(NASA-CR-152535) A DEPOLARIZATION AND ATTENUATION EXPERIMENT USING THE CTS SATELLITE Quarterly Technical Progress Report, 1 Oct. - 31 Dec. 1976 (Virginia Polytechnic Inst. and State Univ.) 36 p HC G3/32
N77-26347
HC A03/MF A01
Unclas
31736

Virginia Polytechnic Institute and State University
Electrical Engineering
BLACKSBURG, VIRGINIA 24061

Quarterly Technical Progress Report I (Second Year)

on

A DEPOLARIZATION AND ATTENUATION EXPERIMENT USING THE CTS SATELLITE

Covering

October 1 - December 31, 1976

Text by

C. W. Bostian
S. B. Holt, Jr.
S. R. Kauffman
E. A. Manus
R. E. Marshall
W. L. Stutzman
P. H. Wiley

Artwork by

Cynthia R. Will

Electrical Engineering Department
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

Prepared for

NASA Goddard Space Flight Center
Greenbelt, Maryland 20771

Contract NAS5-22577

February 28, 1977

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle: A Depolarization and Attenuation Experiment Using the CTS Satellite Quarterly Technical Progress Report I (Second Year)		5. Report Date: Feb. 28, 1977
		6. Performing Organization Code
7. Author(s): C.W. Bostian, S.B. Holt, Jr., S.R. Kauffman, E.A. Manus, R.E. Marshall, W.L. Stutzman, F.H. Wiley		8. Performing Organization Report No.
9. Performing Organization Name and Address: Electrical Engineering Department, Virginia Polytechnic Institute & State Univ., Blacksburg, Virginia 24061		10. Work Unit No.
		11. Contract or Grant No.: NAS5-22577
		13. Type of Report and Period Covered: Quarterly Technical Report (Second Year) Oct. 1 - Dec. 31, 1976
12. Sponsoring Agency Name and Address: NASA Goddard Space Flight Center, Greenbelt, Maryland 20771, E. Hirschmann, Code 953, Technical Officer		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This report presents rain attenuation and depolarization data collected in November and December 1976 on the CTS 11.7 GHz downlink. A 15 GHz weather radar system is described.

17. Key Words (Selected by Author(s))	18. Distribution Statement
wave polarization, rain depolarization, rain attenuation, CTS, millimeter waves, communications satellites, weather radar	unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
U	U	33	

*For sale by the National Technical Information Service, Springfield, Virginia 22151.

Table of Contents

1. Introduction

This report summarizes CTS activities at VPI&SU for the period October 1 - December 30, 1976. It discusses the data collected and changes made in the experimental equipment.

During the reporting period data were collected from November 1 through December 24, 1976. These particular starting and ending dates were dictated by hardware considerations.

The spacecraft was turned off for the eclipse period which began on August 30 and ended on October 16, 1976. While the spacecraft was out of operation the VPI&SU RF front end developed a rain leak that destroyed its power supplies and damaged the parametric amplifier. As the power supply failure took place on the night of October 15, the leak was not discovered until the receiver failed to acquire the satellite signal on October 16.

After consulting the front end manufacturer (who had guaranteed the front end to be watertight), we were able to remove the paramp and operate the rest of the front end from an outboard power supply. This meant that the co-polarized signal levels were normal but that the cross-polarized channel had approximately 14 dB less gain and considerably more thermal noise than before the damage occurred. Increasing the gain of the IF signal processor compensated for the loss in front-end gain. This made the receiver output voltage the same as it had been with the paramp in place, but about 5 dB of dynamic range was lost to the added thermal noise. Fortunately the dynamic range which remained was sufficient for the fades which occurred. On this basis the receiver was back in operation in time to resume data collection on November 1, 1976.

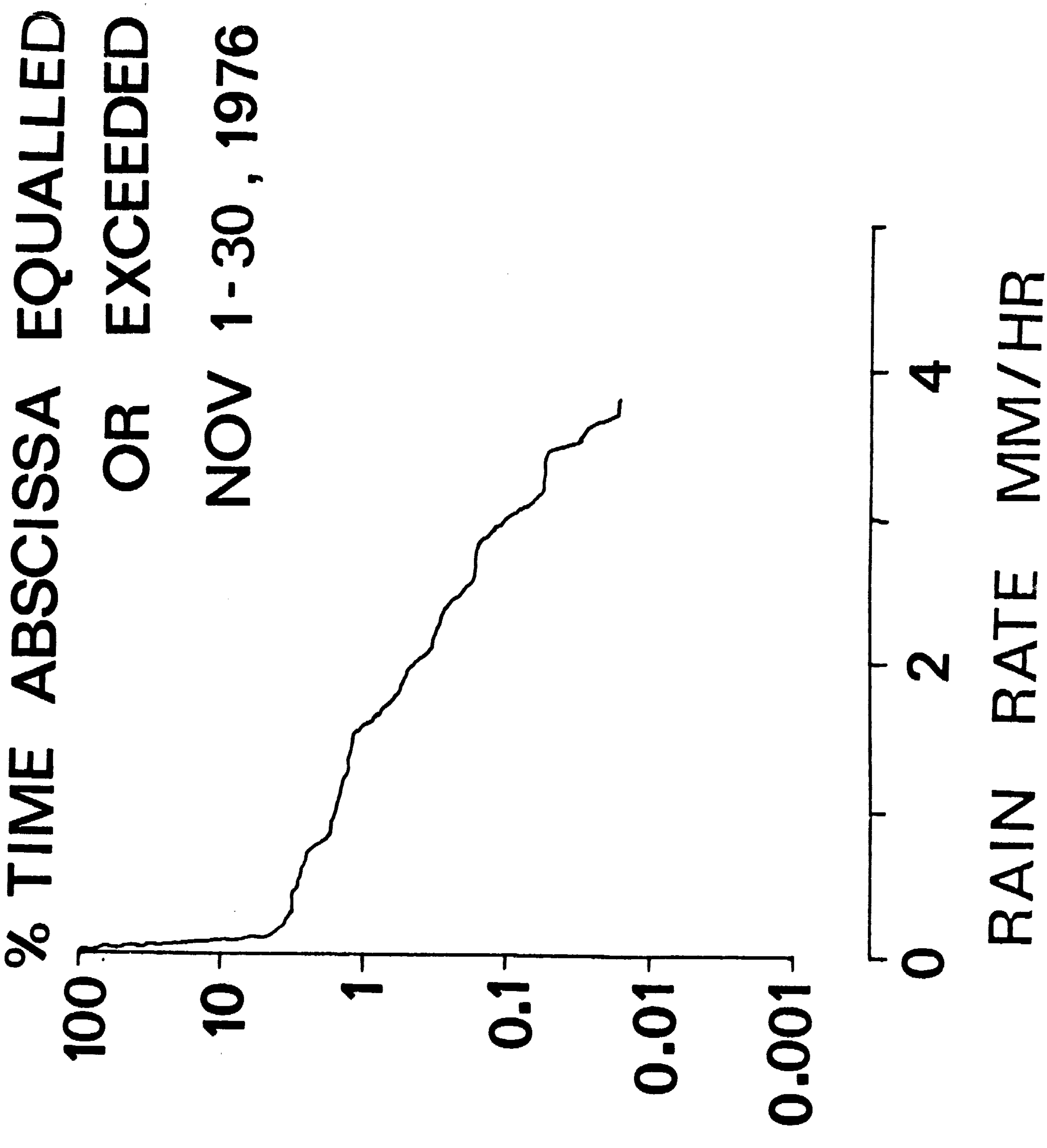
Parenthetically it should be pointed out that receiver operation without the paramp was possible only because of the extensive modifications that have been made to our government-furnished equipment. The original Martin-Marietta receivers could not have maintained lock on the cross-polarized signal without a paramp.

Active data collection was temporarily interrupted on December 25, 1976, by an intermittent failure in our digital controller (interface between the PDP-11 computer and the rest of the experiment) which caused the experiment clock to be reset to an incorrect time. This was repaired early in January, 1977, but much of the data collected December 25-31 was stored with incorrect time codes. As no significant signal fades or depolarization events were noted during this period, we felt that the time and money required to correct the data manually were unjustified. Accordingly data for the period December 25-31 were not included in the data base.

2. Data

2.1 Statistics

During the reporting period no convective storms occurred. The predominant weather pattern was widespread stratiform rain with low ground rainfall rates. For the entire period the maximum rainfall rate was 12.53 mm/hr. This is illustrated in Figures 2.1-1 through 2.1-3 which show the statistical distribution of rain rate for November, for December, and for the total period. Corresponding data for attenuation and isolation are displayed in Figures 2.1-4 through 2.1-9.



% TIME ABSCISSA EQUALLED
OR EXCEEDED
NOV 1-30, 1976
100
10
1
0.1
0.01
0.001
0
2
4
RAIN RATE MM/HR

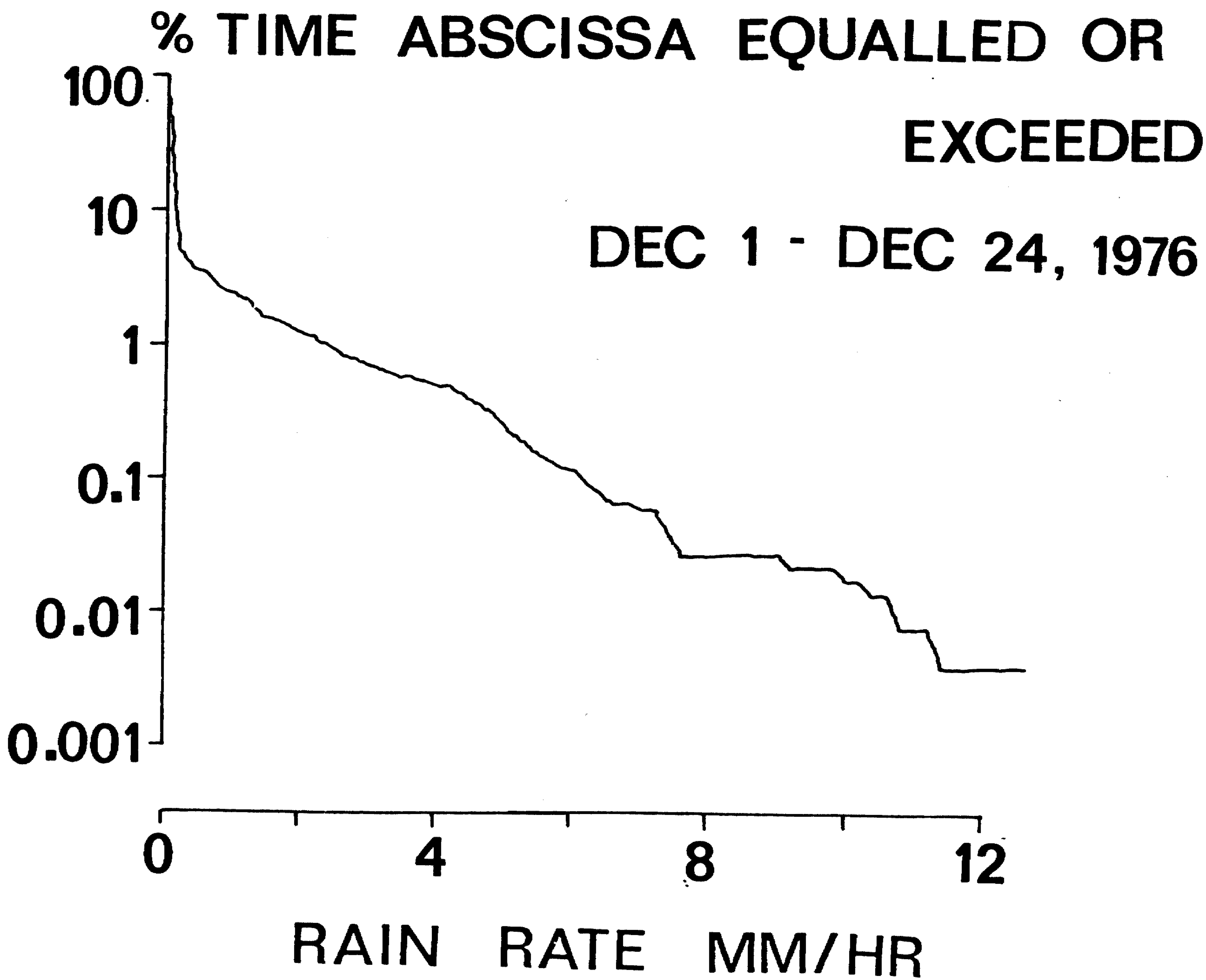
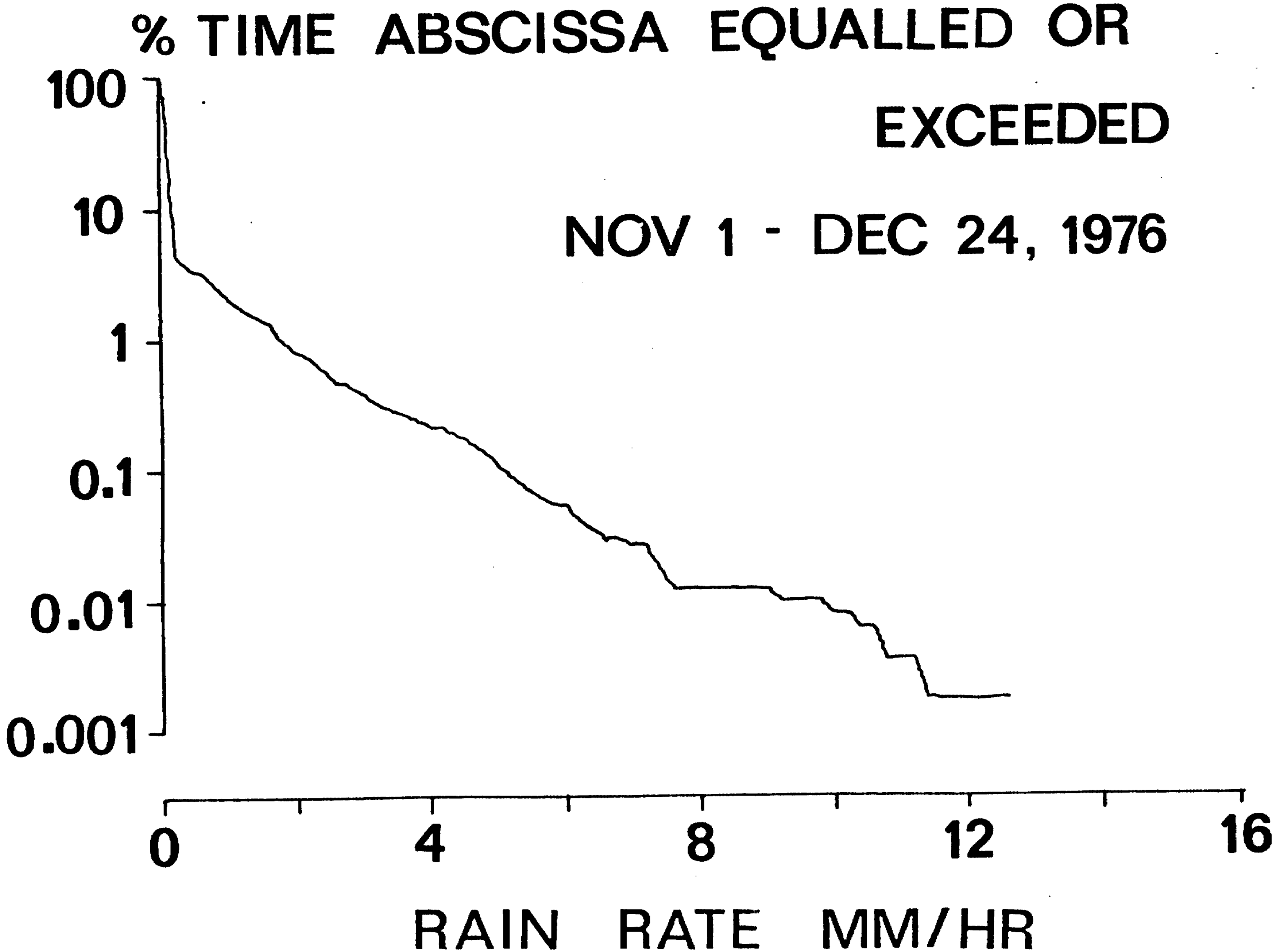


