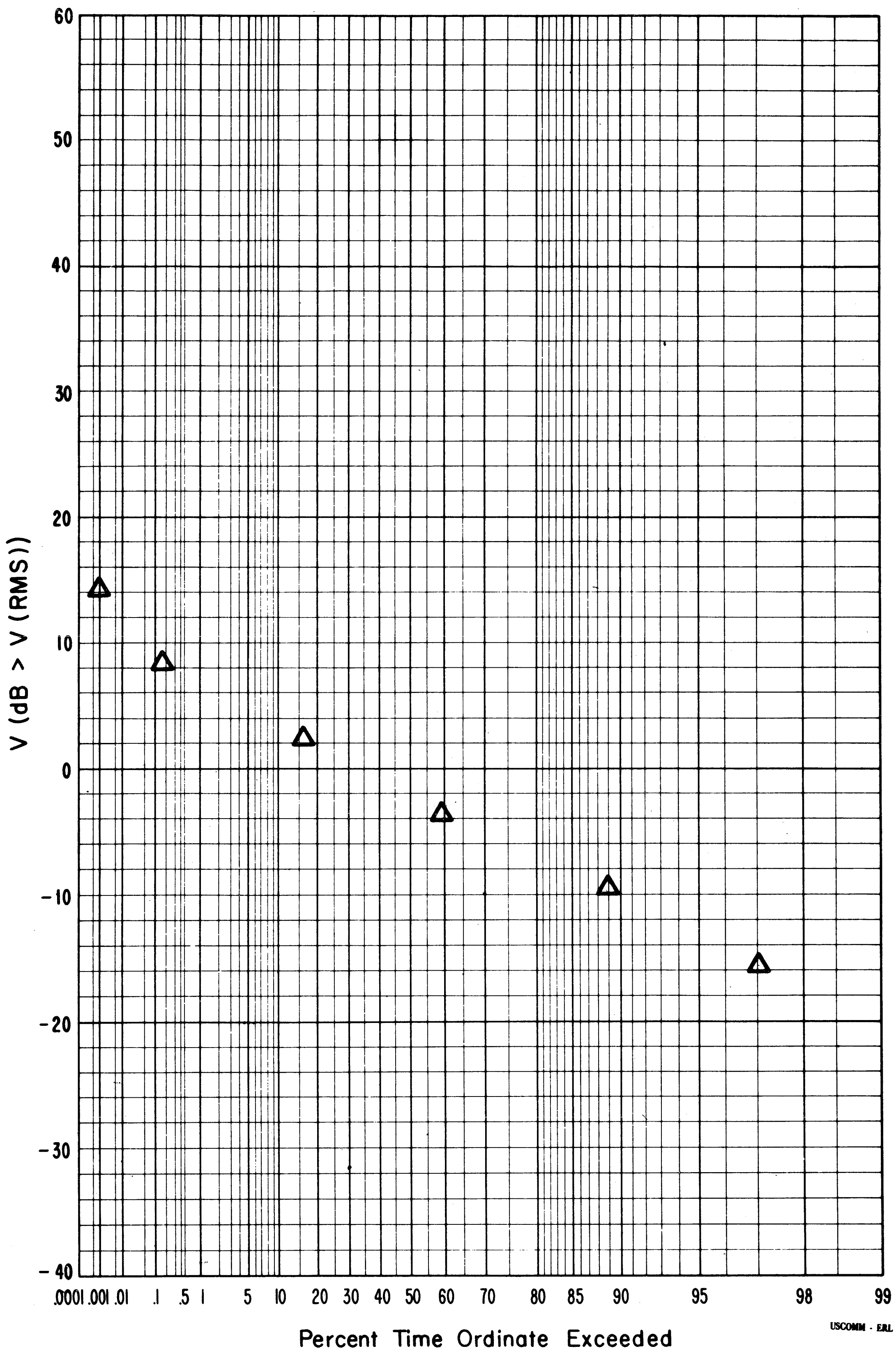


Figure A4. The APD for test 5 at 29 MHz with no vehicles.
V(RMS) = -118.5 dBm.

