ESD-TR-68-380 MTR-749

RESULTS OF CATEGORY II TESTING OF PHILCO-FORD MODEMS AT CAPE KENNEDY AFS

NOVEMBER 1968

R. W. Gilliatt
R. M. Steeves

Prepared for

AEROSPACE INSTRUMENTATION PROGRAM OFFICE
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts

Project 705B
Prepared by
THE MITRE CORPORATION
Bedford, Massachusetts
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FOREWORD

This report was prepared by the Communications Techniques Department of The MITRE Corporation, Bedford, Massachusetts, under Contract AF 19(628)-5165. The work was directed by the Development Engineering Division under the Aerospace Instrumentation Program Office, Air Force Electronics Systems Division, Laurence G. Hanscom Field, Bedford, Massachusetts. Robert E. Forney served as the Air Force Project Engineer for this program, identifiable as ESD (ESSID) Project 5932, Range Digital Data Transmission Improvement.

REVIEW AND APPROVAL

This technical report has been reviewed and is approved.

GEORGE T. GALT, Colonel, USAF
Director, Aerospace Instrumentation
Program Office

ABSTRACT

This document describes the results of Category II field testing of the AN/GSC-20B wireline modem, evaluation tests of the AN/USC-12A HF radio modem and the establishment of the phase jitter characteristics of the ETR submarine cable data transmission system after modification. The testing was accomplished at Cape Kennedy AFS during the week of 23 June 1968.

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SECTION I

INTRODUCTION

This document presents the results of a field measurement program that was performed by MITRE personnel to obtain, a) diversity performance data on the AN/USC-12A modem, b) AN/GSC-20B modem performance, c) phase jitter characteristics of the modified ETR Submarine cable transmission system.

The primary objective of the field test was to perform the Cat II test of the AN/GSC-20B modem.

The secondary test objectives were:

a. A comparison of the hybrid diversity signal processing technique (AN/ USC-12A modem) with the equal weight diversity signal processing technique (AN/USC-12 modem).

b. Measurement of phase jitter characteristics of the ETR wideband submarine cable data transmission system after modification.

SECTION II

DESCRIPTION OF TESTS

HF MODEM TESTS

The AN/USC-12A modem performance test was performed as follows. An AN/USC-12 modem together with an AN/USM-235 modem test set was used to transmit a 23-bit test message (at 2400 bps) from Ascension Island via the operational HF data link to Cape Kennedy (Figure 1). At Cape Kennedy facility, a space diversity HF receiving system was used to receive the transmitted HF test signals which were then transferred to the X-Y Building as analog baseband tone signals. These signals were divided equally in power level and applied to an AN/USC-12 modem and an AN/USC-12A modem in parallel so that both modems received the separate and distinct normal and diversity signal channels. Each modem was connected to an AN/USM-235 test set to measure the bit errors at the output of the modems. The bit errors were then accumulated and recorded automatically on a paper printout in 10 second intervals (Table I).

CAT II TEST

The AN/GSC-20B modem test was performed as follows. The test configuration used to carry out the Cat II test is shown in Figures 2A and 2B. Three circuits were selected that were routed through Antigua and back to the X-Y building via the ETR Submarine Cable System. The frequency response of these circuits was measured using an Acton Labs delay measurement test set. The results of these measurements are given in Figures 3A, 3B, and 3C. The AN/GSC-20B modem was equalized to compensate for

