404376

404 376

DATA TRANSMISSION INVESTIGATION
REPORT NO. 6

SECOND QUARTERLY PROGRESS REPORT

11 December 1962 to 10 March 1963

DA PROJECT NO. 3B31-07-001

CONTRACT NO. DA 36-039-SC-90728

(Continuation of Contract No. DA 36-039-SC-87343)

U.S. ARMY SIGNAL RESEARCH
AND DEVELOPMENT LABORATORY,
FORT MONMOUTH, NEW JERSEY

MOTOROLA INC.
Communications Division
4545 W. AUGUSTA BLVD. CHICAGO 51, ILL.

"QUALIFIED REQUESTORS MAY OBTAIN COPIES OF
THIS REPORT FROM ASTIA"

DATA TRANSMISSION INVESTIGATION
REPORT NO. 6

SECOND QUARTERLY PROGRESS REPORT
11 December 1962 to 10 March 1963

DA PROJECT NO. 3B31-07-001
CONTRACT NO. DA 36-039-SC-90728
(Continuation of Contract No. DA 36-039-SC-87343)

The objective of this program is to determine the characteristics and distribution of errors in digital data communications systems of the tactical army.

SIGNAL CORPS TECHNICAL REQUIREMENT

SCL-4276, Dated 13 October 1960
and
Amendment No. 1 dated 15 November 1961

Written by: R. F. Salava

R. F. Salava
Project Engineer

Approved by: William M. Borman

W. M. Borman
Ass 't Chief Engineer

MOTOROLA INC.
Communications Division

4545 W. AUGUSTA BLVD. CHICAGO 51, ILL.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

SECTION I

PURPOSE

The purpose of this project is to investigate the performance of data transmission terminals over tactical military communications systems. Testing of the data terminals and communications system will take place in the vicinity of Fort Monmouth, New Jersey.

A family of communications systems has been developed for the Army. These systems, designed primarily for voice communications, are to provide the circuits for digital data transmission. The limitations of these systems when functioning as digital data transmission links are to be determined.

Error statistics of the data transmission terminals obtained while operating over the communications systems mentioned above are to be evaluated and reported upon. Included in this study is an investigation of the transmission of digital data in the presence of random and impulse noise. The properties of impulse noise are to be studied with the result being the simulation of impulse noise in cable and radio communications systems.

SECTION II

ABSTRACT

The characteristics of the AN/VRC-12 are discussed and the field test system for digital data transmission using the AN/VRC-12 is presented. Seven fixed transmission sites were used for transmission points to the laboratory where the analysis of the data was conducted. Map profiles of these sites are given and the audio S/N and digital error rates measured over these transmission paths are presented. Error rates varied from 5×10^{-6} to 1×10^{-3} depending upon the site and conditions.

A table of average error rates shows that the error rate of a particular modem is almost independent of bit rate. Further analysis of the results show that single-bit errors, account for about 90% of the characters-in-error in the AN/TYC-1 and Di-phase modems for transmission at 600 bps or less and in these cases error correction codes would be very effective. The cause of the errors is found to be impulse noise and photographs of the noise plus the signal is presented for discussion.

The new digital data test system is discussed with the aid of a system block diagram. Both a printed record and a punched tape record of the error characteristics is provided.

SECTION III

CONFERENCES

On February 21, 1963 a meeting was held between USAERDL and MOTOROLA personnel. The USAERDL representatives were J. Futerfas and J. Duffy; the MOTOROLA representatives were J. Tsimbidis, R. Salava and N. Thomas. The project status and future work were discussed and it was decided that the AN/VRC-12 tests would take up the major portion of the test program for the next few months. The transition of personnel with N. Thomas replacing R. Salava at Ft. Monmouth was discussed and it was agreed by both parties that R. Salava would assume the project engineer's responsibility.

SECTION IV

FACTUAL DATA

4.1 AN/VRC-12 TESTS

Field testing the modems over the AN/VRC-12 radio set required a major portion of the reporting period. In the following paragraphs the characteristics of the radio set and the field test setup are discussed and results of the field tests are presented. The equipments tested over this system were the FSK (AN/TYC-1), Di-phase and Quad-phase modems.

4.1.1 CHARACTERISTICS OF THE AN/VRC-12

Amplitude and delay characteristics of the AN/VRC-12 were given in the third Quarterly Report but these curves were obtained operating into the mike input of the transmitter and using the speaker terminals for the 600 ohm load. It was decided at a later date (see Quarterly Report No. 5) that the X-MODE input/output of the radio set would be utilized since the impedance and power levels (600 ohms, 0-dbm) were compatible with the present modems.

The amplitude and delay curves of a production model of the AN/VRC-12 are shown in Figures 1 and 2. It is noted that the bandwidth of the amplitude curve extends to approximately 17 kc. The lower cut-off frequency, not shown in Figure 1, is at approximately 50 cps. The frequency band of interest in this study program is from 300 to 3200 cps since all the modems are designed to operate in this band. Over this frequency band, the attenuation varies less than 1/2 db and the delay differential is only 0.2 millisecond. These characteristics do not present any problem to data transmission using the modems presently under consideration.

The audio S/N characteristics of the AN/VRC-12 were measured using the test setup shown in Figure 3 and the results for two different carrier frequencies are shown in Figures 4 and 5. These measurements were made at the audio output of the receiver which has a 3 kc bandwidth. It is noted that the threshold of the receiver is approximately at 1 microvolt of carrier signal. There is little difference in the S/N characteristics for the two carrier frequencies shown. The noise plus distortion curve is a measurement of all frequencies in the receiver output except the 1 kc modulating frequency.

The noise density of the X-MODE (wideband) output was measured and found to vary linearly with frequency. Figure 6 shows this characteristic for a typical FM receiver. This characteristic is typical for FM receivers when the carrier-to-noise ratio is large. This noise characteristic affects only the Di-phase modem because this particular modem does not have a bandpass filter in the input circuits of the receiver. Since the operating band is approximately 300 to 3200 cps all the modems are operating in the low noise density area of the wideband output. A typical measured difference in the noise level between the wideband (17 kc) and a filtered output (300-3200) is 20 db. This increase in noise density with frequency should be considered when using the radio set for wideband data transmission since the higher frequency components of the data will be deteriorated by more noise than the components in the lower portion of the band.

The recommended input level for X-MODE operation is 0-dbm for voice operation. The input level into the radio set was varied to determine if an optimum level for data transmission existed. Levels from -10 to +5 dbm were tested on all the modems with the higher data levels resulting in better performance. Saturation of the digital waveform occurs at approximately +3 dbm and higher levels result only in distortion of the signal. The significant improvement in the error rate for the higher input levels is mostly due to the greater frequency deviation of the transmitted FM signal thus resulting in better detection by the receiver. Also the audio S/N is slightly improved due to the higher signal level. A level of 0-dbm into the X-MODE connector of the AN/VRC-12 is satisfactory for all the modems, hence it is recommended that if any standard is set up for operation over the AN/VRC-12 this level should be utilized. In special cases it may be desirable to have the operator vary the input level to determine the level resulting in the lowest error rate.

A block diagram of the test setup used in conducting the field test is shown in Figure 7. The mobile portion of the system consists of the digital data generator (described in Quarterly Report 5), the three modems being tested, the AN/VRC-12 transmitter and a 10 ft. center-fed whip antenna, all housed in a 3/4-ton vehicle. The height of the receiving antenna above sea level is about 100 ft. Admittedly this is not a typical radio link but the location of the laboratory equipment for analysis of the data did not lend itself to a more representative link. The transmission sites were chosen to reduce the effect of the high receiving antenna.

The output of the receiver is fed to the modem through an isolation transformer and a section of spiral four cable. The recovered digital data is fed from the modem into the correlator where each bit in error is detected and recorded in the logging equipment. The link from the receiver on the roof of the building to the modem in the laboratory was carefully checked to insure that no deterioration of the signal would occur. Both amplitude and delay curves were taken and no appreciable distortion was measured. Also the noise introduced between the roof and laboratory is less than -50 dbm.

The error rate figures presented in this report were obtained with the modems operating while the engine of the vehicle was running. It was necessary for the engine to be operating in order to provide the necessary power to operate the equipments. Abbreviated tests were conducted using external power sources to observe the effect of ignition noise and the DC-AC converter noise. In both cases the noise contributed was small and little improvement in error rates were observed. The Di-phase modem was the most susceptible to this noise and the bit error rate was reduced by a factor of one half with the use of external power.

4.1.2 TRANSMISSION SITES

A number of locations used as transmitting sites were tested and data was gathered from seven fixed locations. Ground profile maps for each site were constructed in order to evaluate the results properly. The sites vary from line-of-sight to fairly rough terrain transmission paths. Figures 8 and 9 show the map profiles of the seven sites with the ground elevation as the ordinate and the distance (statute miles) scaled on the abscissa. The "dashed" line connects the transmitting and receiving antennas on a line-of-sight basis. Note that the receiving station is always at the left of the graph and the antenna is actually about 80 ft. above the ground level.

Site numbers 1, 2 and 4 are observed to be line-of-sight transmission paths although it must be noted that at site number 4 a heavily wooded area is located within a few hundred yards of the transmitting antenna which probably caused considerable attenuation of the signal. Sites 5 and 6 presented the most severe conditions in the tests conducted to this date. Difficulty was encountered in maintaining synchronism between the modems in tests conducted over these two sites.

4.1.3 FIELD TEST RESULTS

The field test results are presented in four different forms. First, the average S/N readings are shown for the various sites. Secondly, the error rate data for a sample of the tests conducted is plotted as a function of distance. The third form is a table of average error rates and the last form is a tabulation and discussion of the distribution of errors from the multiple error standpoint.

Signal-to-noise ratio is observed to be the guiding factor in data transmission over the AN/VRC-12. For each test the S/N ratio was measured just previous to the start of the test and then again immediately after the test. Each test was conducted for approximately 200 seconds thus the signal-to-noise ratio reading was a good approximation of that encountered during the test.

Figure 10 is a plot of the variation in S/N ratio vs. distance for each of the individual tests. Each dot is a S/N reading for a particular test. Six "dot groups" are labeled with a site number which corresponds to the sites shown in Figures 8 and 9.