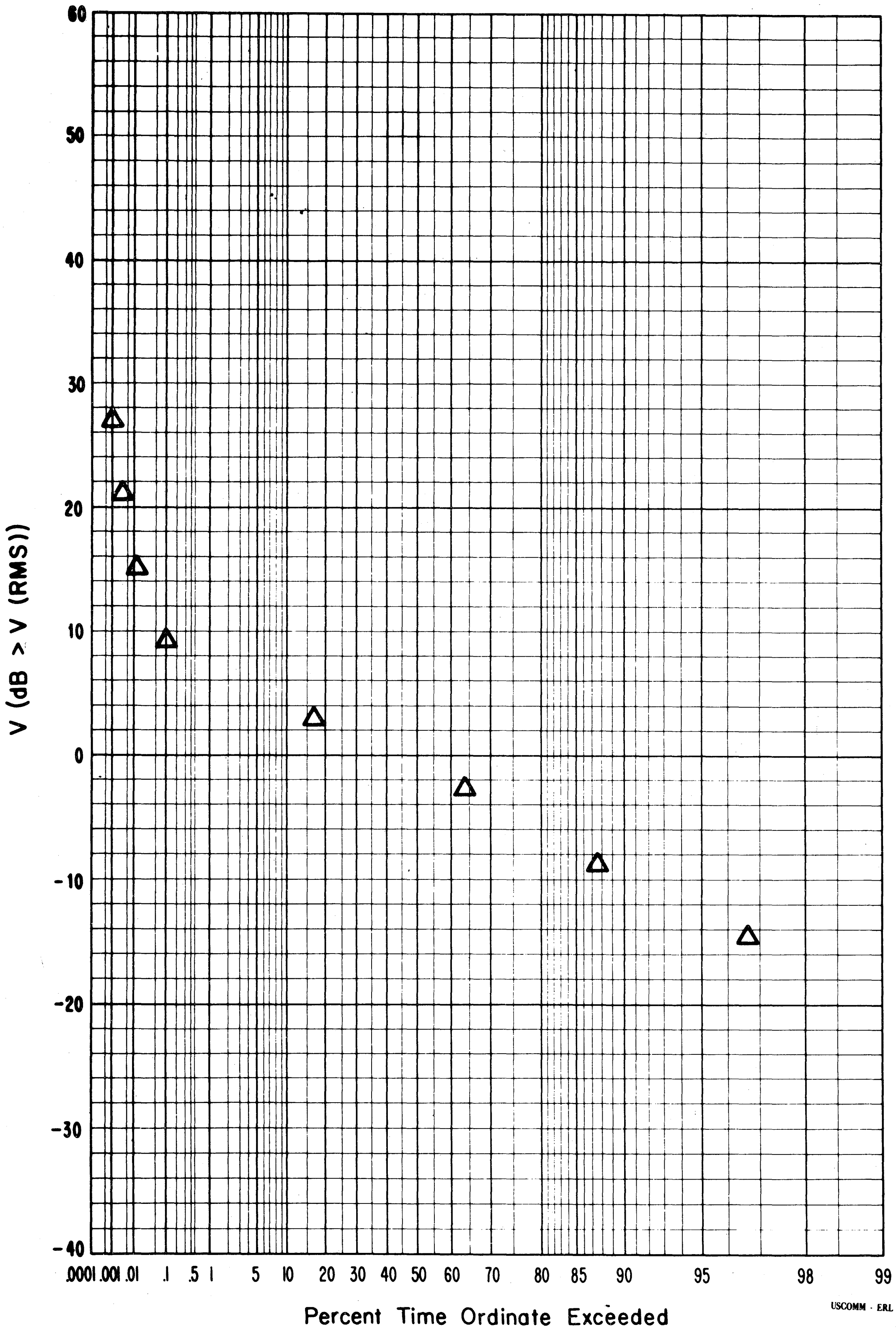


Figure A5. The APD for test 6 at 50 MHz with 6 SAE vehicles. V(RMS) = -119.9 dBm.