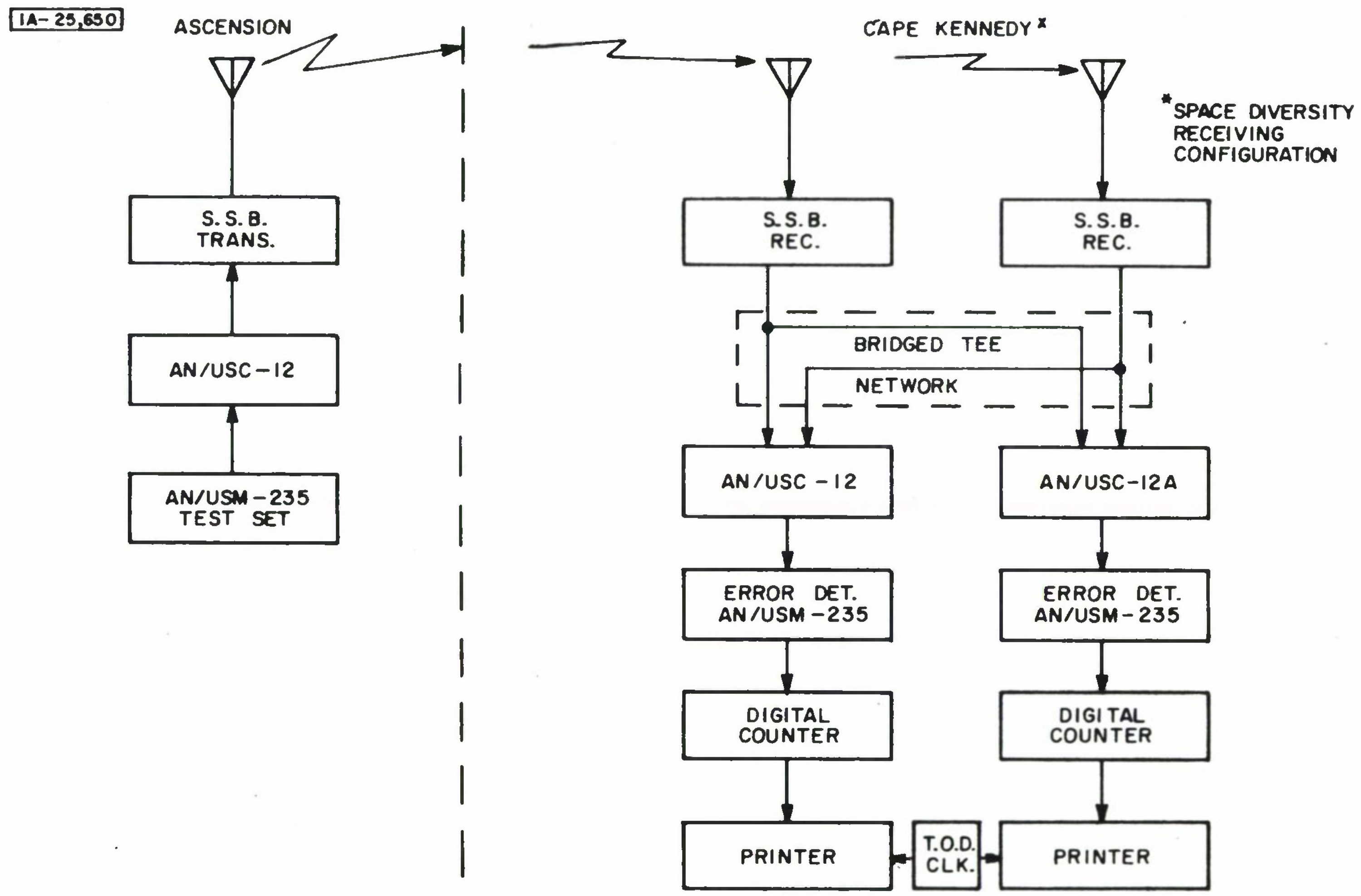

Figure 1. AN/USC-12A Modem Performance Test Configuration

Table I

Typical Error Data Print-Out Tapes (HF Modem Tests)

TIME OF DAY	AN/USC-12 CUMM ERRORS	AN/USC-12A CUMM ERRORS
1324	0640	0049
1324	0640	0049
1324	0640	0048
1323	0624	0048
1323	0593	0047
1323	0582	0045
1323	0552	0043
1323	0544	0043
1323	0540	0042
1322	0537	0042
1322	0522	0042
1322	0514	0042
1322	0491	0040
1322	0481	0040
1322	0474	0039
1321	0470	0029
1321	0466	0039
1321	0457	0039
1321	0449	0039
1321	0444	0029
1321	0427	0036
1320	0422	0033
1320	0385	0022
1320	0385	0022
1320	0350	0022
1320	0340	0026
1320	0325	0026
1319	0317	0025
1319	0291	0023
1319	0252	0022
1319	0240	0022
1319	0223	0021
1319	0187	0020
1318	0171	0019
1318	0157	0017
1318	0120	0017
1318	0117	0016
1318	0109	0016
1318	0095	0014
1317	0079	0004
1317	0053	0004
1317	0035	0006
1317	0015	0004
1317	0007	0001