An interesting point is revealed in Figure 10 when the variation in S/N is observed for each particular test site. Individual test measurements taken at site numbers 1, 2 and 4 show a substantial variation in S/N ratio compared to the remaining sites. This result shows a direct relationship to the map profiles, noting that sites 1, 2 and 4 are line-of-sight transmission links. A line-of-sight path seems to be more readily affected by atmospheric conditions such as snow and rain while the "shadow" effect of hills tend to be the governing factor for obstructed transmission paths. Also noted in Figure 10 is the gradual decrease in S/N ratio as a function of distance.

From this result it would be expected that the error rate will increase as a function of distance and Figures 11 and 12 show that this is true. Both figures give the results for a modem at a particular bit rate. The results show that while the average S/N ratio is sufficient for error-free operation, the error rate is still fairly high. The results obtained with the other modems are essentially the same. All of the errors encountered are believed to be caused by impulse noise. Paragraph 4. 1. 4 discusses this problem to a further extent.

The average bit error rates for the tests conducted over the AN/VRC-12 are shown in Figure 13 where the error rates are tabulated as a function of the modem, bit rate and transmission path. The average error rates are observed to increase from about 5×10^{-6} to 1×10^{-3} but it is also noted that the bit rate has little effect upon the error rate.

The results obtained from site number two are the best for comparison between modems and bit rates since the greatest number of tests were conducted from this point. From this site the bit error rate is seen to be about 4×10^{-5} for most of the modems at their various bit rates. The reason for this non-dependence upon bit rate is that the errors are being caused by large impulses that affect the transmission regardless of the bit rate. It would be expected that each impulse would cause a greater number of bits in error for faster bit rates since the impulse would extend over a greater number of bits. But it is also true for higher bit rates that a greater number of error-free bits are transmitted between impulses thus balancing the effect of the multiple errors.

A slight improvement is noted with the Quad-phase modem over the Di-phase modem where the inverse would normally be expected. Three reasons may account for this result. First the Di-phase modem does not have a bandpass filter in the receiver input circuits thus permitting the wideband noise of the AN/VRC-12 to enter the modem. This will affect the carrier and clock recovery and possibly the demodulator. The Quad-phase modem does have bandpass filter in the receiver; one for the 600, 1200 and 2400 bps bit rates and a second filter for the 4800 bps bit rate. An external filter (3 kc bandpass) was inserted between the AN/VRC-12 receiver and the Di-phase modem and a significant improvement was noted. Sufficient data was not obtained using this filter to obtain exact bit error rate figures. Further tests will be conducted with this modem operating with the filter and the bit error rate improvement will be shown in the next report.

A second reason for the slightly better performance of the Quad-phase modem lies in the clock system which incorporates a highly stabilized clock while the Di-phase modem more easily loses synchronization under marginal conditions. The previously discussed (paragraph 4. 1. 1) susceptibility of the Di-phase modem to external noise is the third noted difference between the two modems. It is believed that the combined aforementioned problems with the present Di-phase modem account for a degradation in error rate by approximately a factor of 10.

The error distribution was studied with the results tabulated in Figure 14. This study was made on the basis of an 8 bit character and each character with more than one bit in error was recorded as a multiple error. Shown in Figure 14 is the percent of characters in error that had more than one bit in error.

As previously discussed, the results show that as the bit rate is increased, the number of multiple errors also increases. Even with the limited data gathered at this time the results show this definite trend in all three of the modems tested. Also noted is the much larger percent of multiple errors encountered using the Quad-phase modem which is partly due to the transmission of data in "bit-pairs". The Quad-phase modem utilizes the differential phase modulation technique which will also contribute to multiple errors.

Studying the results shown in Figures 13 and 14 yields a possible application of error detection and/or correction. This results from the fact that the bit error rate is almost independent of the bit rate and also that the greater percentage of errors are single bit errors. Single bit parity check would be fairly effective for error detection and this is especially true for the 300 and 600 bps rates in the AN/TYC-1 and Di-phase modems. The Hamming (8. 4) code may be used in which 4 check bits are added to every 4 data bits thus reducing the effective information rate in half. This code is capable of single-error-correction and double-error-detection. At a bit rate of 600 bps approximately 90 percent of the errors would be corrected when using the AN/TYC-1 and Di-phase modems for data transmission. This would reduce the error rate by almost a factor of 10, plus also detecting all the double-bit errors. The actual information rate would be one-half the 600 bps transmission rate but since the error rate is independent of bit rate a substantial improvement in transmission would be realized.

Previously mentioned was the fact that the errors are probably caused by impulse noise. Photographs of the data signal from the AN/VRC-12 receiver were taken at the time an impulse occurred, during the actual transmission of data over the system. Figure 15 shows photographs of three different impulses occurring on the data signals of the three modems under test. Most of the noise is observed to be high frequency impulses and thus has little effect upon the modem if it is filtered. The low frequency noise is more difficult to observe since it looks very much like data. Some low frequency noise is present in the photographs in Figure 15 and did cause errors in transmission. Photographs will be taken with a 3 kc filter inserted and the effect of the low frequency noise will be easier to determine.

4.2 NEW DATA LOGGING SYSTEM

The new data logging system was completed during the last quarter. With the new system the bit errors from the data correlator (see the 5th quarterly report for details) are transferred into the logging system for analysis. The logging circuits count the bits-in-error, characters-in-error, bit-errors in the first character-in-error, multiple errors, drop outs, hits and the time at which these conditions occur. Figure 16 illustrates the system in block diagram form. The above analysis is made on a one second basis and the information is then transferred to the buffer for storage. Information is recorded by both a printer and a paper tape punch.

Figure 17 shows the information recorded by the printer which prints the 12 characters simultaneously. In Figure 18, the punched information is shown plus the paper tape code. Figure 18-B shows the code for numbers 0-9 plus the end of message character which follows the 19 data characters. Note that a parity bit is recorded to provide a check for each character by the computer. The paper tape information for each test will be transferred to cards with each 19 data characters appearing on a separate card. Additional information will be added to each card such as modem, test, bit rate, date, S/N, etc. This recording scheme will facilitate sorting of tests by modem, bit rate or any combination of items. It will enable the computation of statistics for any particular test or condition with the minimum of effort.

4.3 AN/TRC-24 FIELD TESTS

The modem field tests over the AN/TRC-24 radio system will be continued in the near future over the new radio link set up during this quarter. This link is approximately 7 miles long and has the ability to vary the transmitter power from 15 to 70 watts to simulate a link of greater distance. It is hoped that over this link error patterns will occur that can be analyzed statistically.

SECTION V

CONCLUSIONS

Digital data transmission at bit rates from 300 to 2400 bps over the AN/VRC-12 radio set was found to be feasible although limited in many cases. It was determined that a satisfactory voice link does not imply that data transmission over the same link will be possible. Impulse noise is a major obstacle to data transmission, while in voice transmission this is not a major problem since its duration is usually short compared to a word.

Error rates were found to be essentially independent of bit rate which points to impulse noise as being the cause of the errors. Although more errors result for each impulse at the higher bit rates, there are also more error-free bits transmitted between impulses. Also the study of multiple errors substantiates that the errors are probably caused by impulse noise. Based on the aforementioned results, error detection and/or error correction could be effective. Even if the transmission rate is double the information rate, the basic effective error rate will be reduced using single error correction codes. Higher accuracy in data transmission may be obtained using more powerful codes and if possible, error detection and re-transmission would also be a very effective means of reducing the error rate.

The new automated data recording system which is in use at the present time, will allow a much more complete analysis of the data being gathered. Up to this time it has been quite tedious to make even the simple error rate calculations for the large amount of data being gathered. Using the new system, the effectiveness of certain coding schemes will be studied and statistics such as the probability of error in messages of various lengths will be determined. Using the computer to calculate statistics that were previously almost impossible to obtain, will greatly increase the effectiveness of the program.

SECTION VI

PROGRAM FOR NEXT INTERVAL

Continuation of the AN/VRC-12 field tests will take place during the next quarter. Additional sites will be chosen for various distances and terrain features. Mobile field tests over the AN/VRC-12 will be conducted and the effect of fading will be noted.

The data reduction phase of the program will be initiated with the paper tape records being converted to cards. Programs for the computer will be written for performing statistical analysis of the data. The programs will be checked out using the data presently being gathered and at the end of the quarter, all the data for that period will be analyzed and reported upon.

SECTION VII

IDENTIFICATION OF KEY PERSONNEL

Dr. J. Cohn	Chief Engineer
W. Borman	Assistant Chief Engineer
R. Salava	Project Engineer
N. Thomas	Field Engineer

Summary of Man-Hours

	11 Dec. 1962 to 10 March 1963	Total to Date
J. Tsimbidis	131	242
R. Salava	389	861
N. Thomas	276	276

NEIL E. THOMAS
Senior Field Representative

EXPERIENCE . . .

1962 to present: Motorola, Inc. Field Engineering

Field Engineer, assigned to the Digital Electronics Section of the Applied Research Department.

1960 to 1962: General Dynamics Electronics

Field service engineer I, base manager for retrofit modifications, final checkout, and final sell-off of the High Frequency/Single Sideband (HF/SSB) and Ultra High Frequency radio equipment at Lowry Air Force Base, Colorado. Duties included maintenance and repair of SAC owned General Dynamics/Electronics equipment in order to demonstrate associated OD/E 1,000 watt PEP linear amplifier. (1962)

Field service engineer I, base manager for installation and checkout of interim configuration of HF/SSB and UHF radio equipment at F. E. Warren Air Force Base, Cheyenne, Wyoming. (1961 to 1962)

Electrical engineer II, lead liaison engineer for AN/GLR-1 Integration Check Out Area. Served as representative for Electrical Engineering Department (EED) in Reconnaissance Systems Department (RSD) area. (1960 to 1961)

1954 to 1960: Eastman Kodak Company

Test equipment engineer, Electronic Test Equipment Department. Work on integration and checkout of final test console for Air Force Project WS-117L. This was a visual reconnaissance satellite, employing electrical, mechanical and chemical systems. Designed and supervised fabrication of several individual control drawers and telemetering devices in test console. Designed and supervised fabrication and installation of all console cabling, internal and external.