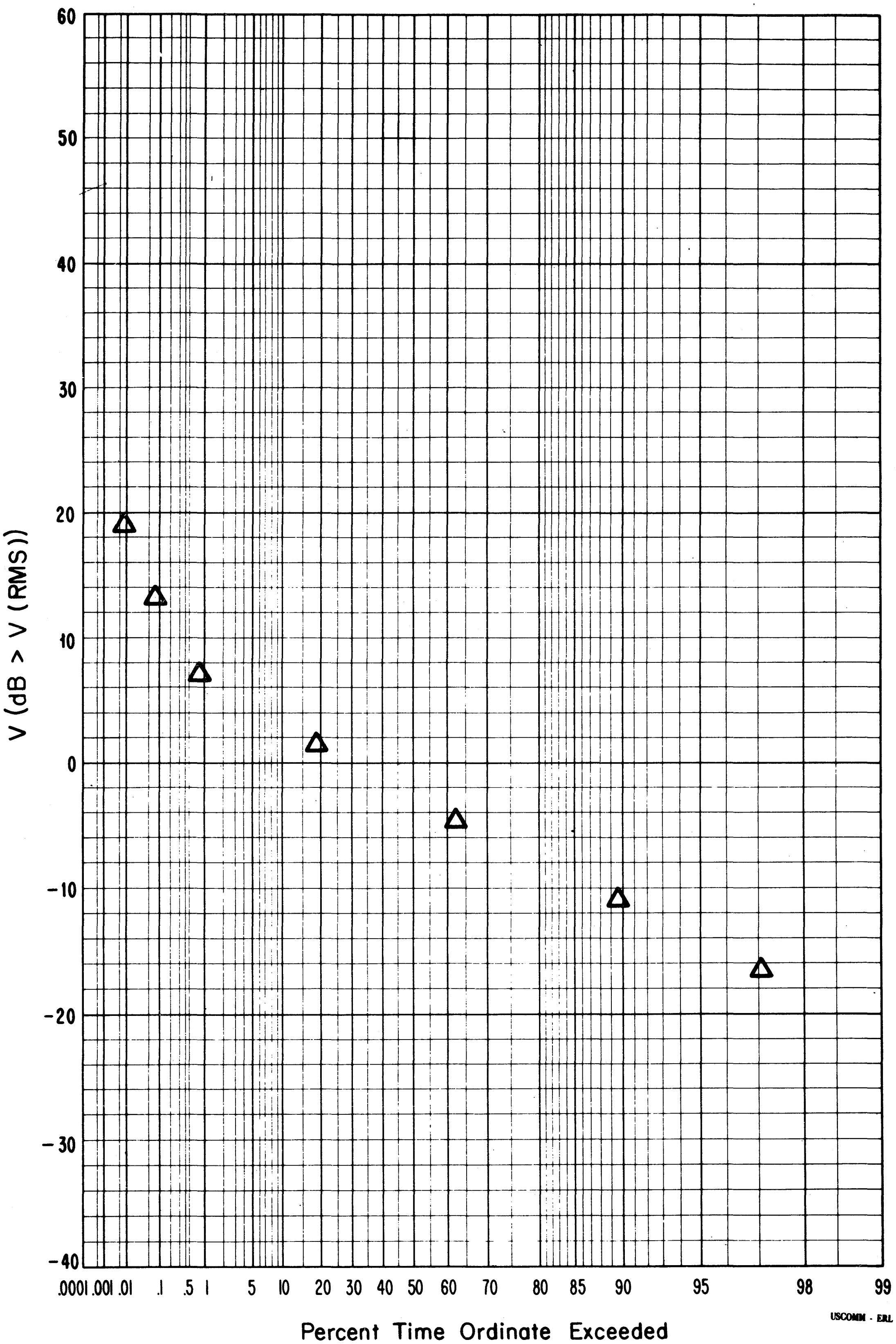


Figure A6. The APD for test 7 at 29 MHz with 12 SAE vehicles. V(RMS) = -117.4 dBm.