Figure 2.1-2 Rain rate statistics for Dec. 1-24, 1976.


% TIME ABSCISSA EQUALLED OR EXCEEDED
NOV 1 - DEC 24, 1976
100
10
1
0.1
0.01
0.001
0
4
8
12
16
RAIN RATE MM/HR

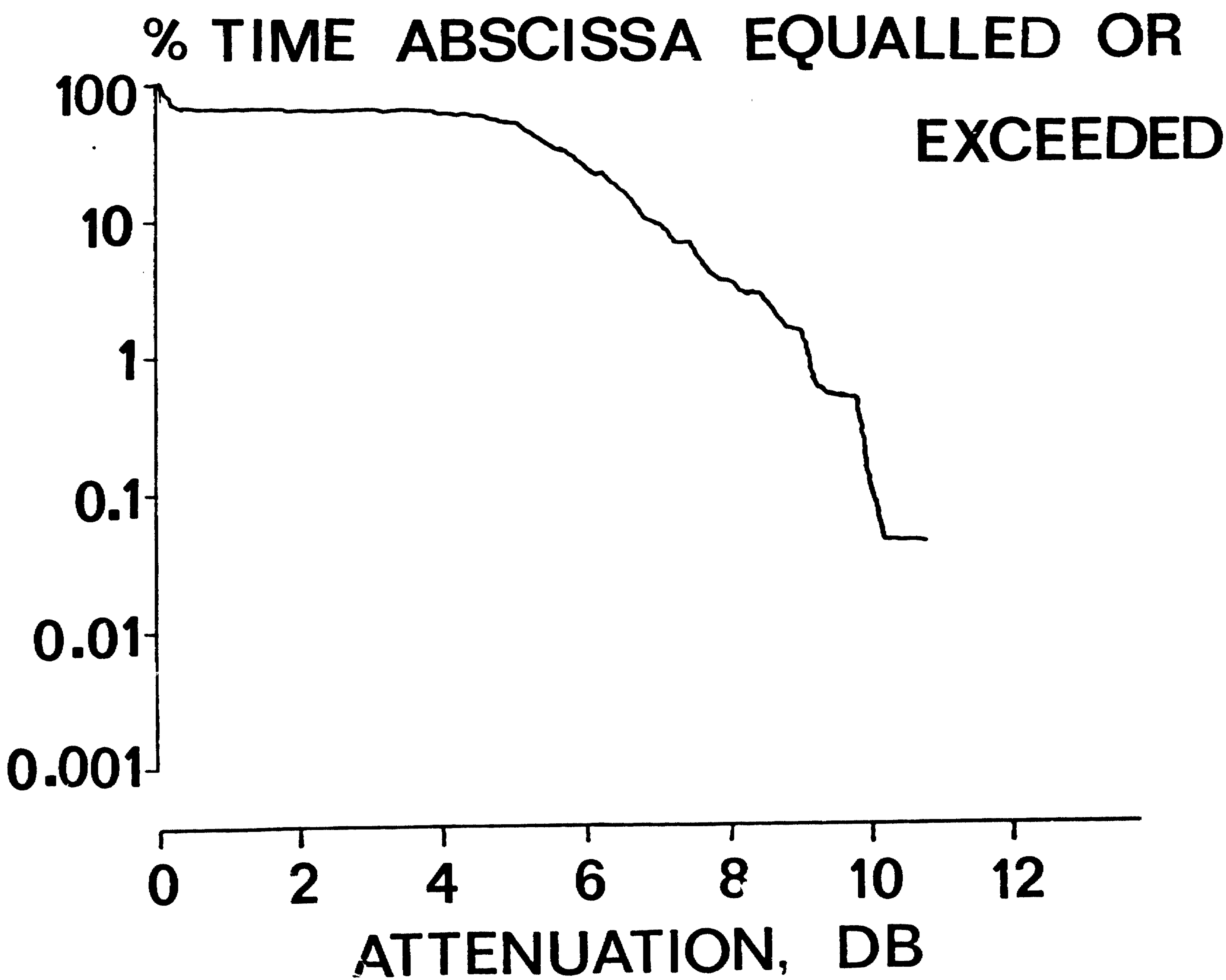


Figure 2.1-4 Attenuation statistics for Nov. 1-30, 1976.

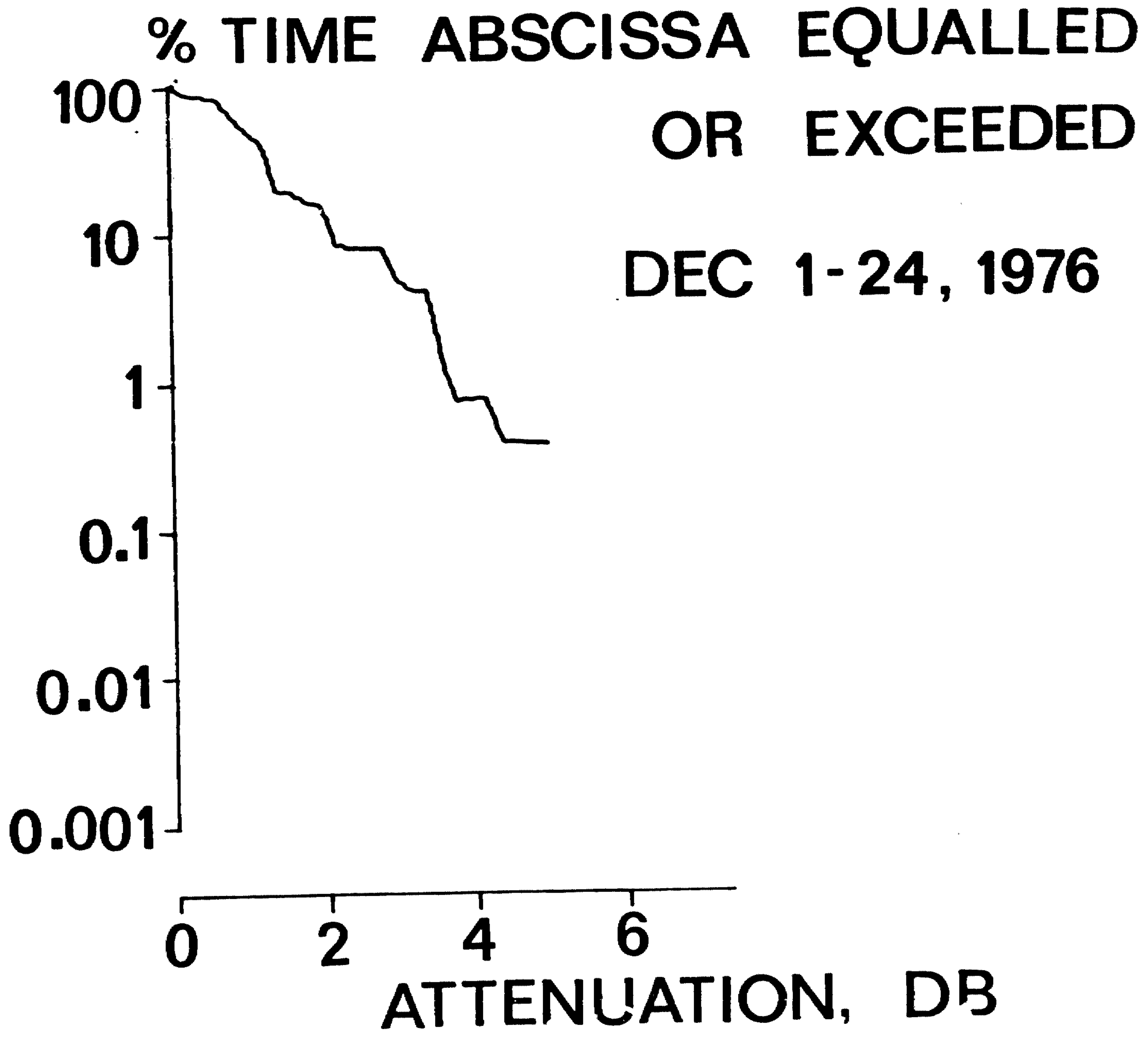


Figure 2.1-5 Attenuation statistics for Dec. 1-24, 1976.

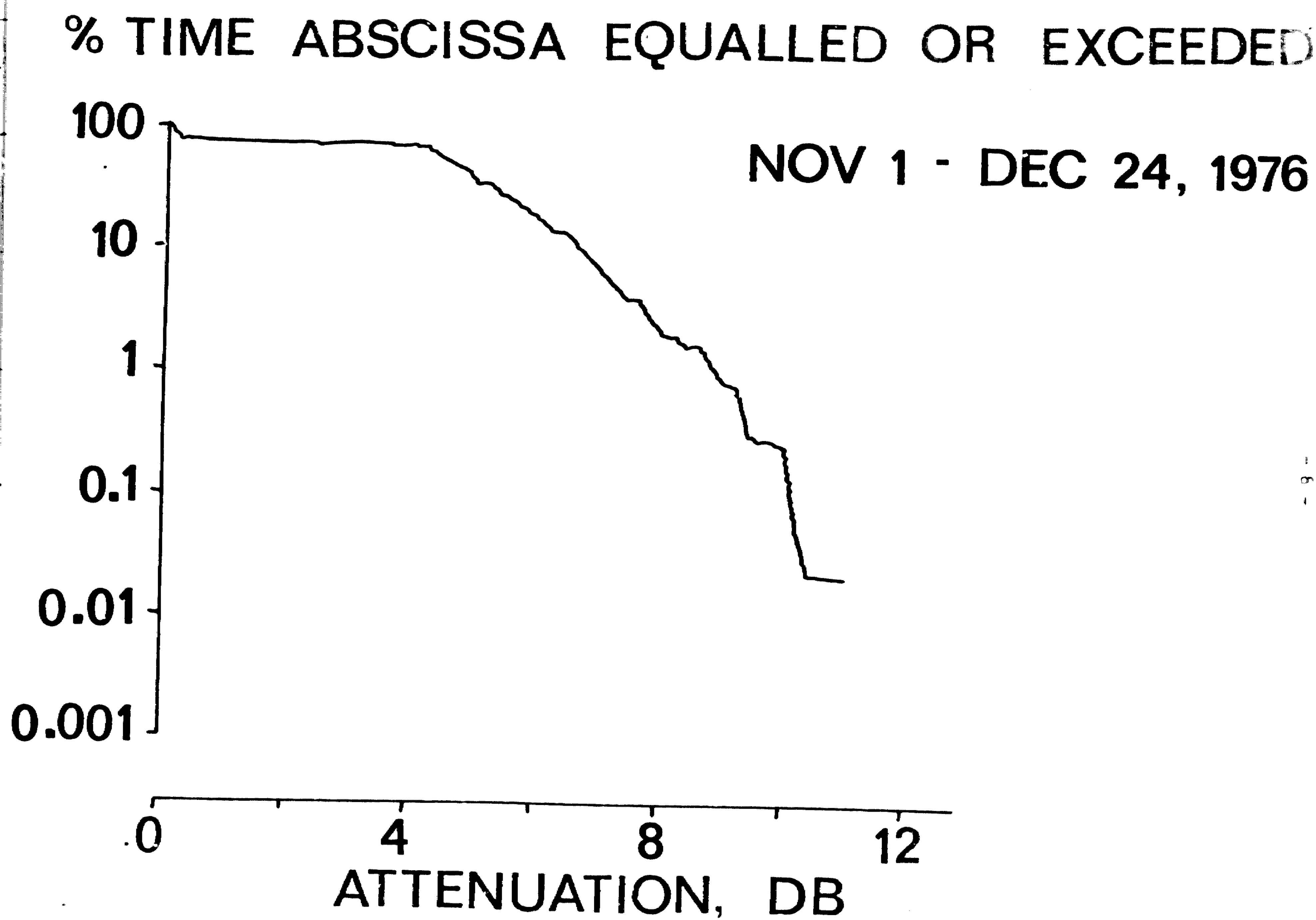


Figure 2.1-6 Attenuation statistics for Nov. 1 - Dec. 24, 1976.