1953: Rensselaer Polytechnic Institute

Computer technician, operated, maintained, and assisted in setup of Reeves Electronic Analog Computer to solve complex differential equations for aircraft and geology companies.

EDUCATION . . .

B. E. E., Renssalaer Polytechnic Institute, 1952

B. S. Mathematics and Physics, University of Rochester, 1959

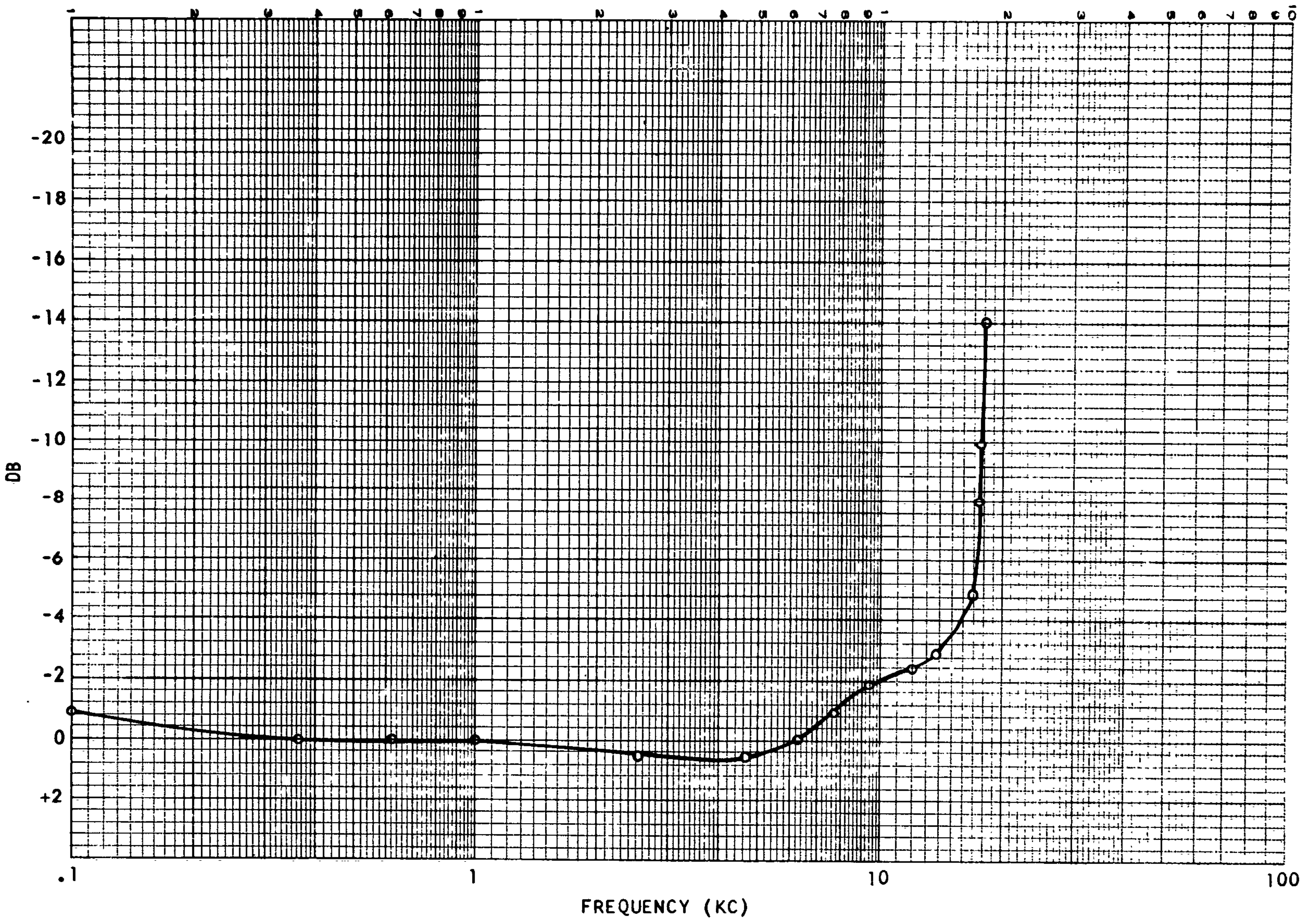