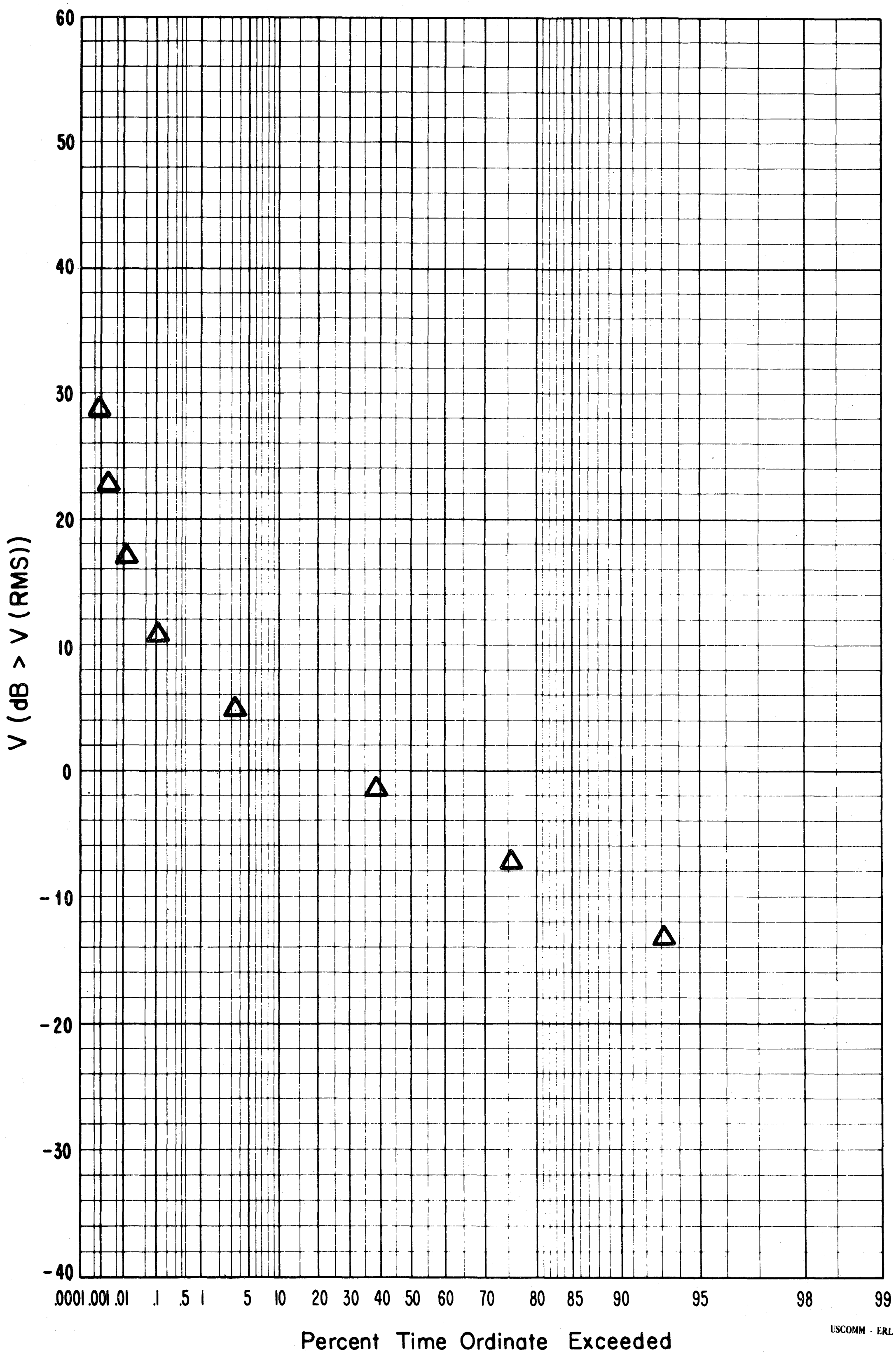


Figure A7. The APD for test 8 at 50 MHz with 12 SAE vehicles. V(RMS) = -119.7 dBm.