6/27/68
RUN #1
@ 10 SEC P.O.
F = 25.161

TIME OF DAY	AN/USC-12 CUMM ERRORS	AN/USC-12A CUMM ERRORS
1028	1443	0176
1028	1443	0176
1027	1443	0176
1027	1443	0176
1027	1398	0166
1027	1386	0164
1027	1371	0161
1027	1313	0148
1026	1246	0107
1026	1193	0094
1026	1138	0090
1026	1132	0090
1026	1118	0089
1026	1105	0086
1025	1055	0086
1025	1045	0083
1025	1008	0080
1025	0966	0076
1025	0939	0075
1025	0875	0075
1024	0802	0073
1024	0760	0073
1024	0735	0073
1024	0679	0073
1024	0650	0073
1024	0636	0072
1023	0602	0052
1023	0591	0052
1023	0537	0051
1023	0527	0051
1023	0452	0051
1023	0394	0050
1022	0356	0045
1022	0339	0045
1022	0329	0042
1022	0283	0041
1022	0247	0041
1022	0170	0041
1021	0144	0041
1021	0111	0038
1021	0099	0036
1021	0036	0002
1021	0018	0001
1021	0000	0000

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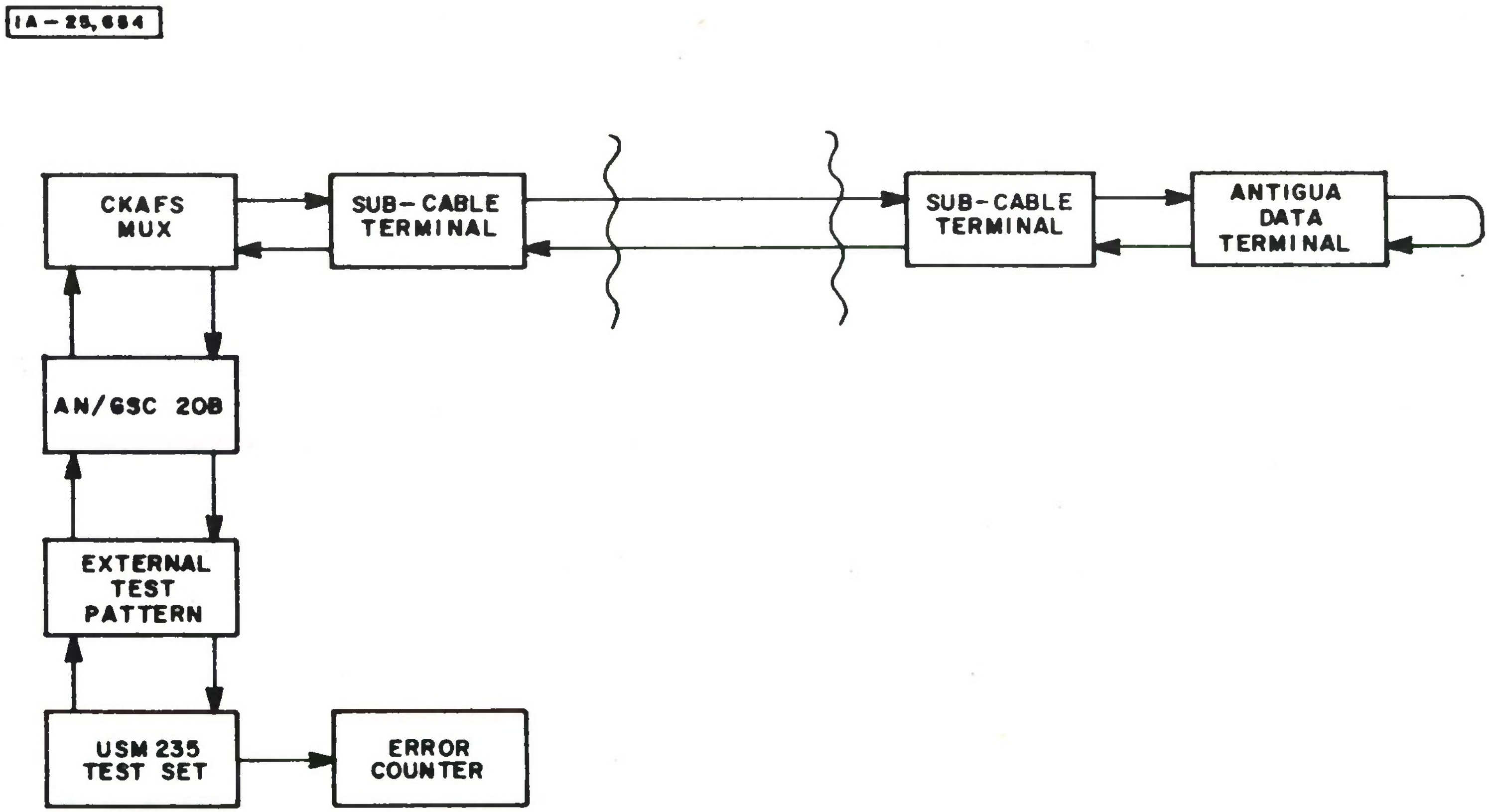