Figure 1. Amplitude Characteristics of the AN/VRC-12

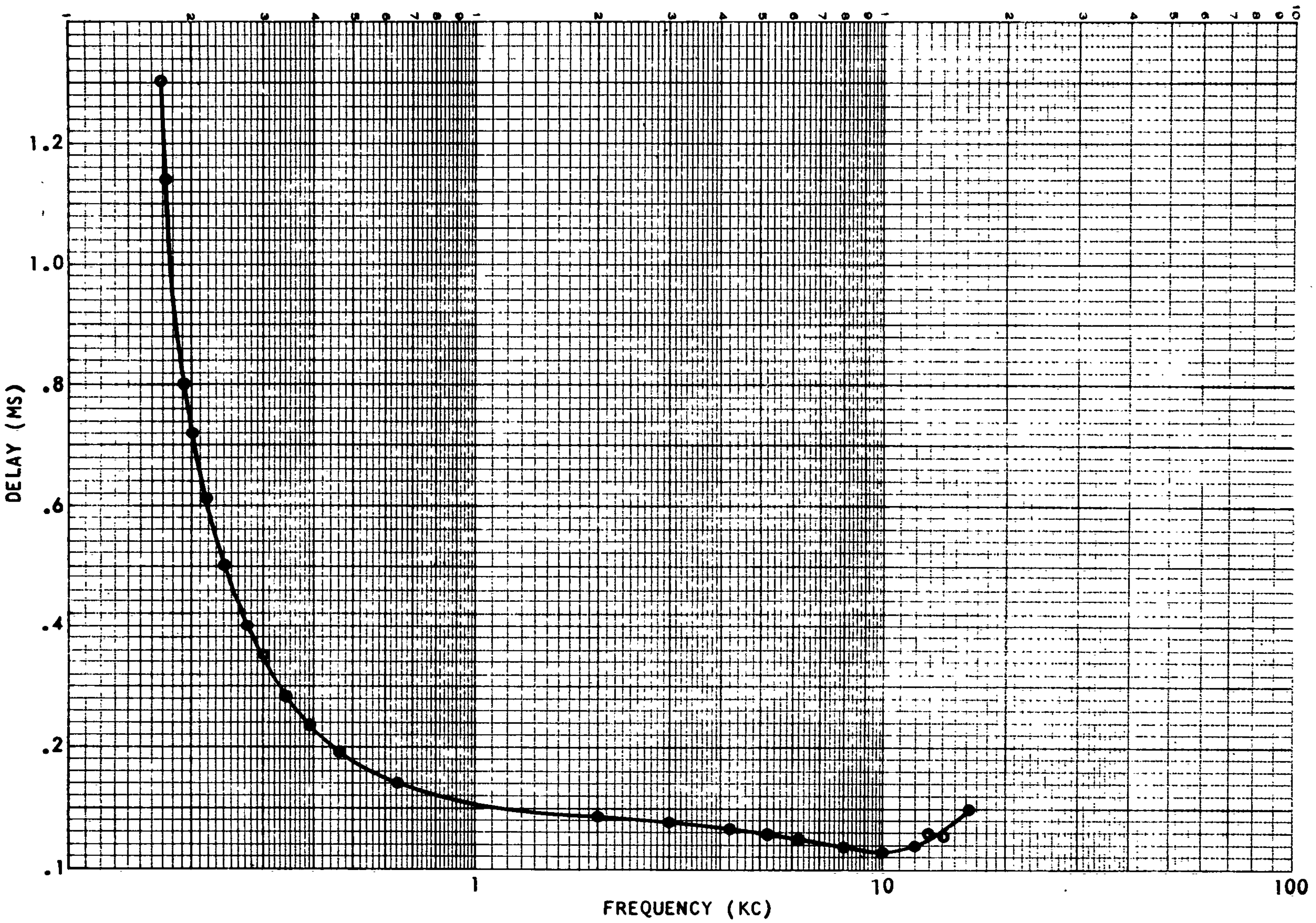


Figure 2. Delay Characteristics of the AN/VRC-12

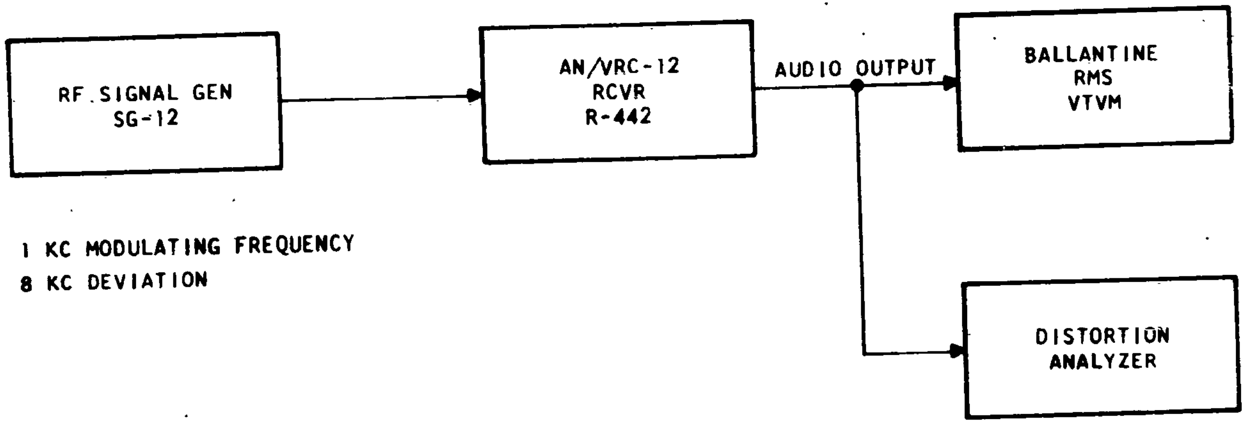


Figure 3. Test Setup for AN/VRC-12 S/ Measurements

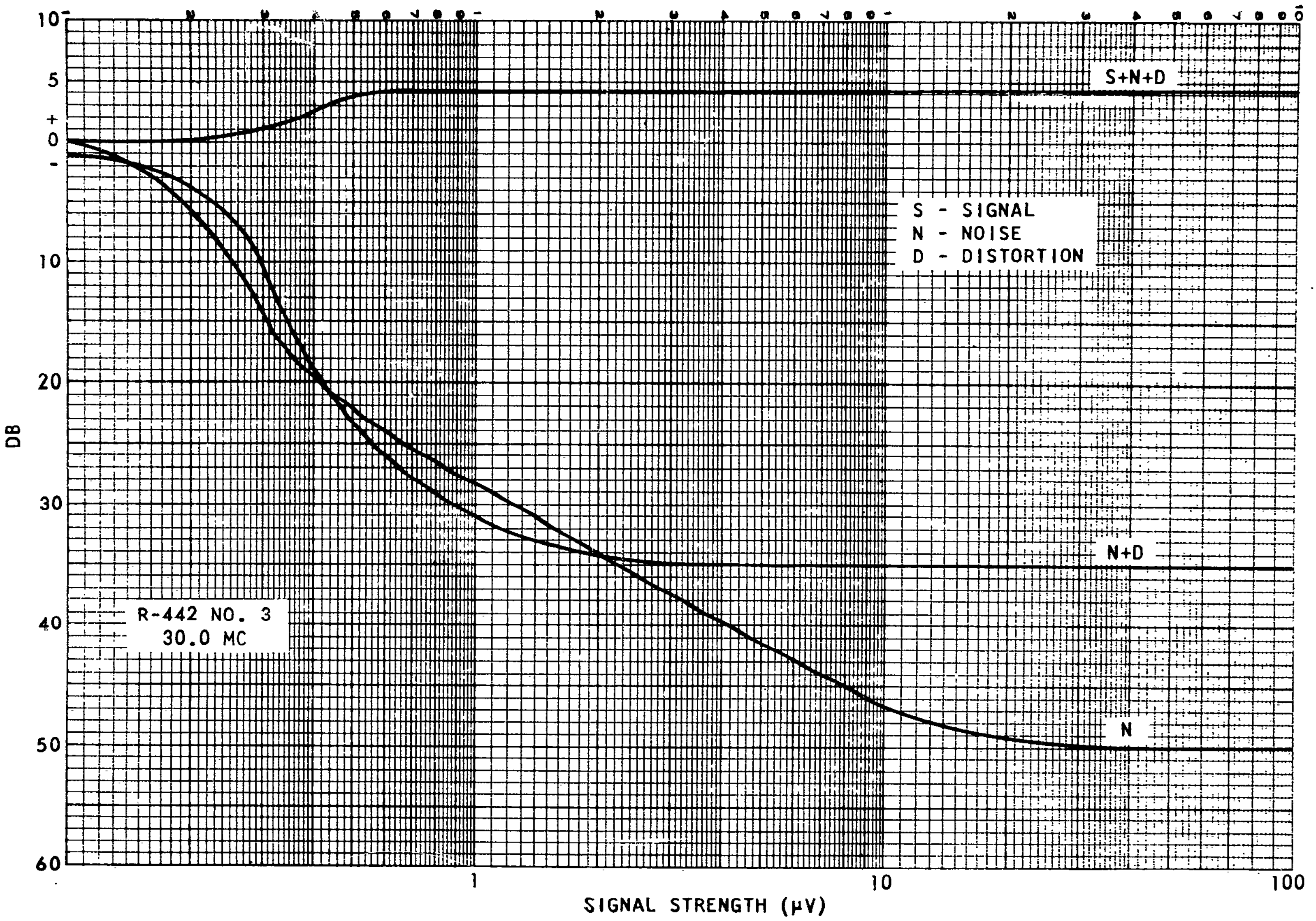


Figure 4. AN/VRC-12 Receiver S/N Characteristics (30 MC)

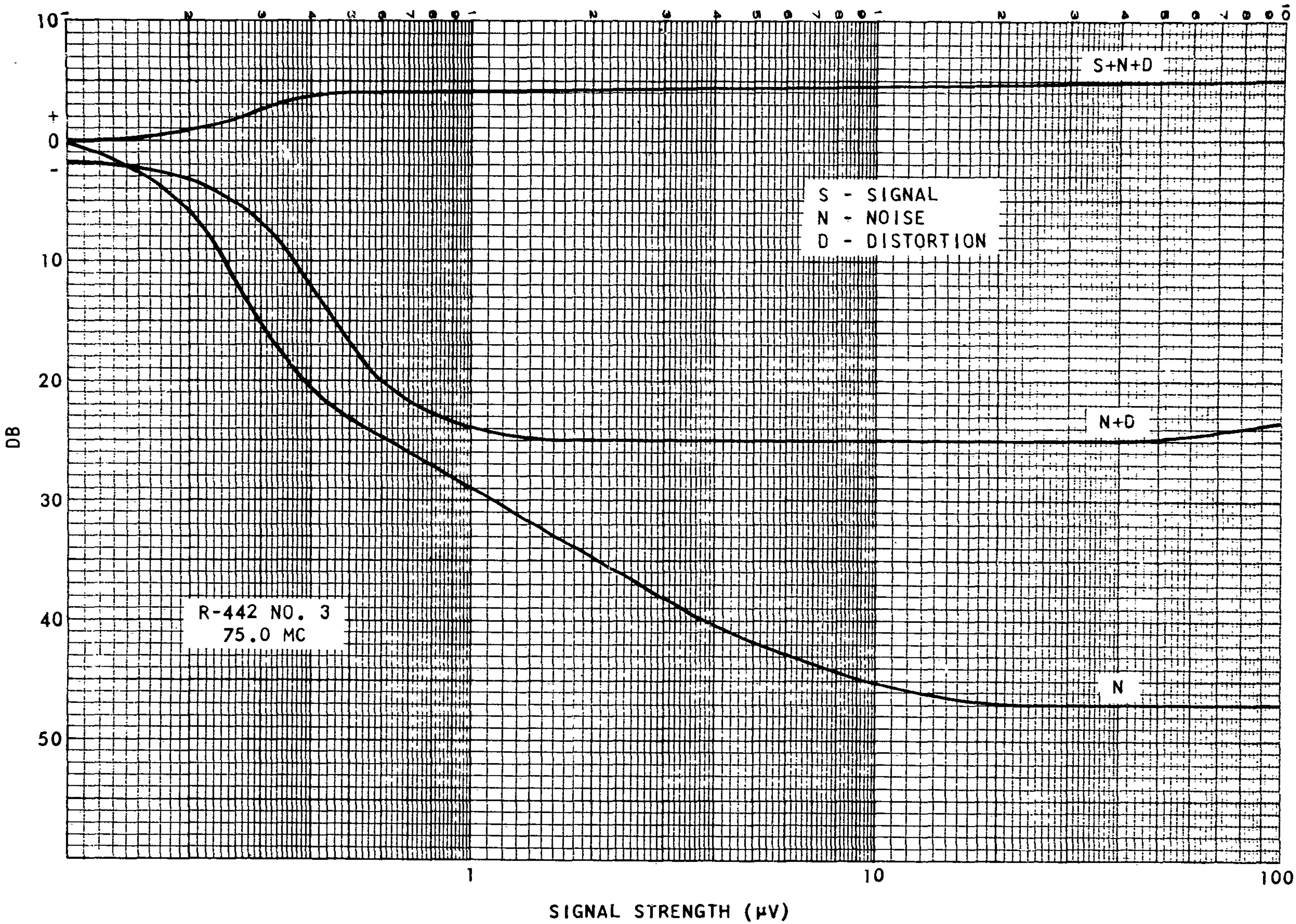


Figure 5. AN/VRC-12 Receiver S/N Characteristics (75 MC)