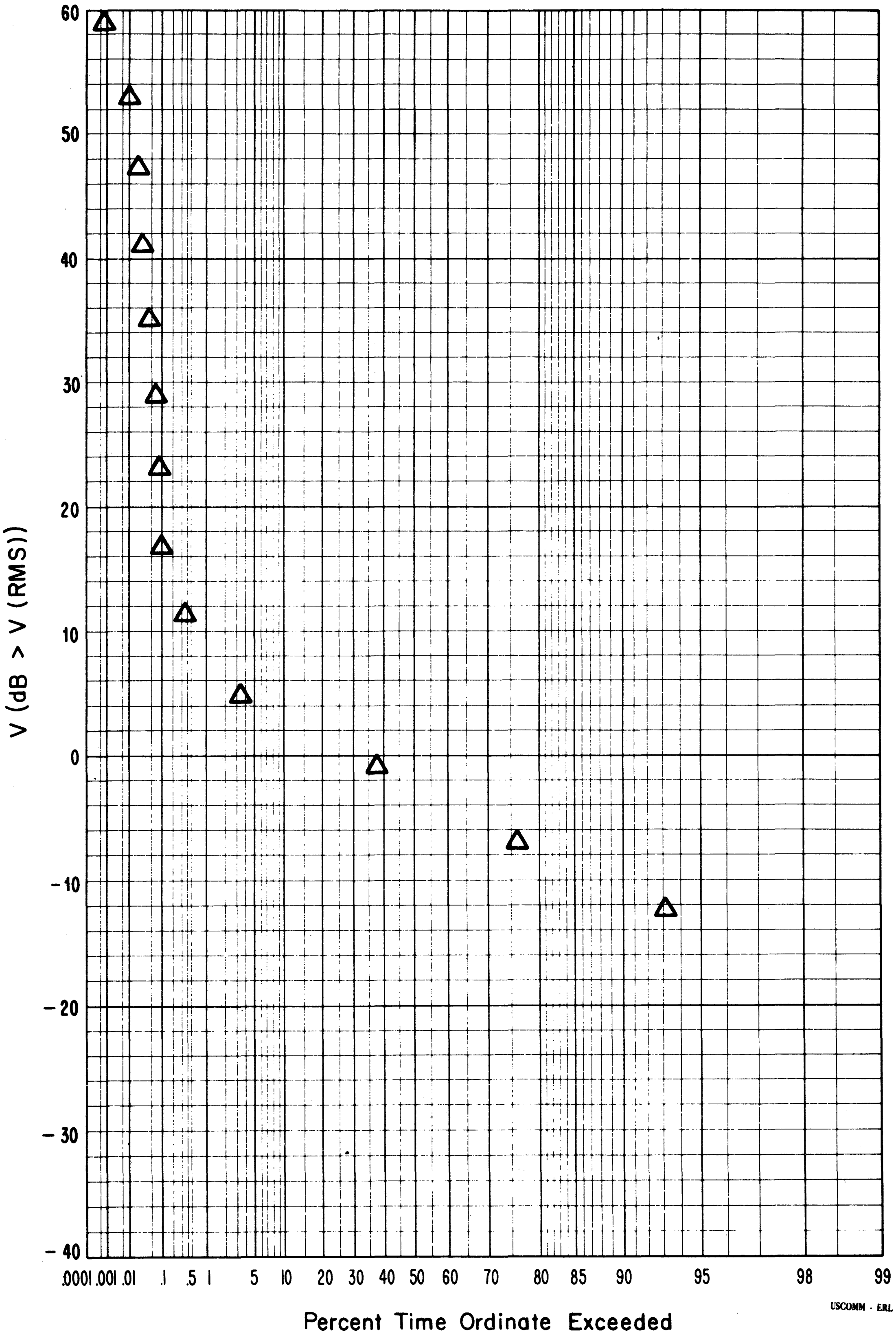


Figure A8. The APD for test 9 at 50 MHz with 11 SAE and 1 super noisy vehicle. V(RMS) = -102.9 dBm.