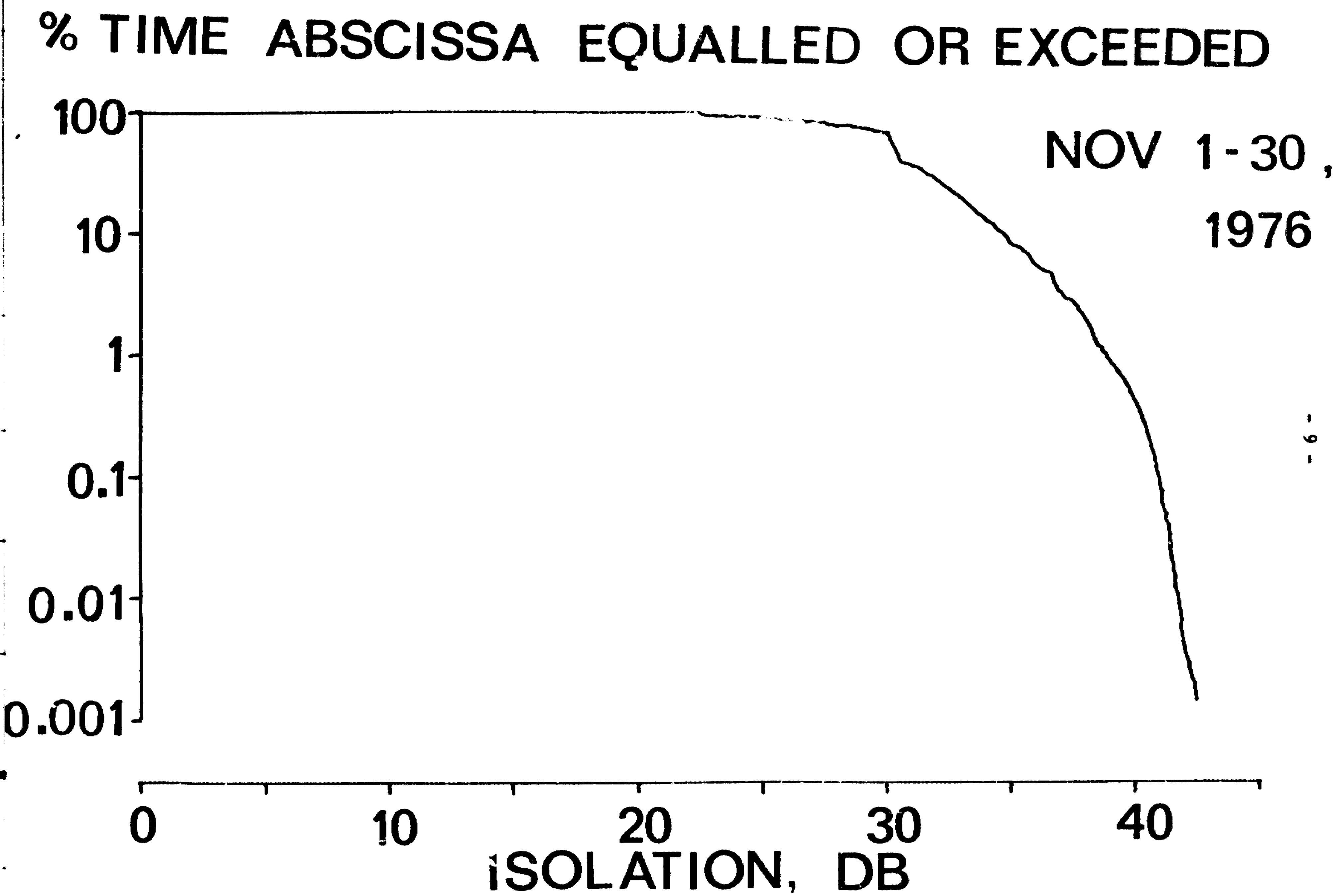


Figure 2.1-7 Isolation statistics for Nov. 1-30, 1976.

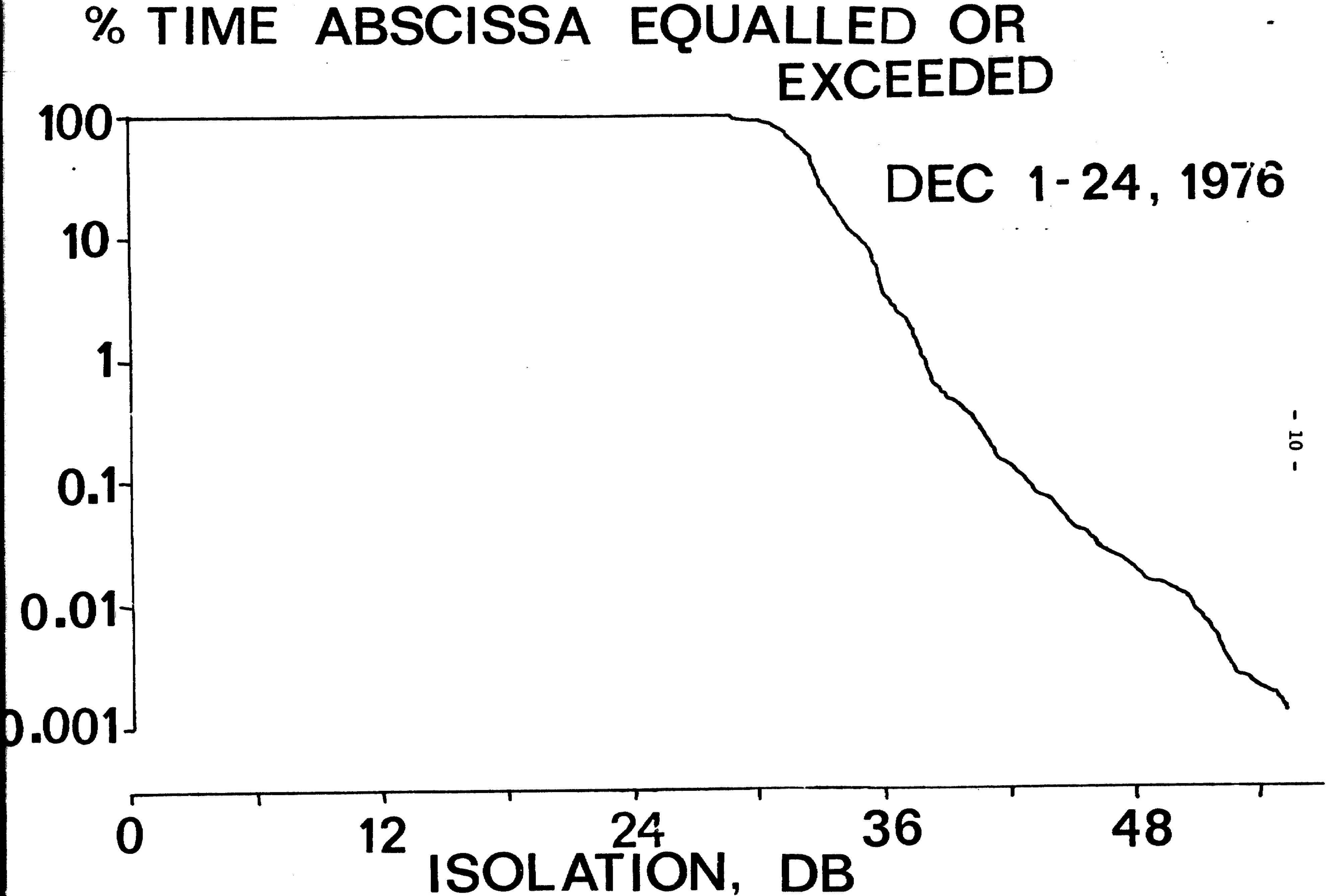


Figure 2.1-8 Isolation statistics for Dec. 1-24, 1976.

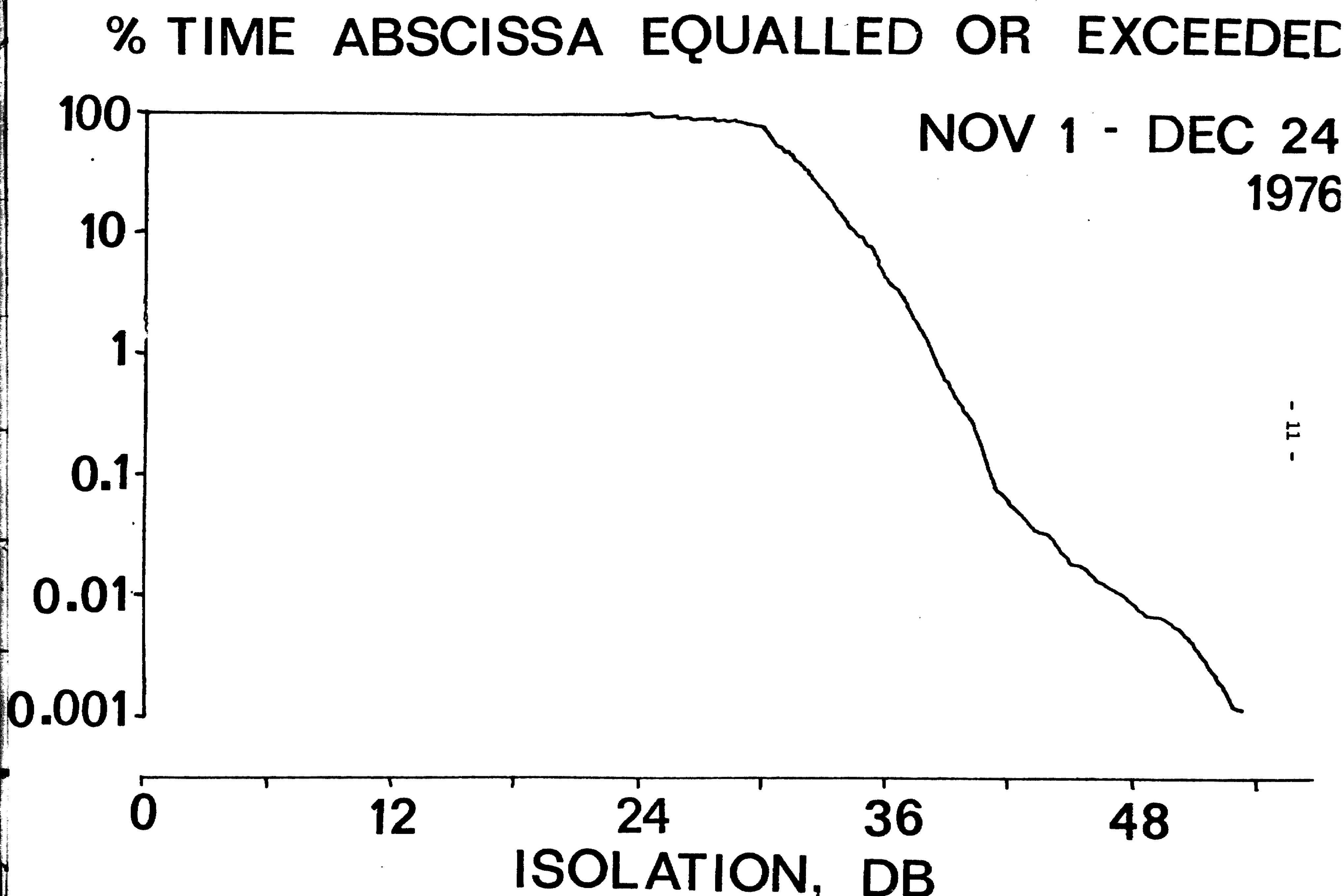


Figure 2.1-9 Isolation statistics for Nov. 1 - Dec. 24, 1976.