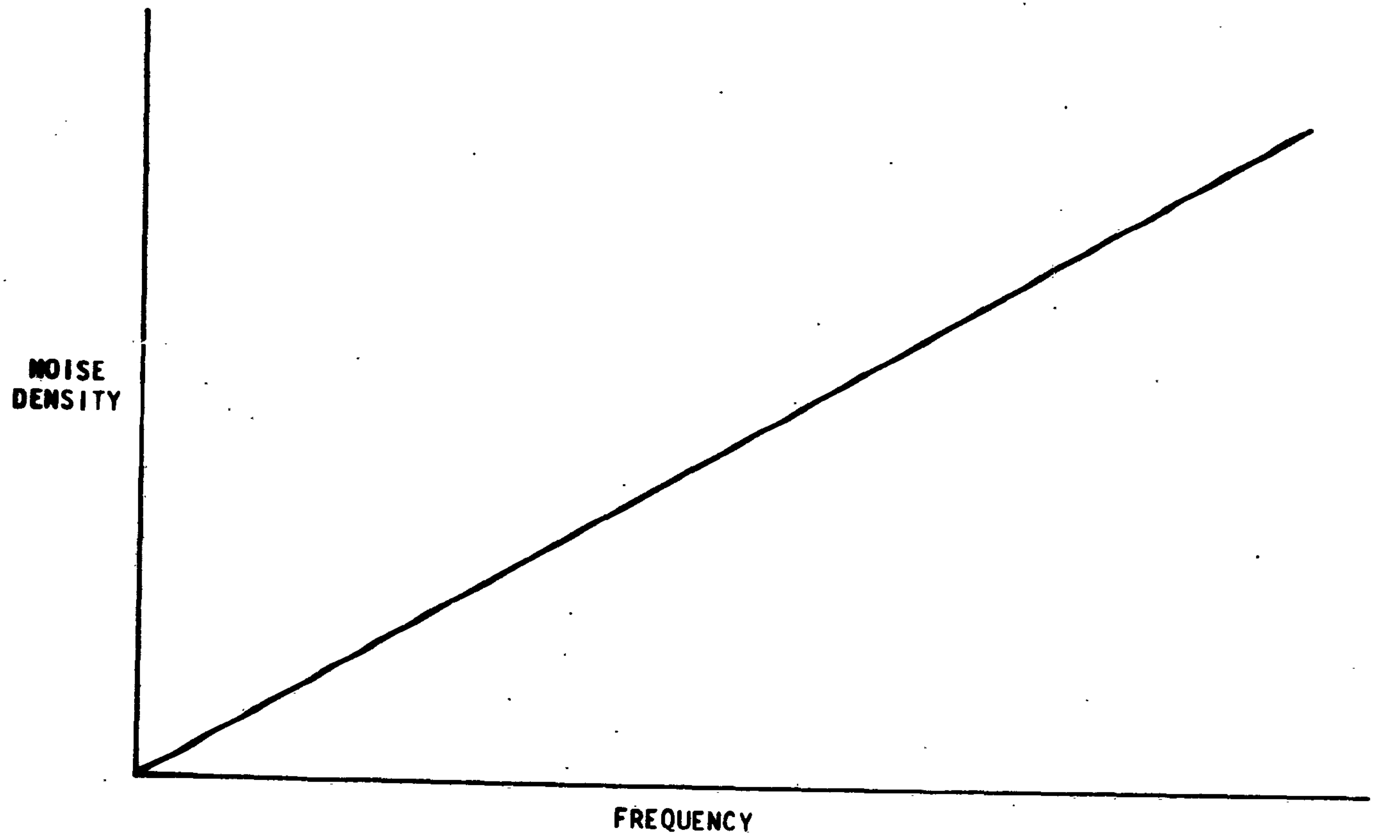


Figure 6. Noise Characteristics of Typical FM Receiver

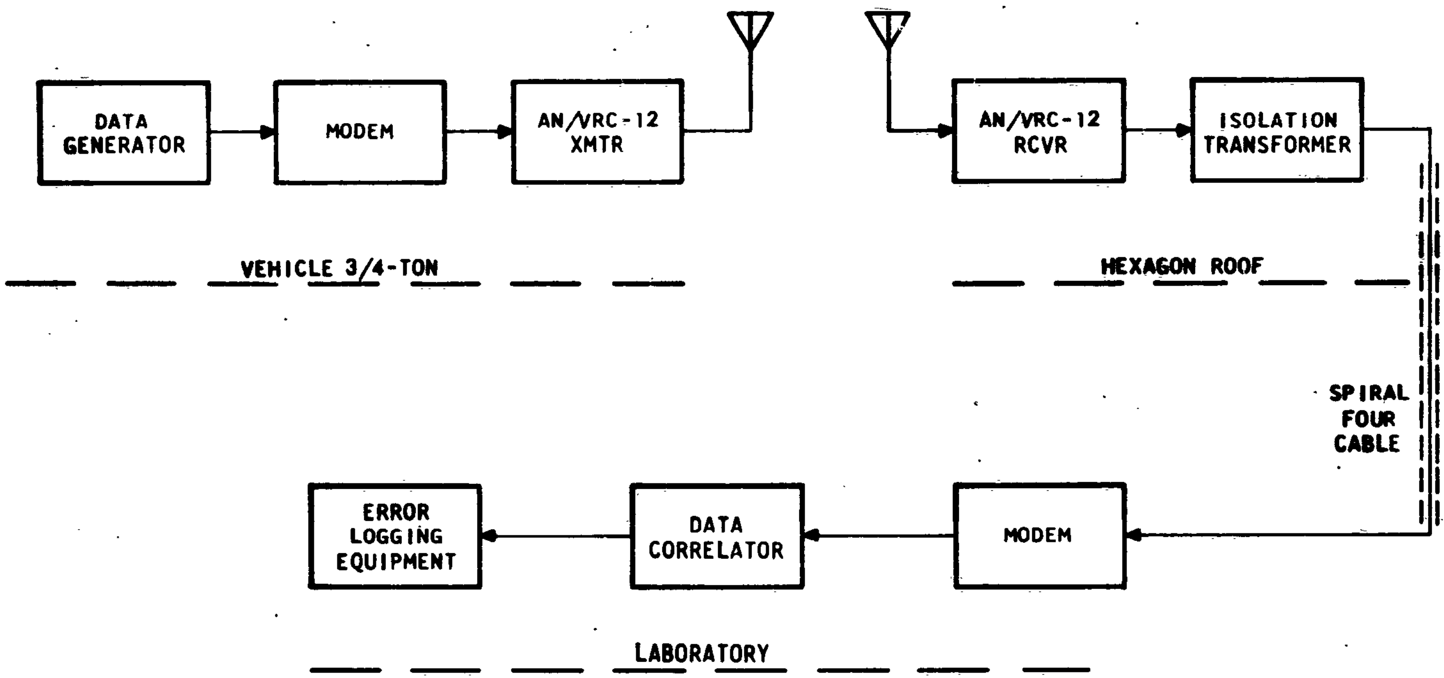


Figure 7. AN/VRC-12 Field Test Setup

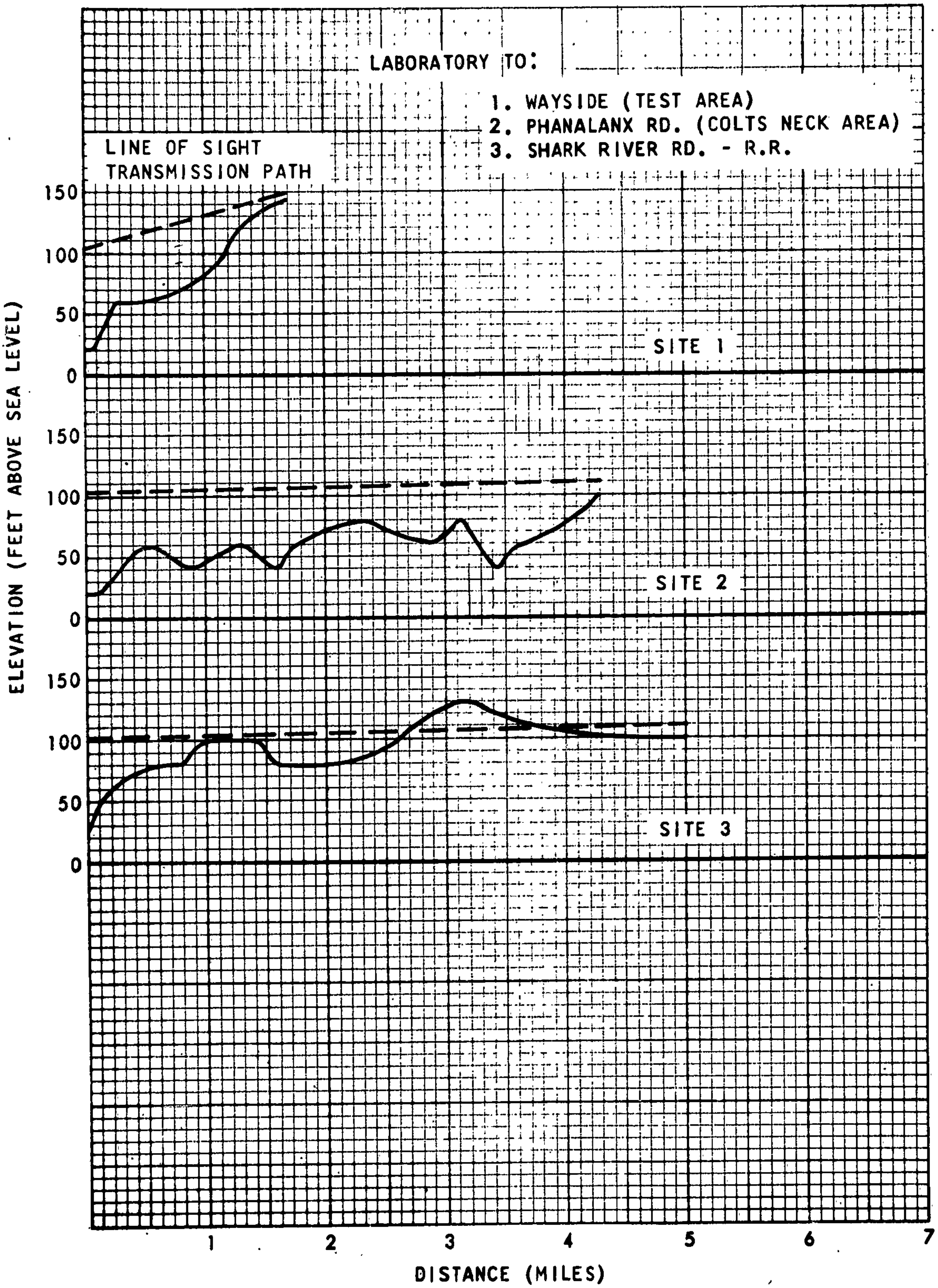


Figure 8. Transmission Path Map Profiles (Sites 1-3)