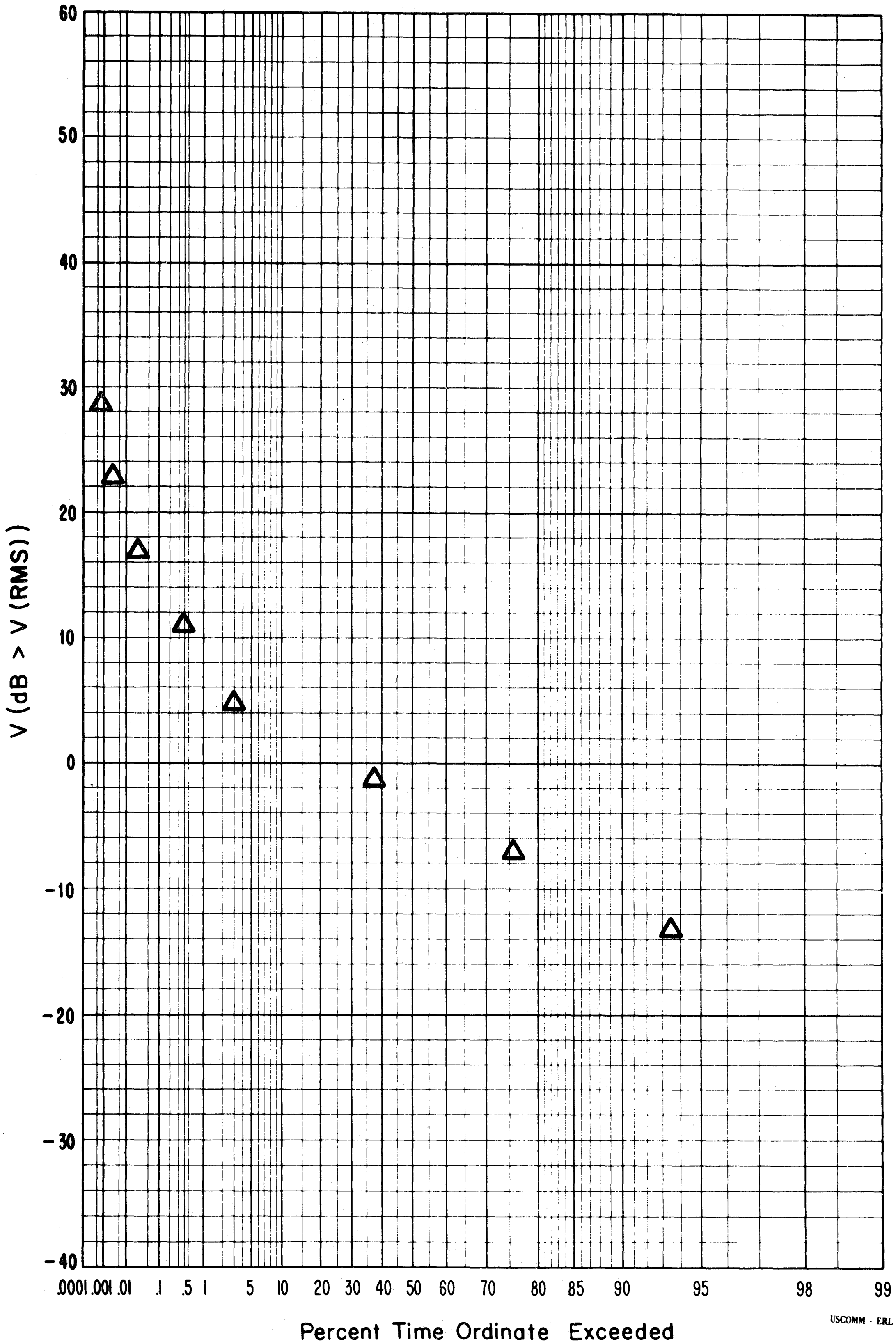


Figure A9. The APD for test 10 at 147 MHz with 12 SAE vehicles V(RMS) = -118.1 dBm.