In the final report for the first year of work under this contract we discussed a possible relationship between the isolation value equalled or exceeded P% of the time and the attenuation value equalled or exceeded (100-P)% of the time, where P is a variable. These complementary values of isolation and attenuation for both summer and winter data are compared in Table 2.1 and displayed in Figure 2.1-10.

At the present time it is difficult to draw any firm conclusions about the differences between the summer and winter statistics. The winter data were taken during a period of light rain but comparatively heavy snow. During November and December we had great difficulty obtaining timely orbital elements for CTS; this affected the accuracy of our antenna pointing and may have added some bias to the winter statistics. The orbital element problem was resolved in January and the statistical behavior of attenuation and isolation will be pursued during the coming year.

Table 2.1 Attenuation and Isolation for Corresponding

Percentages of Time

	November-December 1976		Summer 1976	
P	Isolation Equalled or Exceeded P% of Time, dB	Attenuation Equalled or Exceeded (100-P)% of Time, dB	Isolation Equalled or Exceeded P% of Time, dB	Attenuation Equalled or Exceeded (100-P)% of Time, dB
99.90	11.49	10.16	13.01	12.64
99.75	12.10	10.02	15.40	10.90
99.50	12.74	9.34	21.34	8.08
99.00	13.58	8.93	27.01	4.76
98.00	23.63	8.28	28.39	3.93
95.00	25.35	7.29	29.46	2.86
90.00	27.27	6.76	*	*

* Unavailable

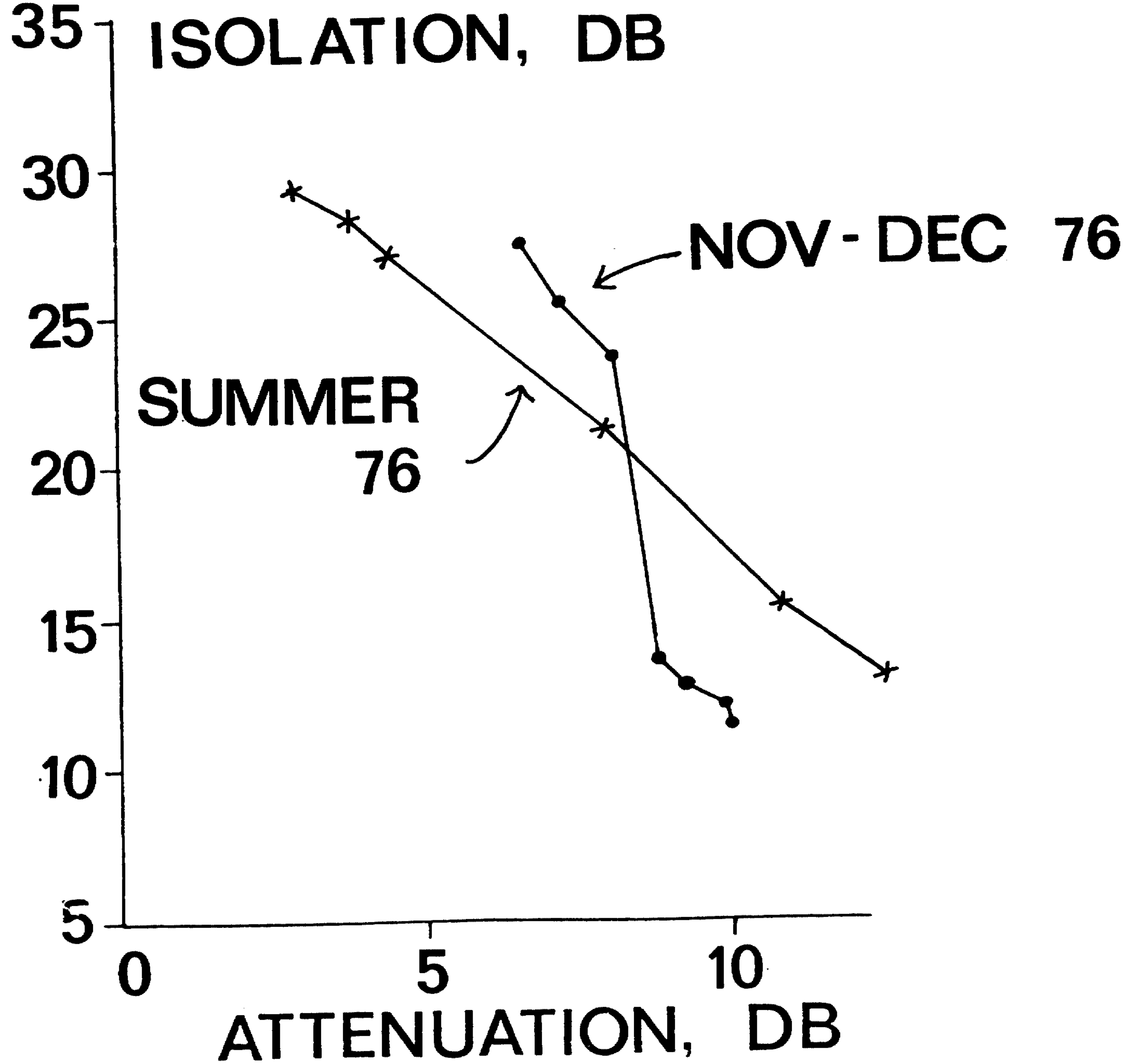


Figure 2.1-10 Comparison of complementary attenuation and isolation data for winter and summer.

2.2 Signal Behavior and Rainfall Rate: The Significance of Detector Bandwidth

At very low rainfall rates the behavior of the cross-polarized signal component on a satellite downlink is ambiguous. A small amount of rain depolarization may bring the incident wave polarization into better alignment with the receiving antenna polarization, yielding isolation values which are better than those which occur in clear weather. This effect has been noted in almost all measurements of rain depolarization. For this reason extensive plots of signal behavior and rain rate versus time have been omitted from this report.

Shortly before the start of the Fall 1976 eclipse period, detectors with 1-second time constants (0.16 Hz bandwidth) were installed in parallel with the 10-second time constant (0.016 Hz bandwidth) detectors that have been used since the start of the experiment. Because the fast detectors produce a noisier output and fill up the available data storage locations faster than the slow detectors, the computer records fast detector data only during significant precipitation events. Since the rain rate was significant only for short intervals during the report period, we have gathered no conclusive information about the effects of detector bandwidth on attenuation and isolation measurements.

The first period for which we will compare the two detector outputs extends from 01:59:52 (UT) to 05:57:10 on November 28, 1976. Figure 2.2-1 displays the rain rate as recorded by the rain gauge nearest to the antenna. On both detectors the co-polarized signal remained constant and is not reproduced here. Figures 2.2-2 and 2.2-3 illustrate the cross-polarized signal behavior as recorded by the slow and fast detectors. The fast detector plot terminates earlier because the rain stopped. While the two

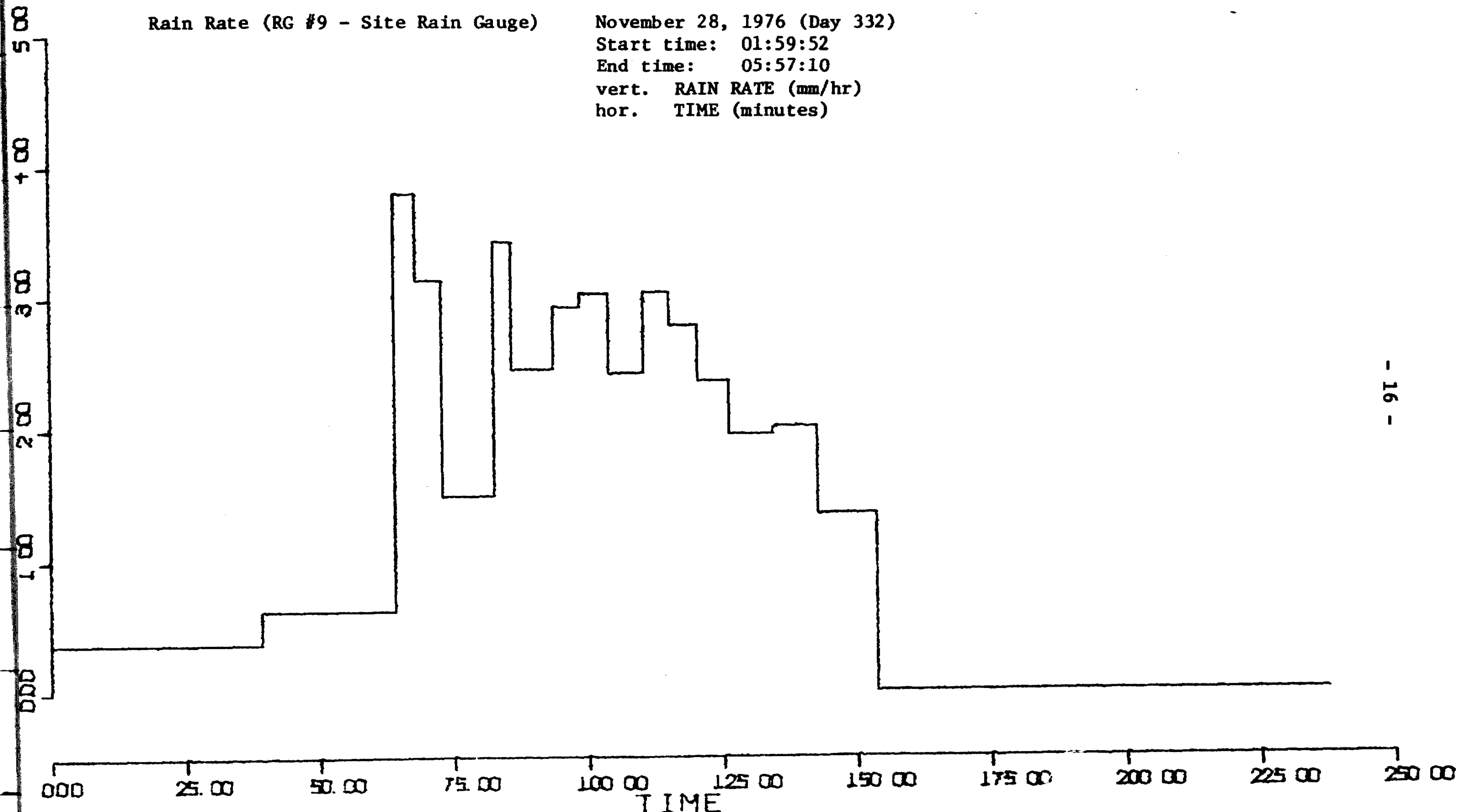


Figure 2.2-1 Rain rate versus time for the period in which detector outputs are compared.

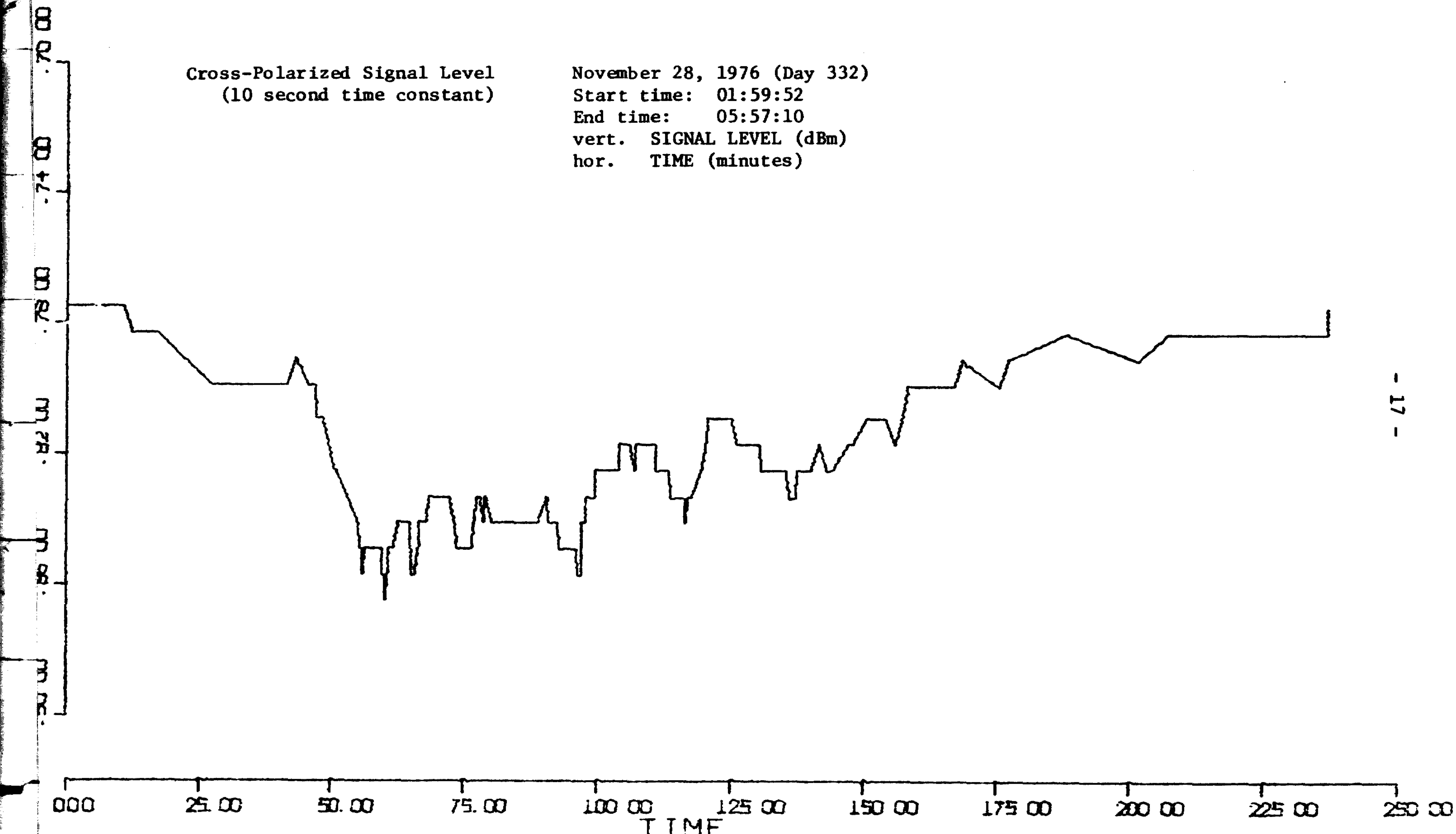


Figure 2.2-2 Cross-polarized signal behavior measured by the slow detector.