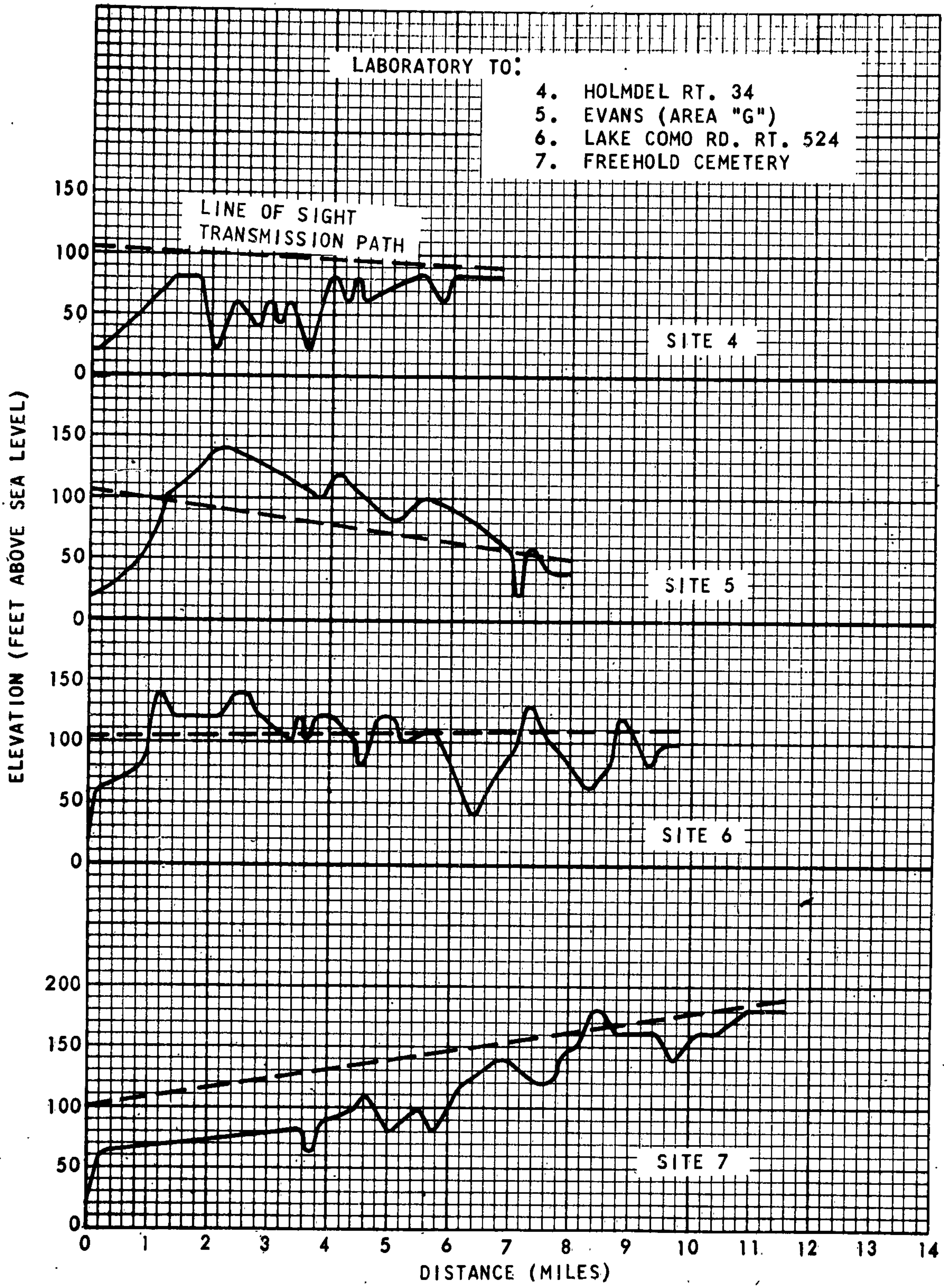


Figure 9. Transmission Path Map Profiles (Sites 4-7)