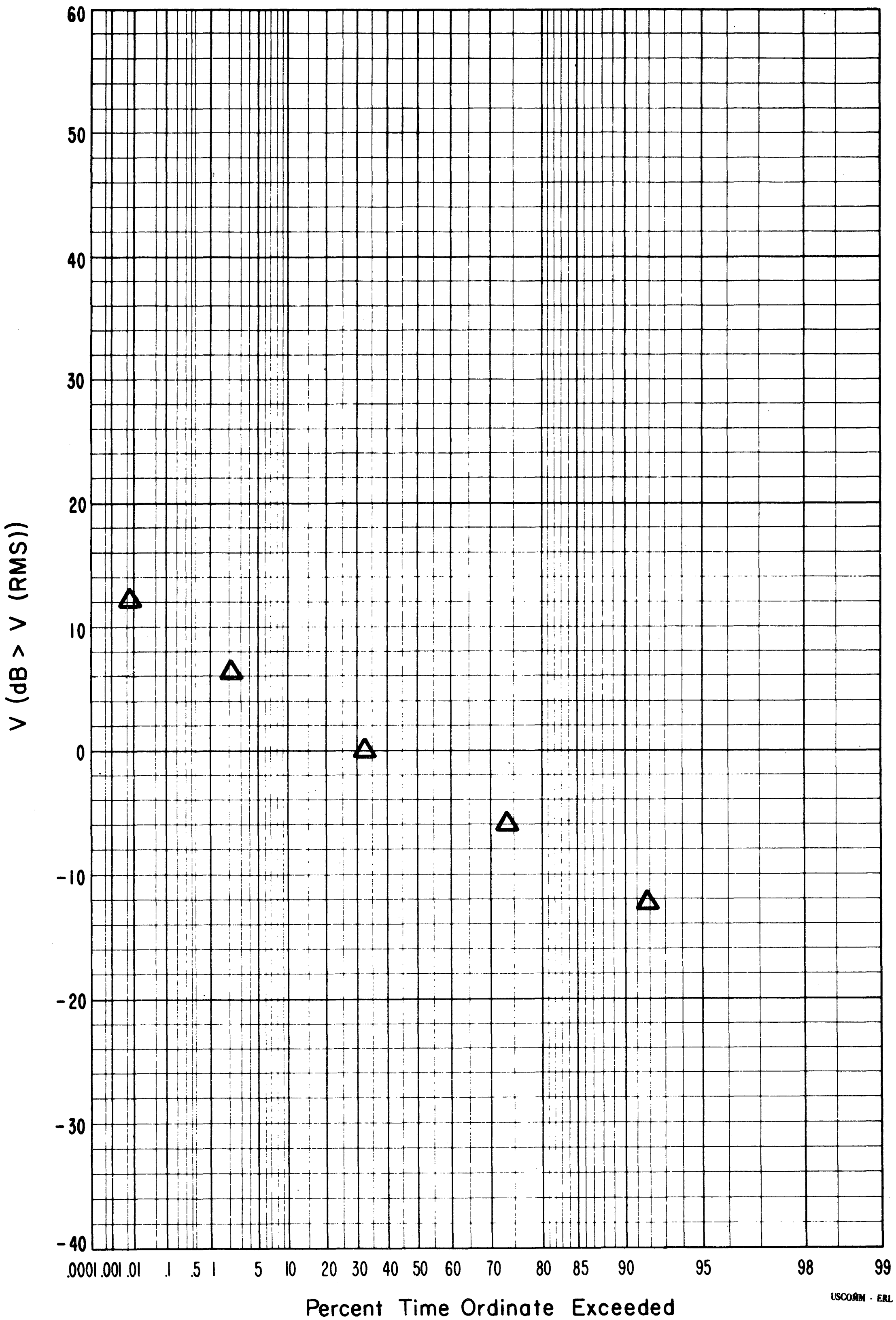


Figure A10. The APD for system noise through the filter, amplifier, spectrum analyzer and DM3. V(RMS) = -121.0 dBm.

FORM **NTIA-29** (4-80)

U.S. DEPARTMENT OF COMMERCE
NAT'L. TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION

# BIBLIOGRAPHIC DATA SHEET

| | 1. PUBLICATION NO. | 2. Gov't Accession No. | 3. Recipient's Accession No. |
|---|---|---|---|
| | NTIA Report 80-43 | | |

4. TITLE AND SUBTITLE

Measurement of the Effect of Vehicle Ignition Noise on Land-Mobile Voice Channels

5. Publication Date

June 1980

6. Performing Organization Code

NTIA/ITS-2


7. AUTHOR(S)

W. J. Hartman

8. PERFORMING ORGANIZATION NAME AND ADDRESS

U. S. Department of Commerce
NTIA/ITS-2
325 Broadway
Boulder, CO 80303


9. Project/Task/Work Unit No.

9104387

10. Contract/Grant No.

ITS 7925-C2.52

11. Sponsoring Organization Name and Address

Motor Vehicle Manufacturers Association of the United States, Inc.
Detroit, MI 48202

12. Type of Report and Period Covered

NTIA Report

13.

14. SUPPLEMENTARY NOTES

15. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*


Measurements of the noise intelligibility over land-mobile systems in the presence of vehicle noise are presented. These are compared with several statistical noise parameters obtained from measured amplitude probability distributions.


16. Key Words *(Alphabetical order, separated by semicolons)*

Impulse noise; intelligibility; scoring; vehicle noise.

| 17. AVAILABILITY STATEMENT | 18. Security Class. *(This report)* | 20. Number of pages |
|---|---|---|
| ☒ UNLIMITED. | Unclassified | 32 |
| | 19. Security Class. *(This page)* | 21. Price: |
| ☐ FOR OFFICIAL DISTRIBUTION. | Unclassified | |


☆ U.S. GOVERNMENT PRINTING OFFICE: 1980-0-679-075/478