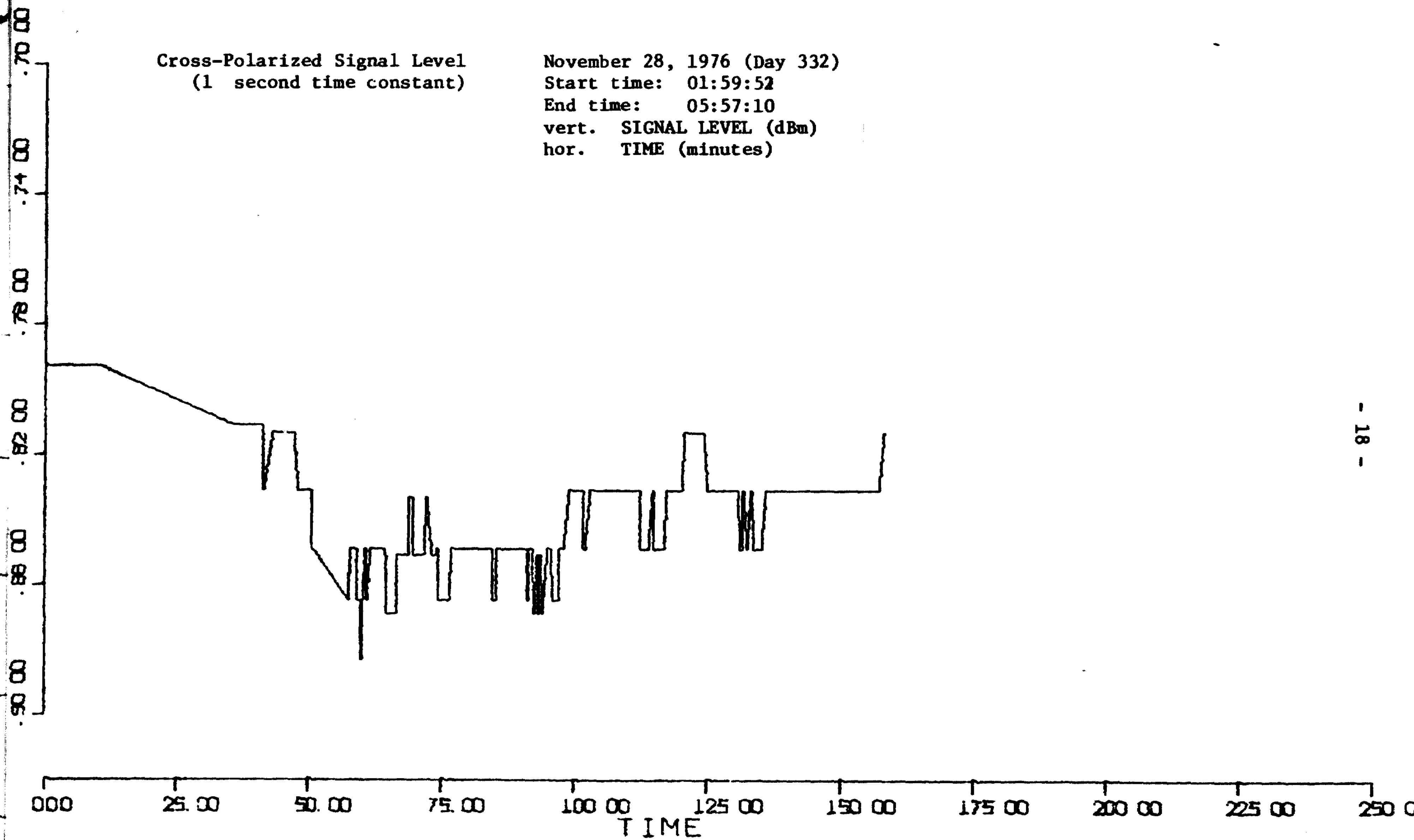


Figure 2.2-3 Cross-polarized signal behavior measured by the fast detector.

plots differ in their fine structure, no obvious "fast" or "slow" distinguishing characteristics seem to be present.

The issue is further blurred by our inadvertent use of different significance criteria in recording data from the two detectors. The fast detector output must change by a greater amount (about 3 dB) than the slow detector output (about 1 dB) before the computer stores a new data value. This eliminates small-scale scintillations from the fast-detector output and makes the responses of the two detectors look somewhat alike. In future work the same significance level (about 1 dB) will be used for both detectors.

3. Radar Observations

3.1 Introduction

A NASA-supplied Bendix RDR-110 15.5 GHz aviation weather radar has been added to our experimental system and used to monitor precipitation backscatter during this reporting period. The physical layout of the radar and the philosophy of its operation were described by the same authors on pages 30-36 of Quarterly Technical Progress Report I of the COMSTAR portion of this contract and will not be repeated here. This report concentrates on the technical details of the radar-computer interface which are important to data interpretation and presents the initial data from the radar system.

3.2 The Radar-Computer Interface

The radar computer interface transforms the video returns from the RDR-110 radar into a data base that represents the original video wave forms. The video wave form of a normal backscatter display are sketched in Figure 3.2-1.

The RDR-110 radar system trigger and the video signal are routed to the interface circuit through RG-122 coaxial cable. The system trigger initiates the firing of the RDR-110 magnetron; therefore, it is used to synchronize the gate pulse generator shown in Figure 3.2-2 with each burst of radar transmission.

The gate pulse generator generates the pulses that separate the backscatter return into 6 one-mile divisions. The system trigger voltage is attenuated at the input of the gate pulse generator by a voltage divider (resistors R_1 and R_2) so the incoming pulse will meet TTL level requirements. The falling edge of the modified system trigger pulse activates the first one-shot multivibrator with a Schmitt trigger (74121) and initiates a 2.47 μ sec delay pulse. The falling edge of the delay pulse activates the second one-shot multivibrator and this produces a 10.7 μ sec pulse. The falling edge of this pulse activates the next multivibrator and produces another 10.7 μ sec pulse and so on down the chain of multivibrators. Wave forms are shown in Figure 3.2-3. The level of the output pulses is set at 15 volts by the open-collector buffer gate (a 7407).

The video signal from the radar unit is attenuated at the input to the interface by a factor of four to give an appropriate level for the integrators that follow (See Figure 3.2-4). An operational amplifier (NE 531) acts as a buffer to prevent any loading effects on the radar. The NE 531 was chosen because its high slew rate insures adequate reproduction of the video wave form. Capacitor C_1 and resistor R1 form a DC blocking network to remove any DC component from the video signal. This is necessary because a DC component would produce an undesireable response

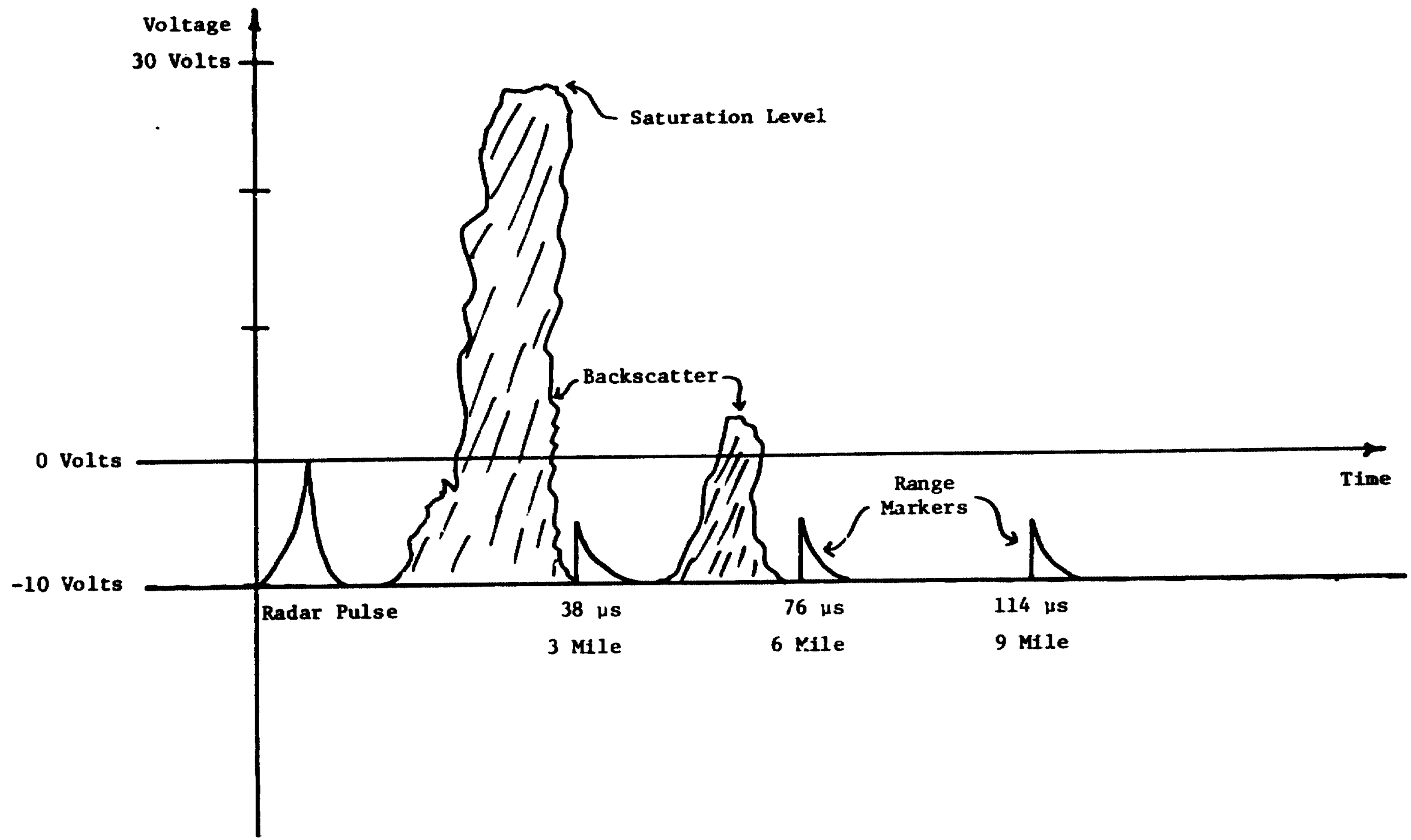


Figure 3.2-1 Typical video waveform for the RDR-110 radar output.