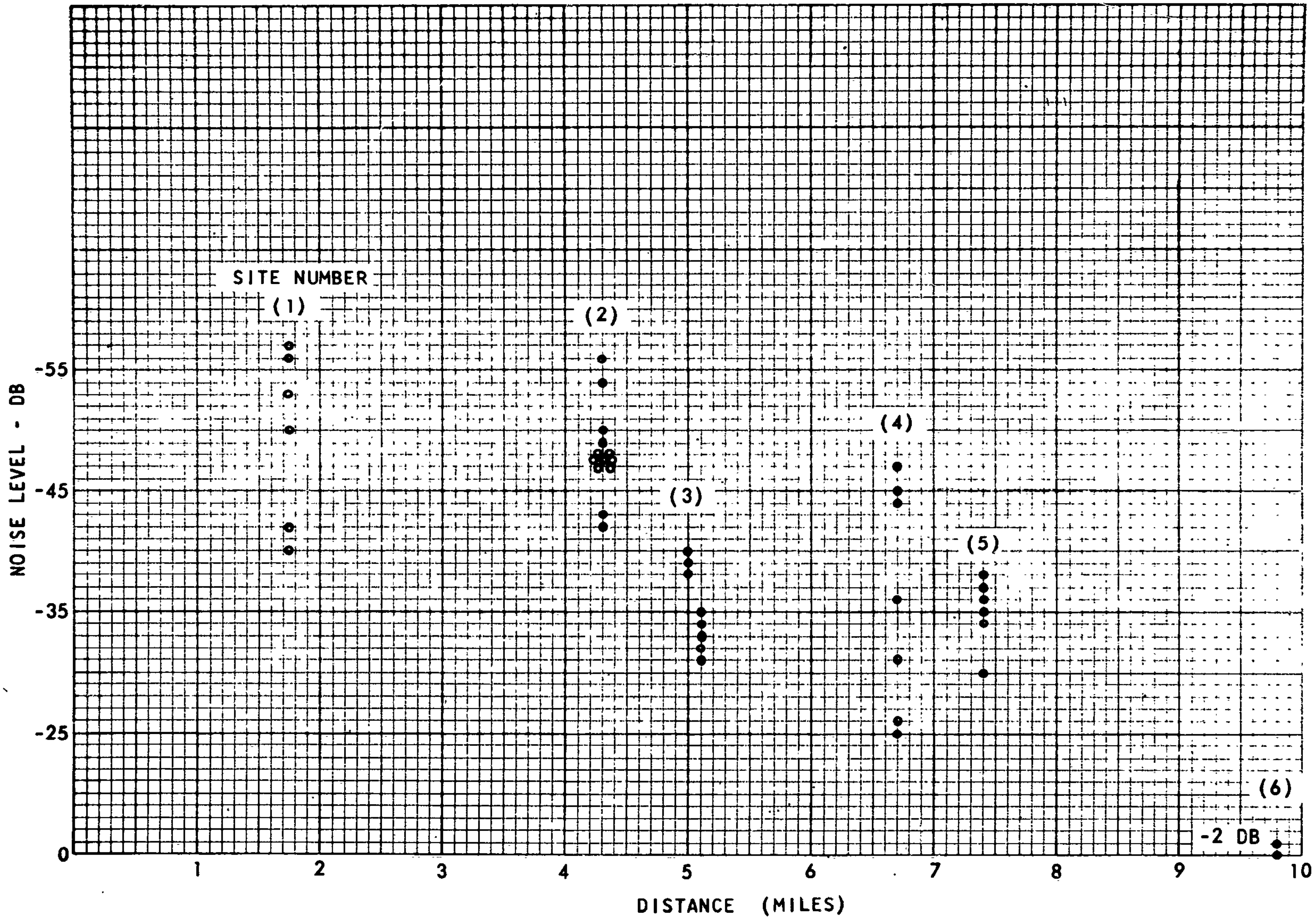


Figure 10. AN/VRC-12 Average Noise Level vs. Distance

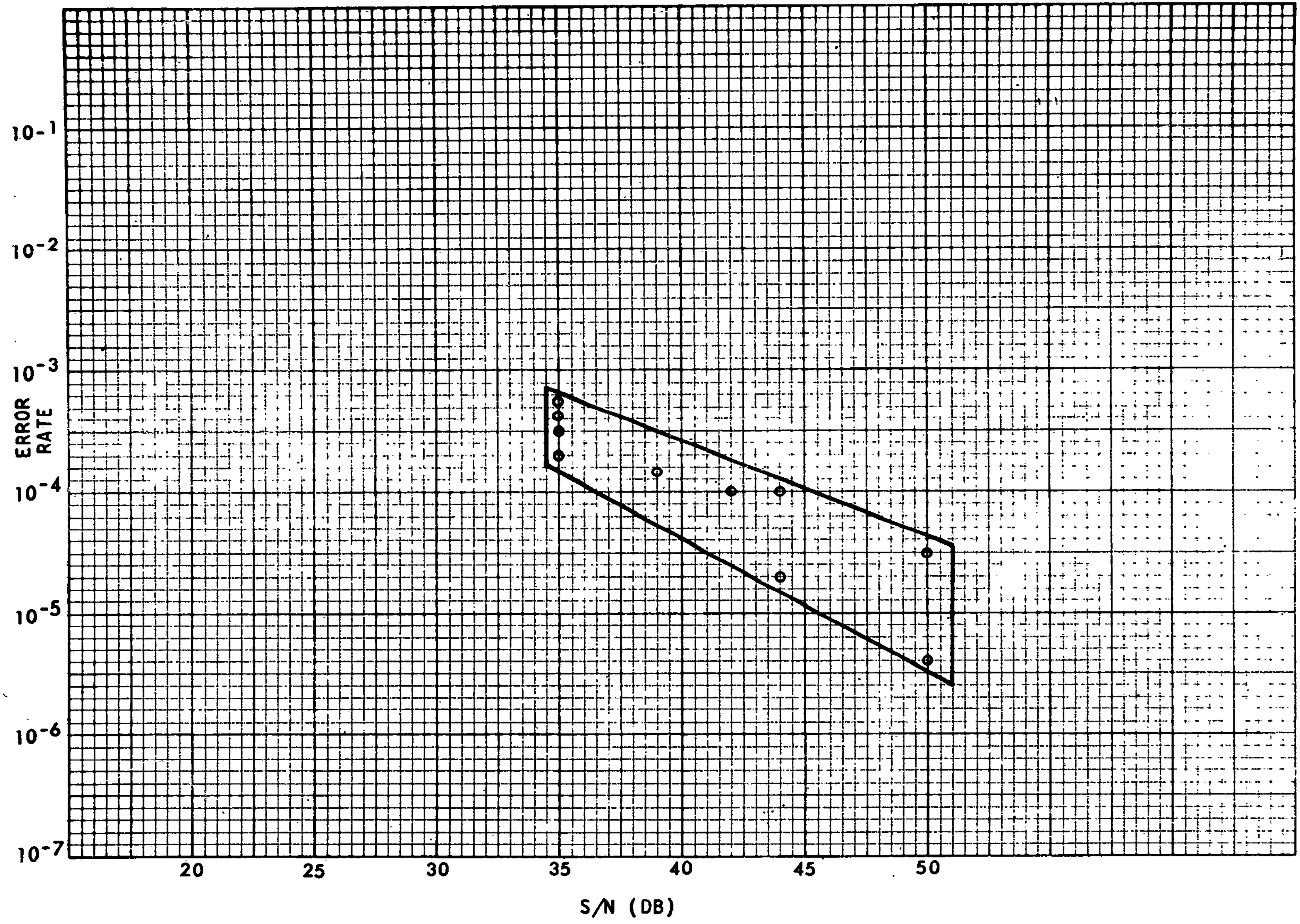


Figure 11. Error Rate vs. S/N; AN/TYC-1 (XC-2), 1200 bps

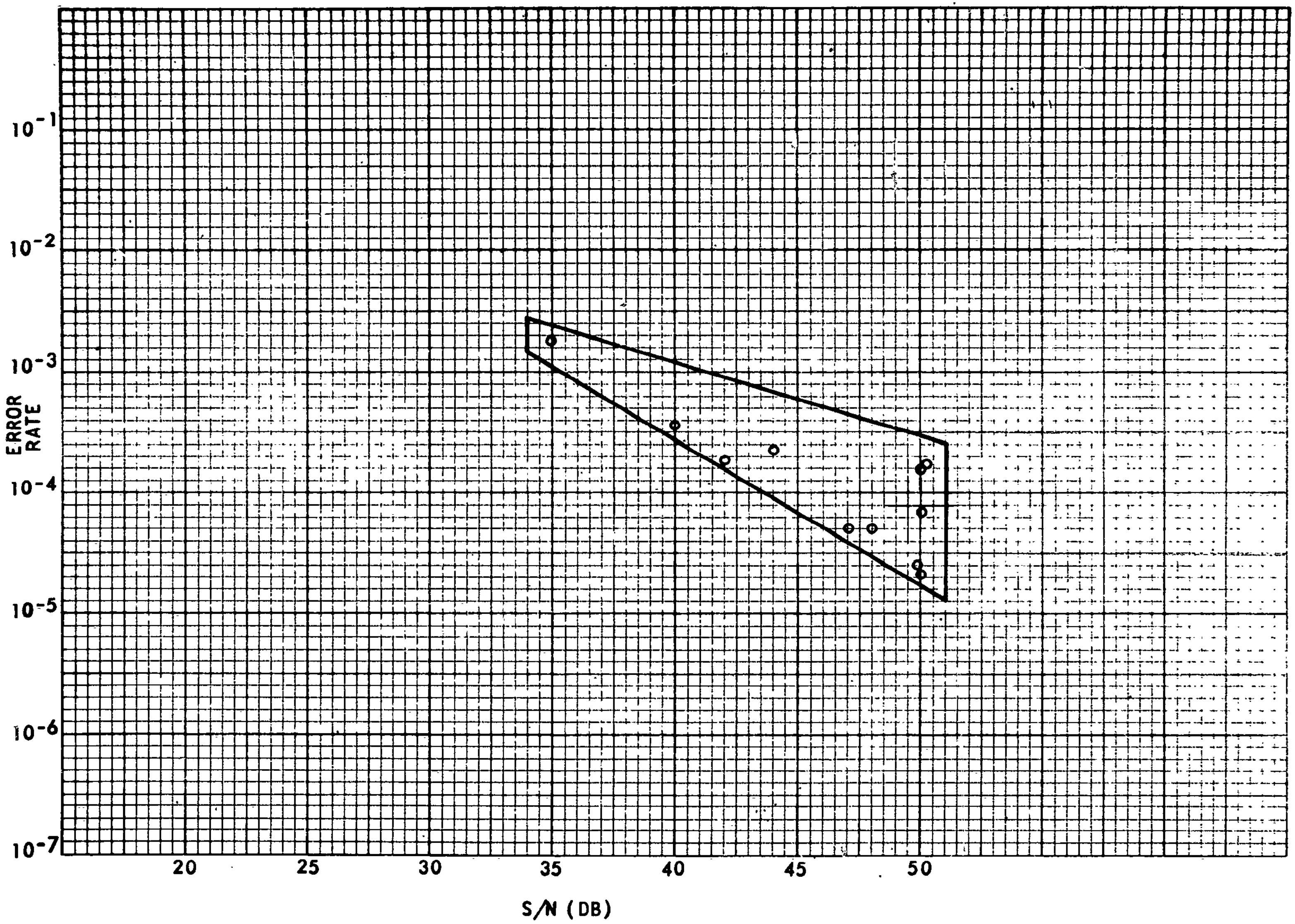


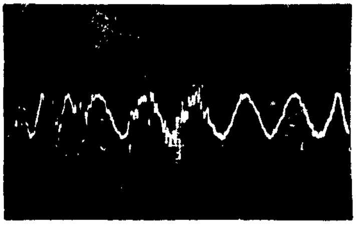
Figure 12. Error Rate vs. S/N; Di-Phase Modem, 600 bps

		SITE						
MODEM	BIT RATE	1	2	3	4	5	6	7
AN/TYC-1 (XC-2)	300	8.3×10^{-5}	3.5×10^{-5}	2.8×10^{-5}	5.5×10^{-4}	2.6×10^{-4}		
	600	4.2×10^{-5}	4.5×10^{-5}	1.1×10^{-4}	5.0×10^{-4}	3.4×10^{-4}		1.7×10^{-3}
	1200	1.2×10^{-4}	3.7×10^{-5}	1.2×10^{-4}	7.7×10^{-4}	4.5×10^{-4}		
DI-PHASE	300	5.8×10^{-4}	2.9×10^{-4}	3.3×10^{-4}		1.6×10^{-3}		
	600	3.4×10^{-4}	1.0×10^{-5}	2.4×10^{-4}	4.2×10^{-4}	1.1×10^{-3}		
	1200	1.4×10^{-4}	6.8×10^{-5}			3.7×10^{-4}		
QUAD-PHASE	600			4.16×10^{-5}	3.1×10^{-4}		4.2×10^{-3}	7.5×10^{-4}
	1200	3.9×10^{-5}	5.2×10^{-6}	1.1×10^{-4}	4.5×10^{-4}			
	2400	7.5×10^{-5}	1.8×10^{-5}	1.4×10^{-4}				

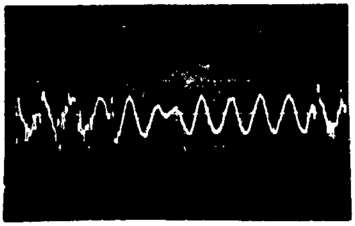
Figure 13. Average Bit Error Rates over AN/VRC-12

	BIT RATE (BPS)			
MODEM	300	600	1200	2400
AN/TYC-1 (XC-2)	6.8%	10.2%	26.6%	N.A.
DI-PHASE	4.4%	5.1%	22.5%	N.A.
QUAD-PHASE	N.A.	25.0%	48.5%	54.0%

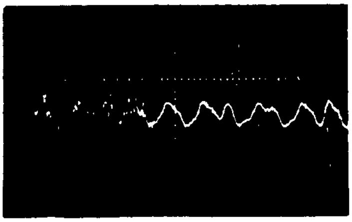
Figure 14. Percent Characters with Multiple Errors