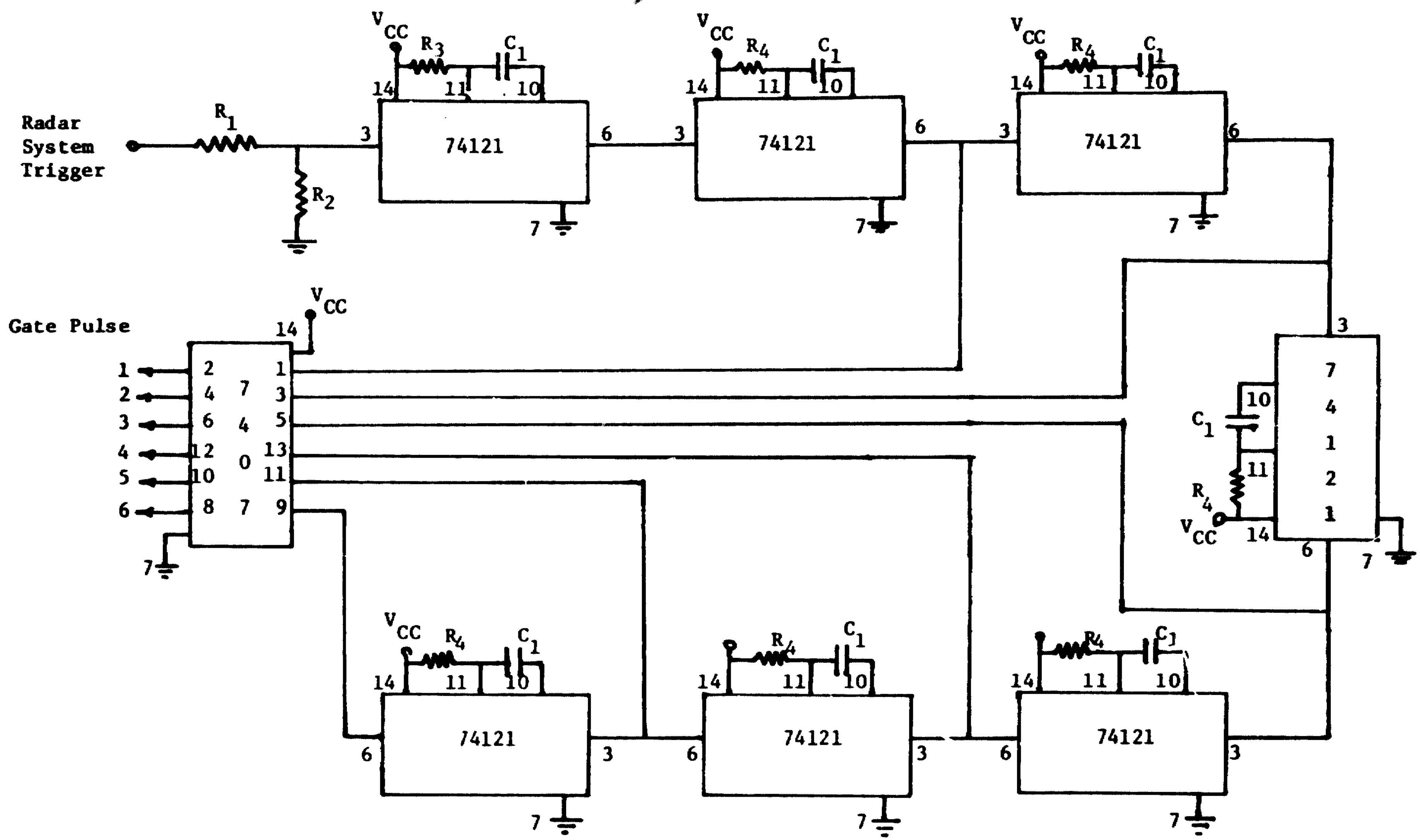


Figure 3.2-2 Gate pulse generator.

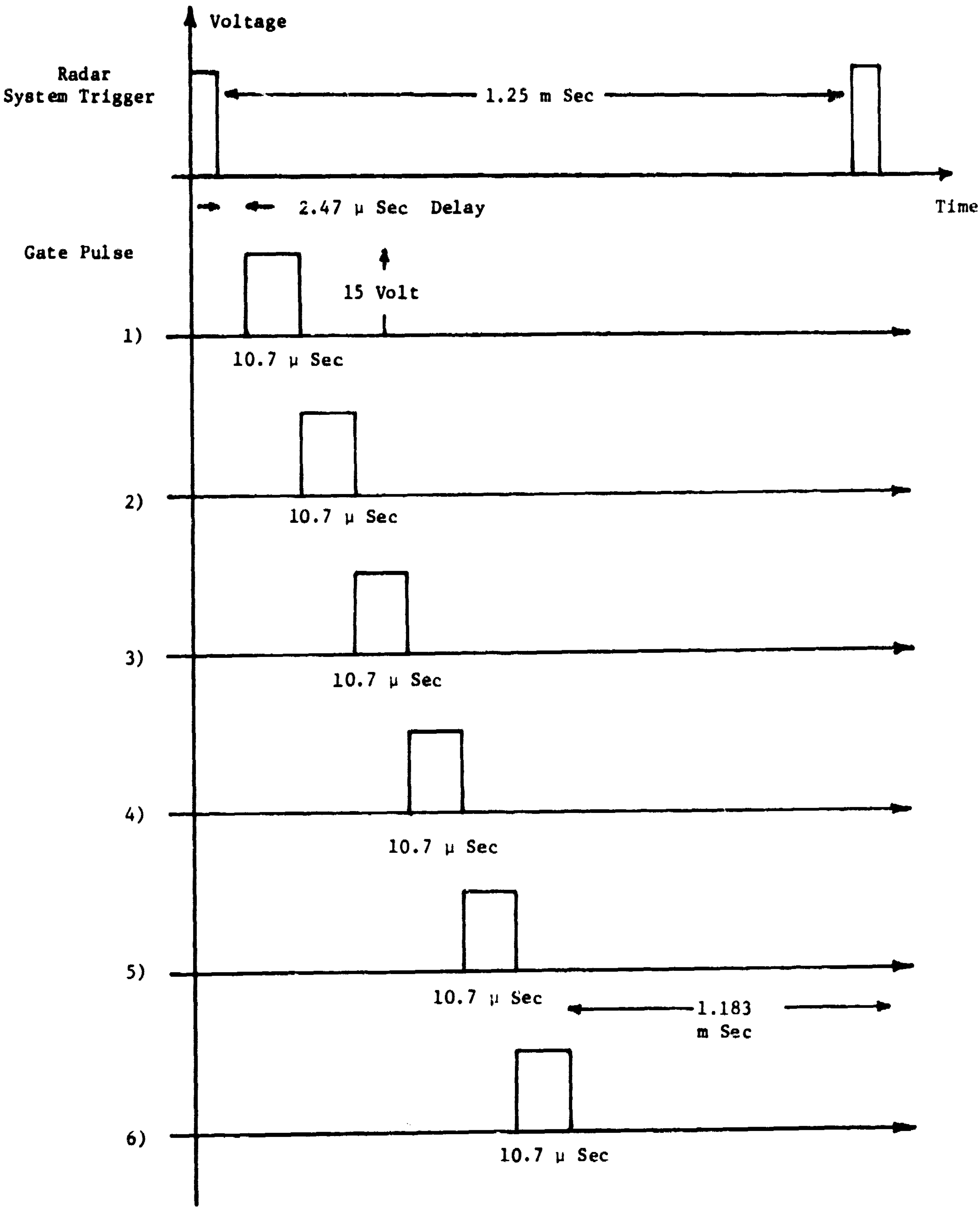


Figure 3.2-3 Waveforms that appear in the gate pulse generator.

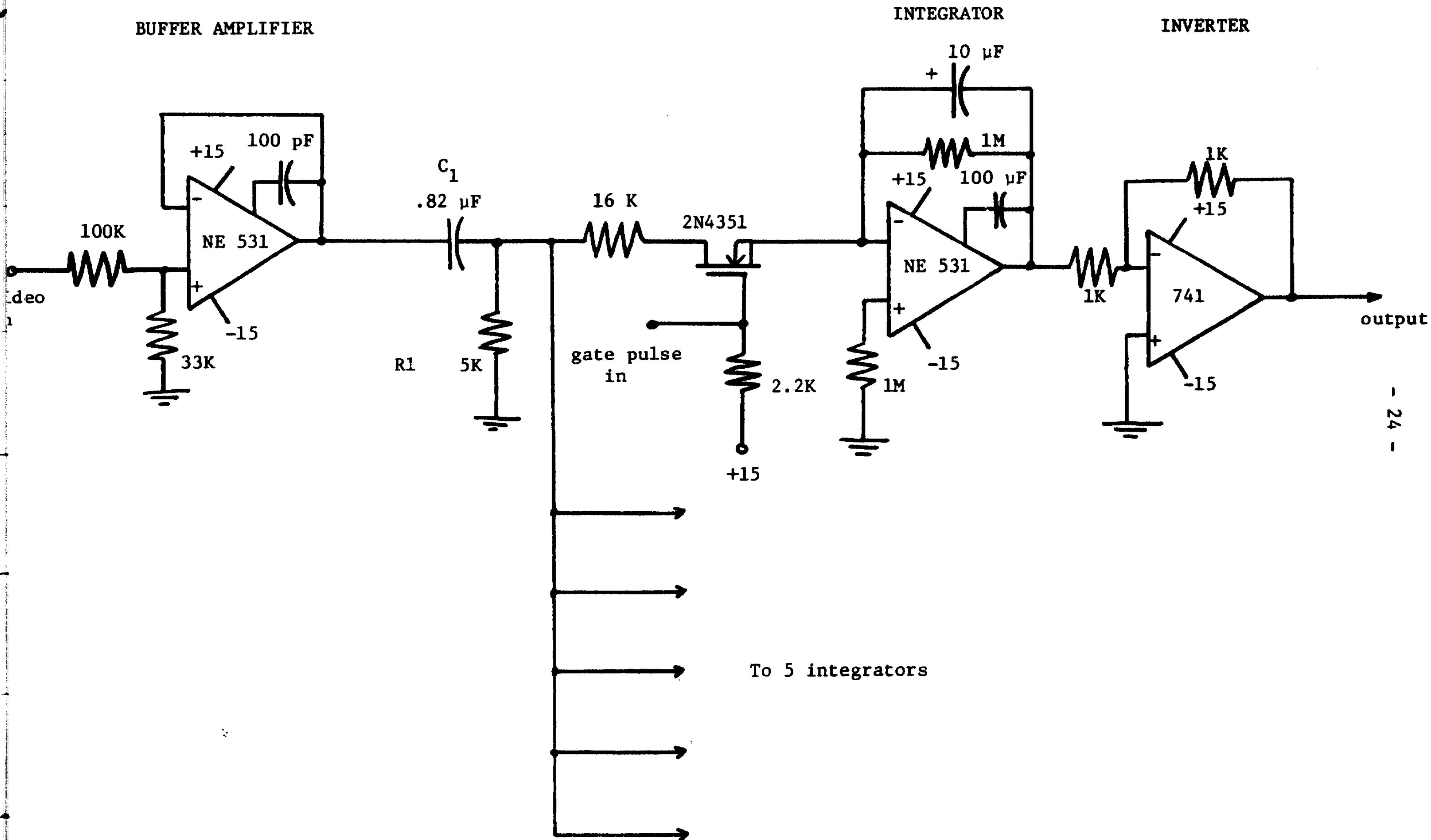


Figure 3.2-4 Schematic diagram of the radar interface.

at the output. The signal then passes to one of 6 integrators via an associated MOSFET transistor (2N4351) which acts as a switch.

Each MOSFET is controlled by the gate pulse generator. The first MOSFET is turned on during the first 10.7 μ sec pulse, and the second MOSFET during the second 10.7 μ sec pulse and so on. When a MOSFET is on the signal passes to the integrator and when it is off no signal is passed. Each integrator integrates the video signal during the appropriate 10.7 μ sec period and produces a 0 to -5 volt DC level at its output. The NE 531 was chosen again because of its high slew rate. The 10.7 μ sec integration period corresponds to integrating a one mile increment of backscatter. The RDR-110 radar has a blind zone which extends for about a quarter of a mile from the antenna. The 2.47 μ sec delay pulse begins the integration after the blind zone.

The time constant of each integrator is 10 seconds which tends to smooth out any rapid changes in the video waveform. Since the PDP-11 computer requires a positive input signal, a 741 operational amplifier with unity gain is used to invert the DC level giving a positive output for each integrator. The PDP-11 computer looks at each output every 4 seconds. If the output level has changed more than 0.25 volts since the previous recorded value, the computer stores this value and its corresponding time as a data point for later analysis.

3.3 Radar Data

The rainfall rates during the report period were not large enough to generate any meaningful information on the relationships between radar backscatter and attenuation and isolation. But to indicate the general performance of the radar system in this section we present some radar, rain rate, and attenuation data for a 24-hour period covering December 8, 1976.

Figures 3.3-1 through 3.3-3 show integrated radar video output as a function of time. Each of the three plots shows video level integrated over the 0 to 1 mile range, 1 to 2 mile range, and 2 to 3 mile range. Note that the zero mile reference point is 1/4 mile from the radar antenna. Shown in Figures 3.3-4 through 3.3-6 are rain rates measured by three tipping bucket rain gauges located 0, 0.11, and .35 miles from the radar. The horizontal axis covers the identical time period as the radar plots. Correspondence between rain rate and radar backscatter is evident. Note the period between 14 and 42 on the time axis and especially note the agreement between rain rate and backscatter at time 56.

These are the first data received from the radar system. The data are significant as an indication that the system is working and collecting useable information. Voltage outputs of the integrators were somewhat high for the given rain rate, indicating that a reduction in system gain is necessary. More data of this type are needed in order to calibrate the system.

Figure 3.3-7 shows received copolarized signal level over the same 24 hour period. The time correspondence with radar backscatter is evident but the small fade in received signal level compared to the high amplitude of radar output also indicates a reduction in radar gain is required.