AN/TYC-1
1200 BPS
VERTICAL SCALE = 2V/CM
HORIZONTAL SCALE = 0. 5 MS/CM



DI-PHASE
1200 BPS
VERTICAL SCALE = 2V/CM
HORIZONTAL SCALE = 0. 5 MS/CM



QUAD-PHASE
2400 BPS
VERTICAL SCALE = 5V/CM
HORIZONTAL SCALE = 0. 5 MS/CM

Figure 15. Photographs of Signal plus Impulse Noise

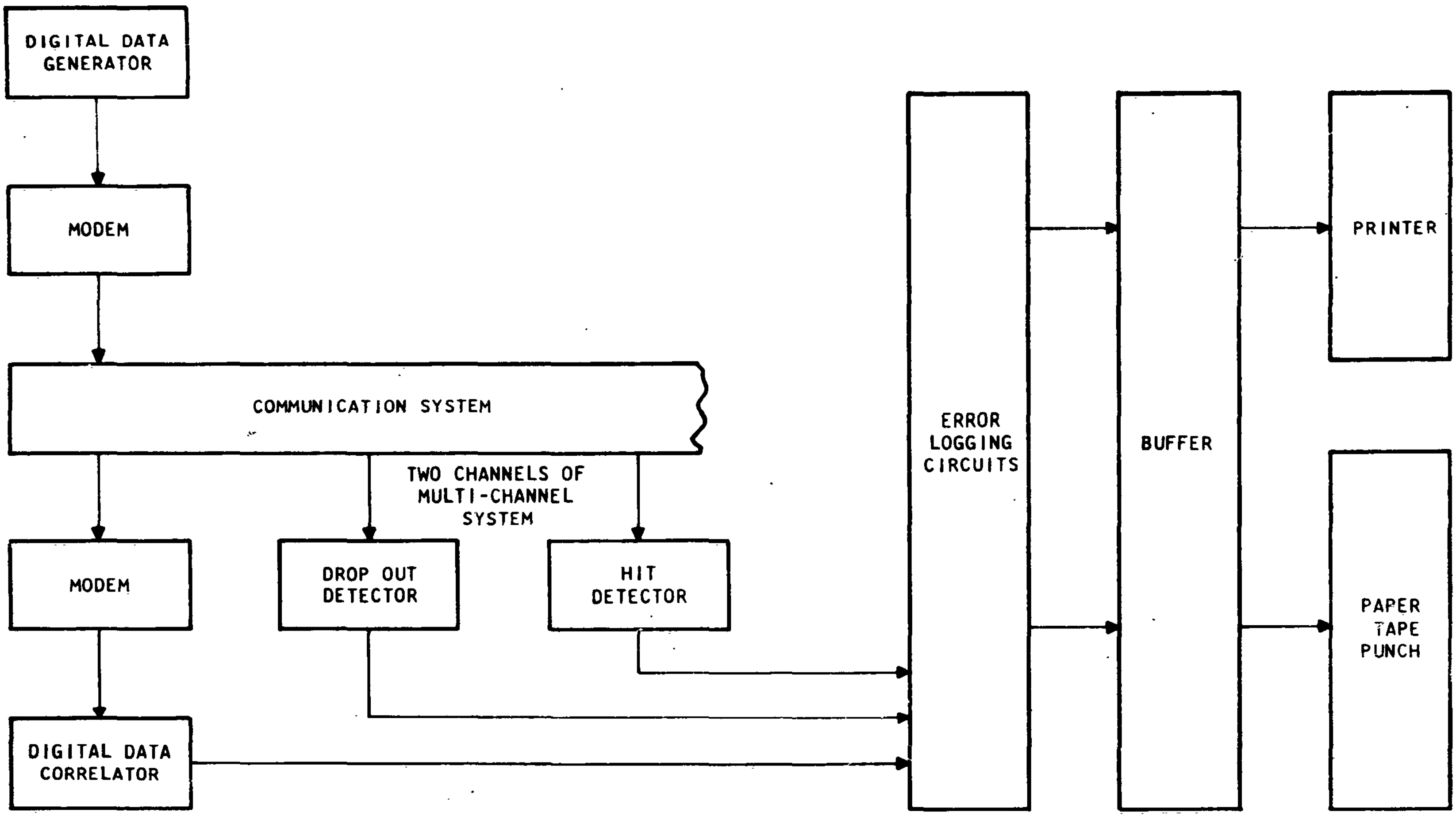


Figure 16. Digital Data Test System

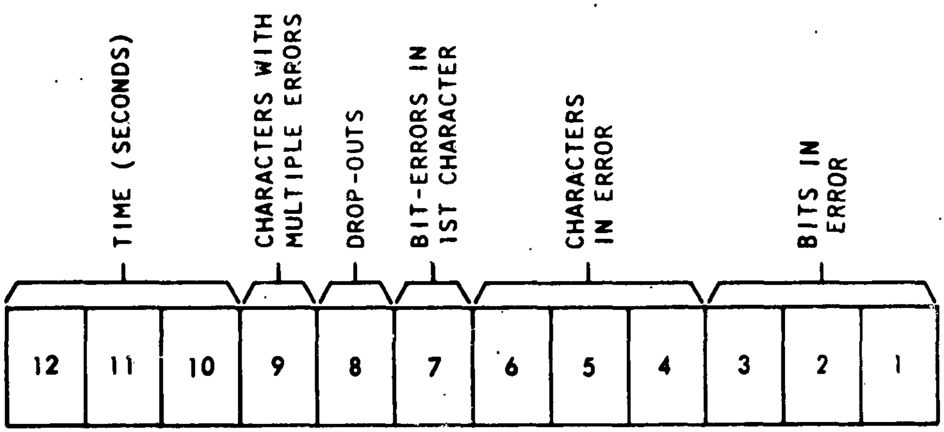
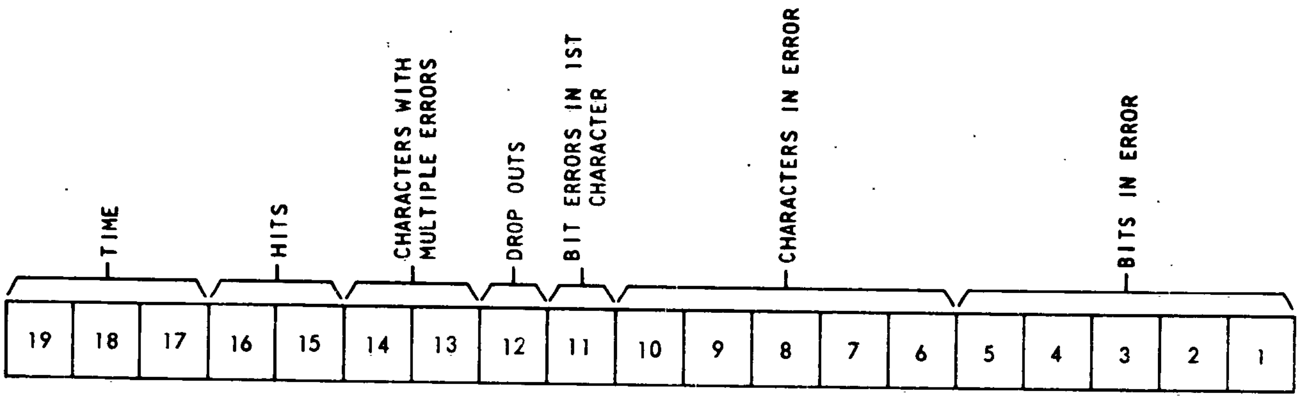
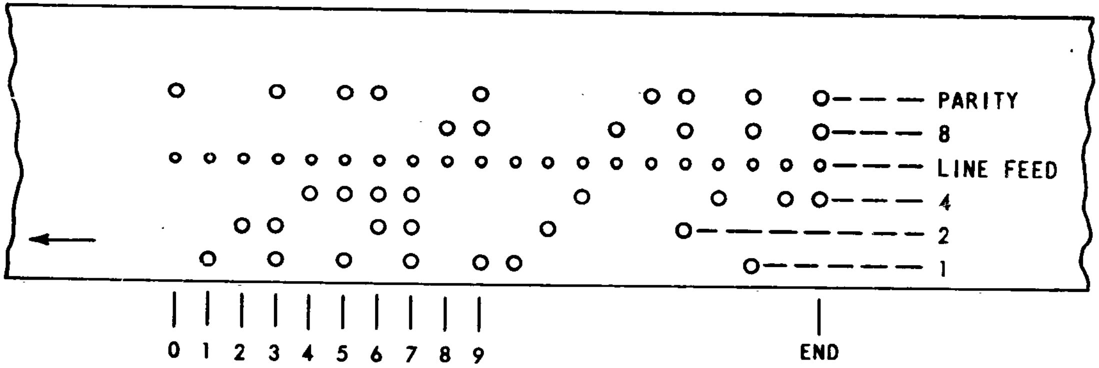


Figure 17. Printed Information



A - - PUNCHED INFORMATION (19 CHARACTERS)



B -- TAPE FORMAT

Figure 18. Paper Tape Information

HEADQUARTERS
UNITED STATES ARMY ELECTRONICS RESEARCH AND DEVELOPMENT LABORATORY

FORT MONMOUTH, NEW JERSEY

CONTRACT NO. DA 36-039 SC-90728

DISTRIBUTION LIST

SECOND QUARTERLY PROGRESS REPORT

1. Commanding Officer
U.S. Army Electronics R&D Laboratory
Fort Monmouth, New Jersey — 9 Cys

2. Armed Services Technical Information Agency
Arlington Hall Station
Arlington 12, Virginia
ATTN: TIPDR — 7 Cys

3. Commanding General
U.S. Army Electronics Command
ATTN: AMSEL-RD
Fort Monmouth, New Jersey — 1 Cy

4. Commanding General
U.S. Army Electronics R&D Activity
ATTN: SIGPG-DFF
Fort Huachuca, Arizona — 1 Cy

5. Commanding General
U.S. Army Electronics R&D Activity
Fort Huachuca, Arizona — 1 Cy

6. Chief, Technical Division
USASCSA
ATTN: SIGCR-4X
Arlington Hall Station
Arlington 12, Virginia — 1 Cy

7. U.S. Army Combat Development Command Liaison Office
USAERDL
Fort Monmouth, N. J. — 2 Cys

8. Director
U.S. Naval Research Laboratory
ATTN: CODE 1071
Washington 25, D.C. — 1 Cy

9. Commanding Officer
Frankford Arsenal
ATTN: Mr. Thomas Gibbons
Philadelphia, Pa. — 1 Cy

10. Commanding General
U.S. Army Electronics R&D Activity
ATTN: CCIS-70 Project Office
Fort Huachuca, Arizona — 1 Cy

AD__________ Accession No. ______________

MOTOROLA, INC., Communications Division, Chicago 51, Illinois

Second Quarterly Progress Report, "Data Transmission Investigation", R. F. Salava; 11 December 1962 to 10 March 1963; Contract No. DA 36-039-SC-90728, File No. 00113-PM-62-91-91 (6607) 21 pp. 18 figs.

This document reports on the study of digital data transmission over existing military voice communications systems. Characteristics of the AN/VRC-12 field test system are discussed and the results of data transmission from various locations in the area of Fort Monmouth are presented. The new error logging equipments are shown in a block diagram and the automated error logging system is described.

Unclassified

1. Data Transmission Investigation
2. Contract No. DA 36-039-SC-90728 (continuation of Contract No. DA 36-039-SC-87343)

AD__________ Accession No. ______________

MOTOROLA, INC., Communications Division, Chicago 51, Illinois

Second Quarterly Progress Report, "Data Transmission Investigation", R. F. Salava; 11 December 1962 to 10 March 1963; Contract No. DA 36-039-SC-90728, File No. 00113-PM-62-91-91 (6607) 21 pp. 18 figs.

This document reports on the study of digital data transmission over existing military voice communications systems. Characteristics of the AN/VRC-12 field test system are discussed and the results of data transmission from various locations in the area of Fort Monmouth are presented. The new error logging equipments are shown in a block diagram and the automated error logging system is described.

Unclassified

1. Data Transmission Investigation
2. Contract No. DA 36-039-SC-90728 (continuation of Contract No. DA 36-039-SC-87343)

AD__________ Accession No. ______________

MOTOROLA, INC., Communications Division, Chicago 51, Illinois

Second Quarterly Progress Report, "Data Transmission Investigation", R. F. Salava; 11 December 1962 to 10 March 1963; Contract No. DA 36-039-SC-90728, File No. 00113-PM-62-91-91 (6607) 21 pp. 18 figs.

This document reports on the study of digital data transmission over existing military voice communications systems. Characteristics of the AN/VRC-12 field test system are discussed and the results of data transmission from various locations in the area of Fort Monmouth are presented. The new error logging equipments are shown in a block diagram and the automated error logging system is described.

Unclassified

1. Data Transmission Investigation
2. Contract No. DA 36-039-SC-90728 (continuation of Contract No. DA 36-039-SC-87343)

AD__________ Accession No. ______________

MOTOROLA, INC., Communications Division, Chicago 51, Illinois

Second Quarterly Progress Report, "Data Transmission Investigation", R. F. Salava; 11 December 1962 to 10 March 1963; Contract No. DA 36-039-SC-90728, File No. 00113-PM-62-91-91 (6607) 21 pp. 18 figs.

This document reports on the study of digital data transmission over existing military voice communications systems. Characteristics of the AN/VRC-12 field test system are discussed and the results of data transmission from various locations in the area of Fort Monmouth are presented. The new error logging equipments are shown in a block diagram and the automated error logging system is described.

Unclassified

1. Data Transmission Investigation
2. Contract No. DA 36-039-SC-90728 (continuation of Contract No. DA 36-039-SC-87343)