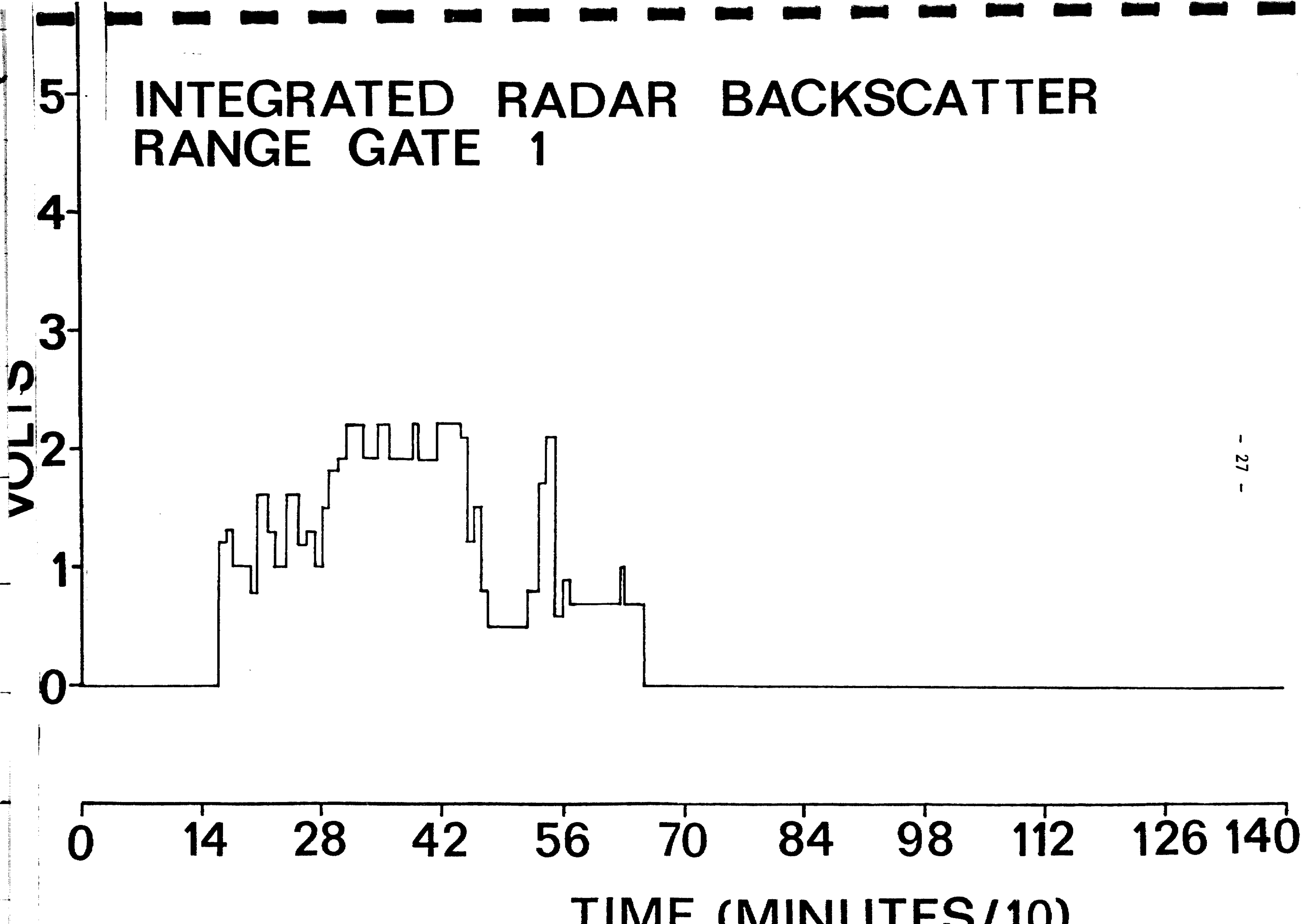


Figure 3.3.1. Radar backscatter from range gate 1

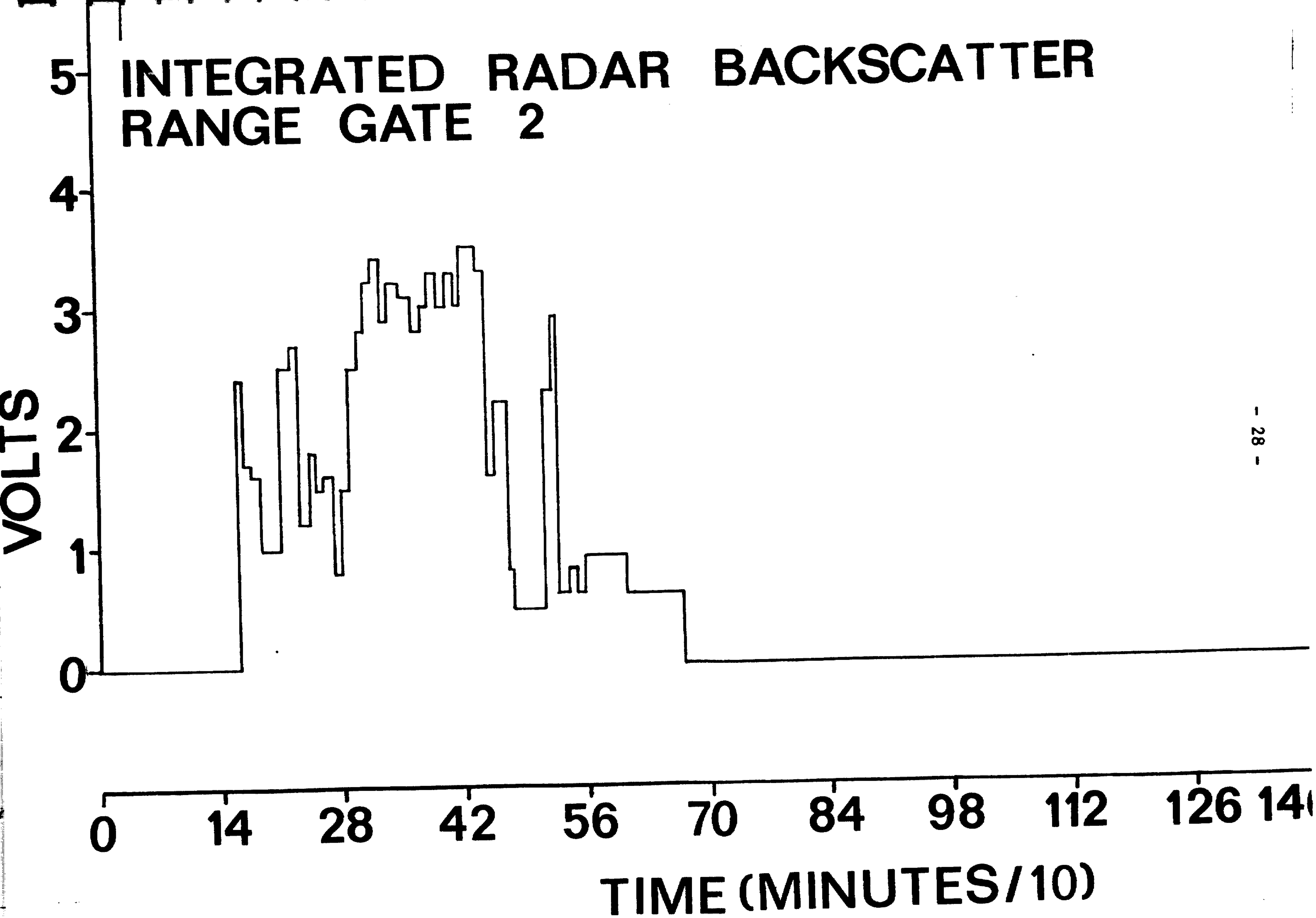


Figure 3.3-2 Radar backscatter from range gate 2.

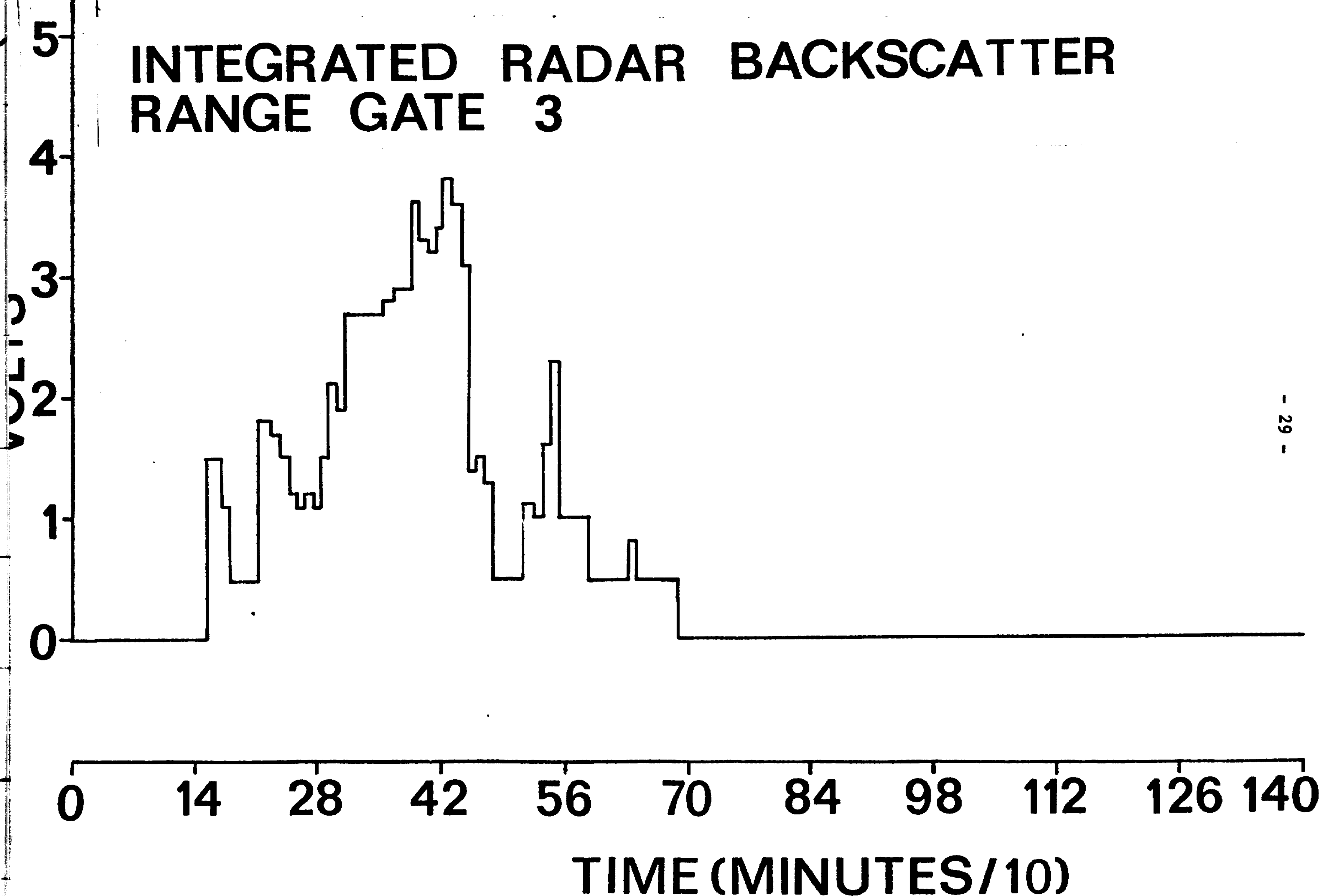


Figure 3.3-3 Radar backscatter from range gate 3.

Rain Rate (RG #9 - Site Rain Gauge)

December 8, 1976 (Day 341)
Start time: 01:05:07
End time: 01:02:42
vert. RAIN RATE (mm/hr)
hor. TIME (minutes/10)

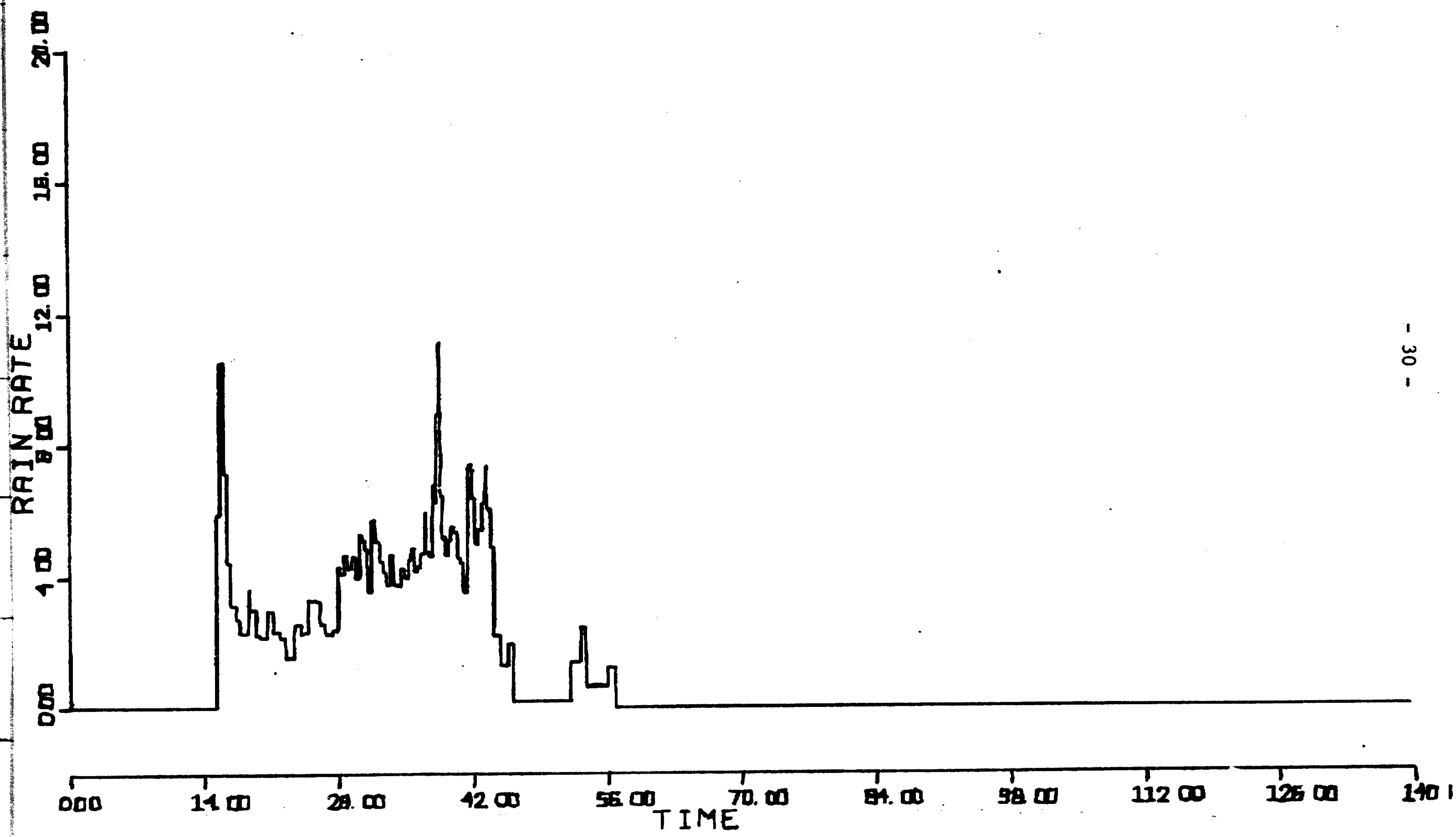


Figure 3.3-4 Rain rate at gauge 9 versus time for December 8, 1976.

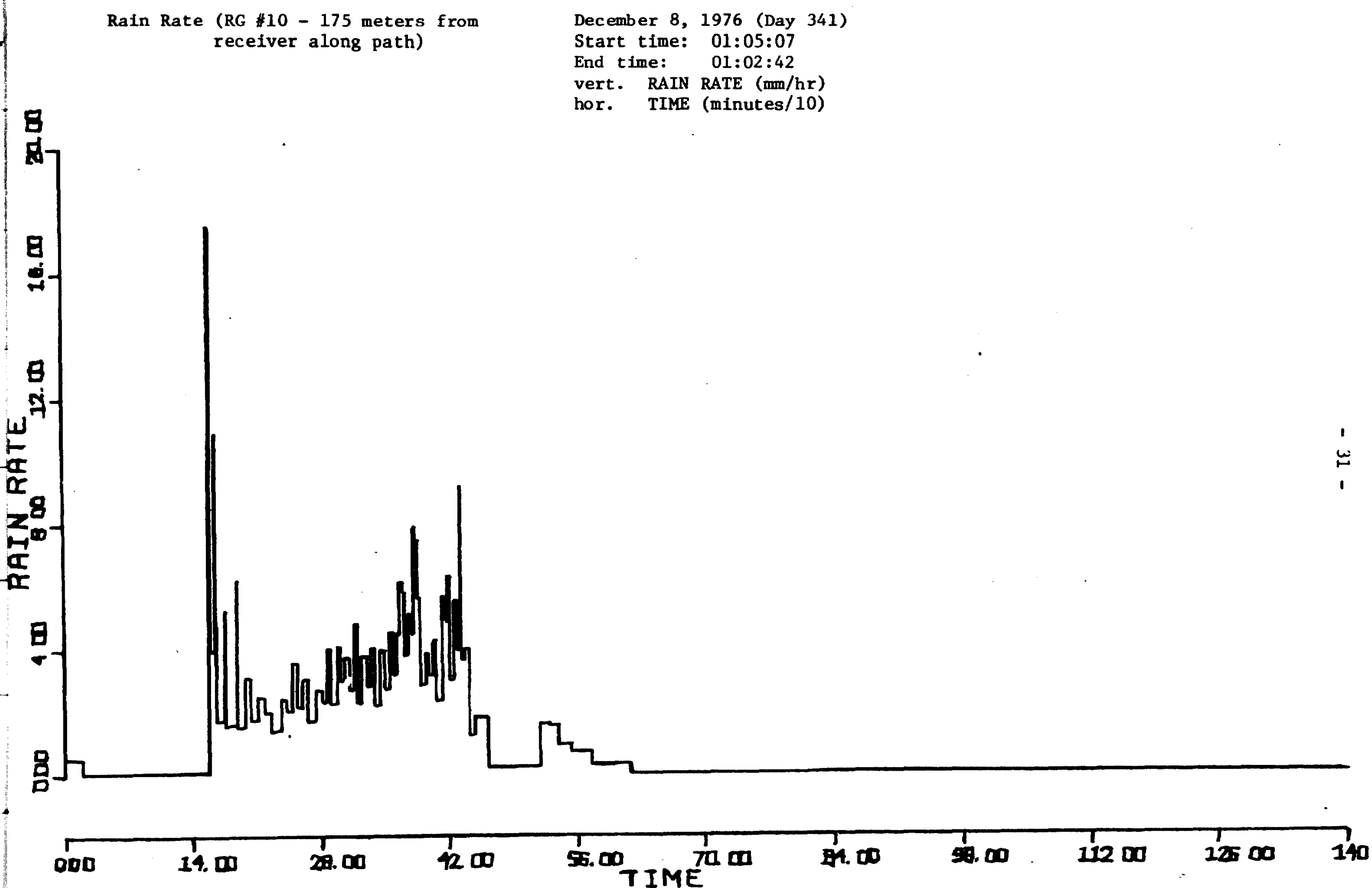


Figure 3.3-5 Rain rate at gauge 10 versus time for December 8, 1976.

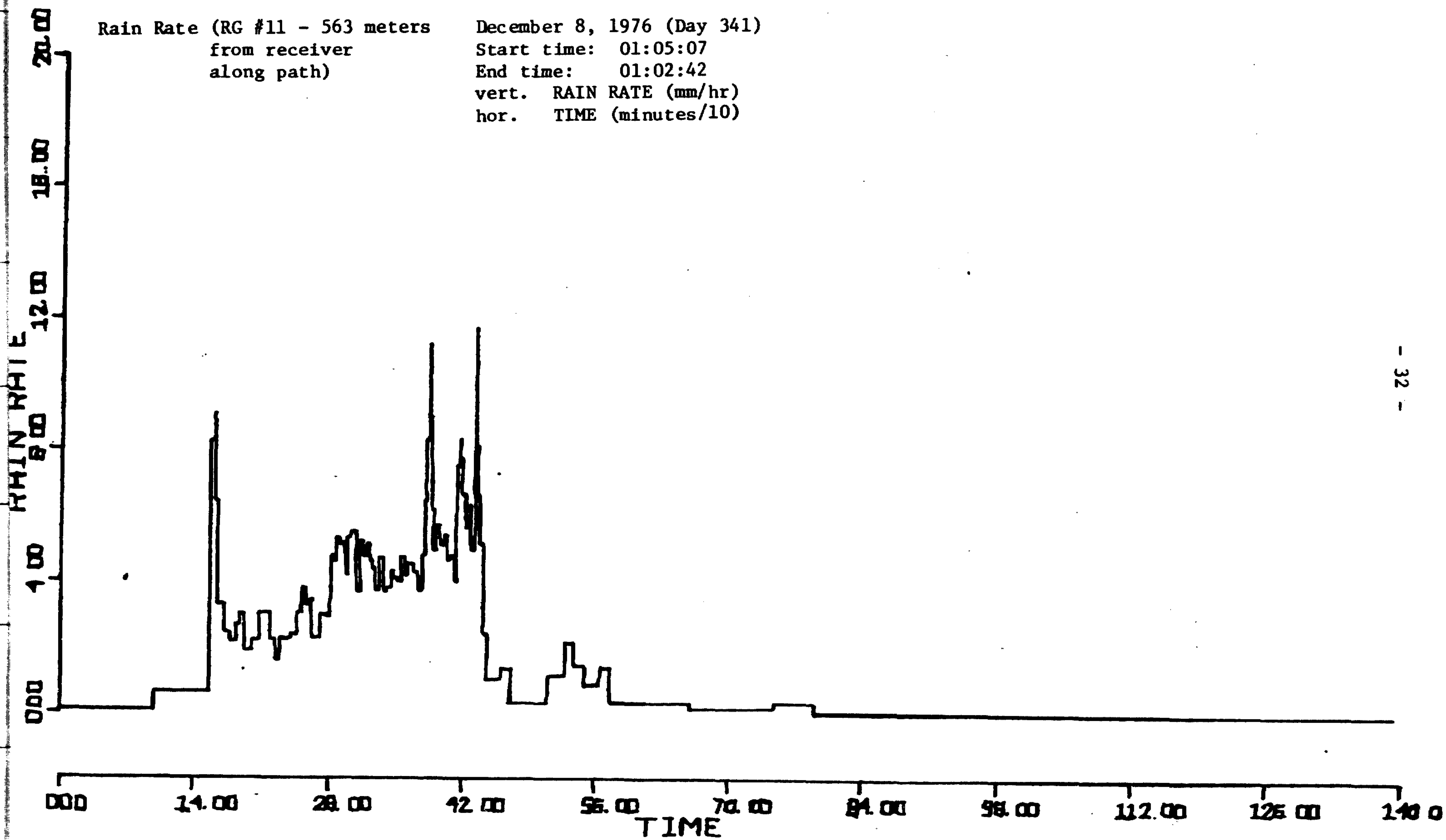


Figure 3.3-6 Rain rate at gauge 11 versus time for December 8, 1976.

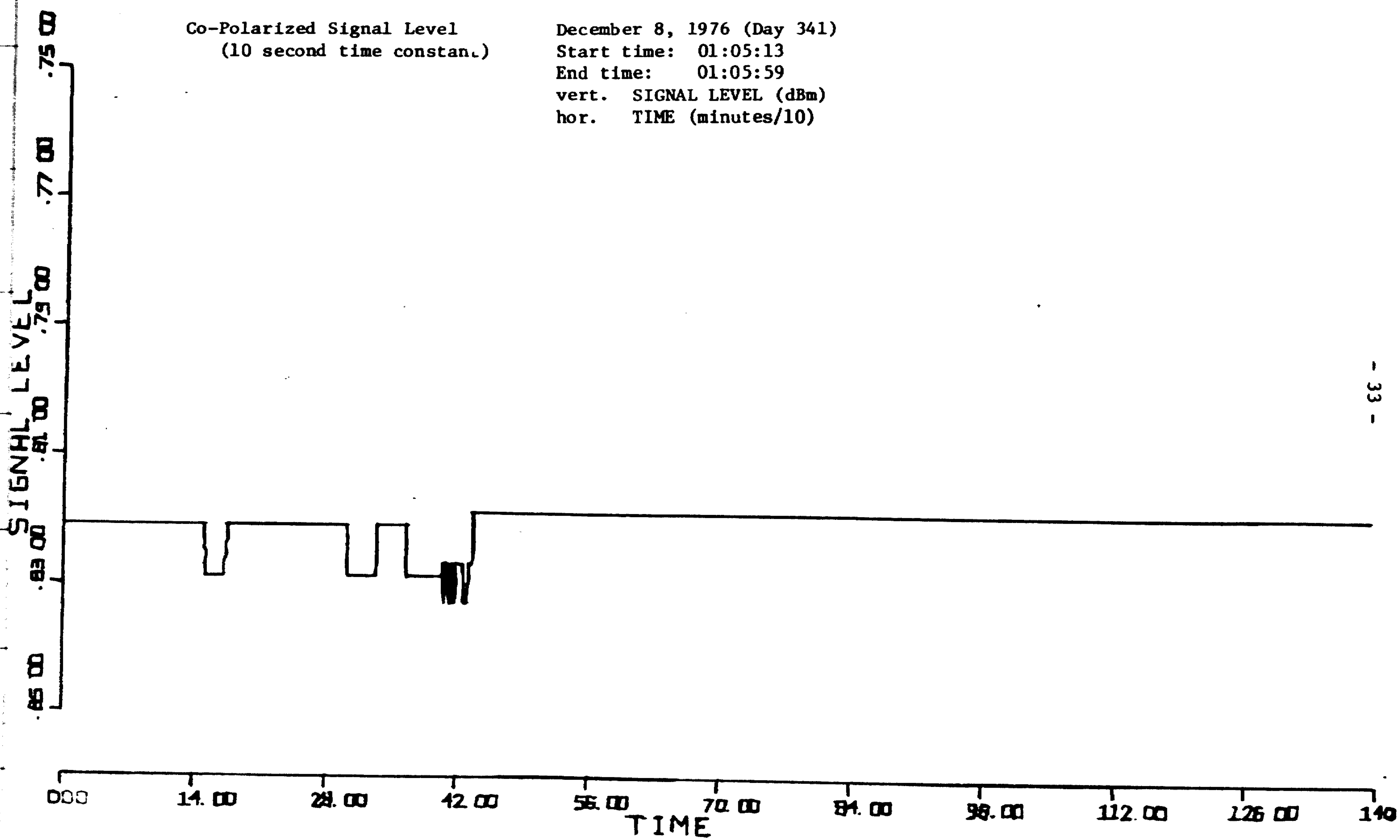


Figure 3.3-7 Co-polarized signal behavior on December 8, 1976.