Figure 2A. AN/GSC-20B Modem Performance Test Configuration (Test Runs 1 and 2)

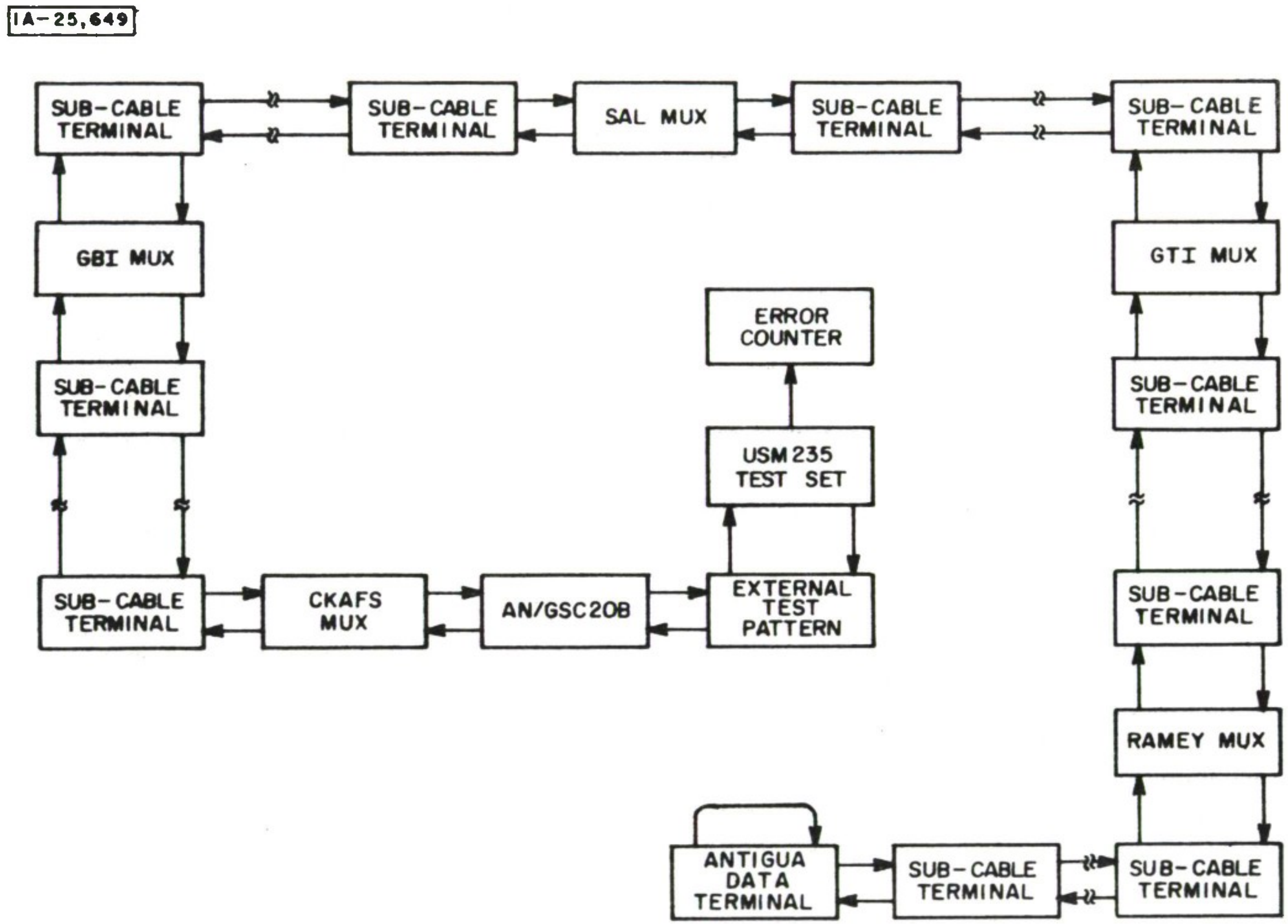

Figure 2B. AN/GSC-20B Modem Performance Test-Configuration (Test Run 3)

IB-25,657

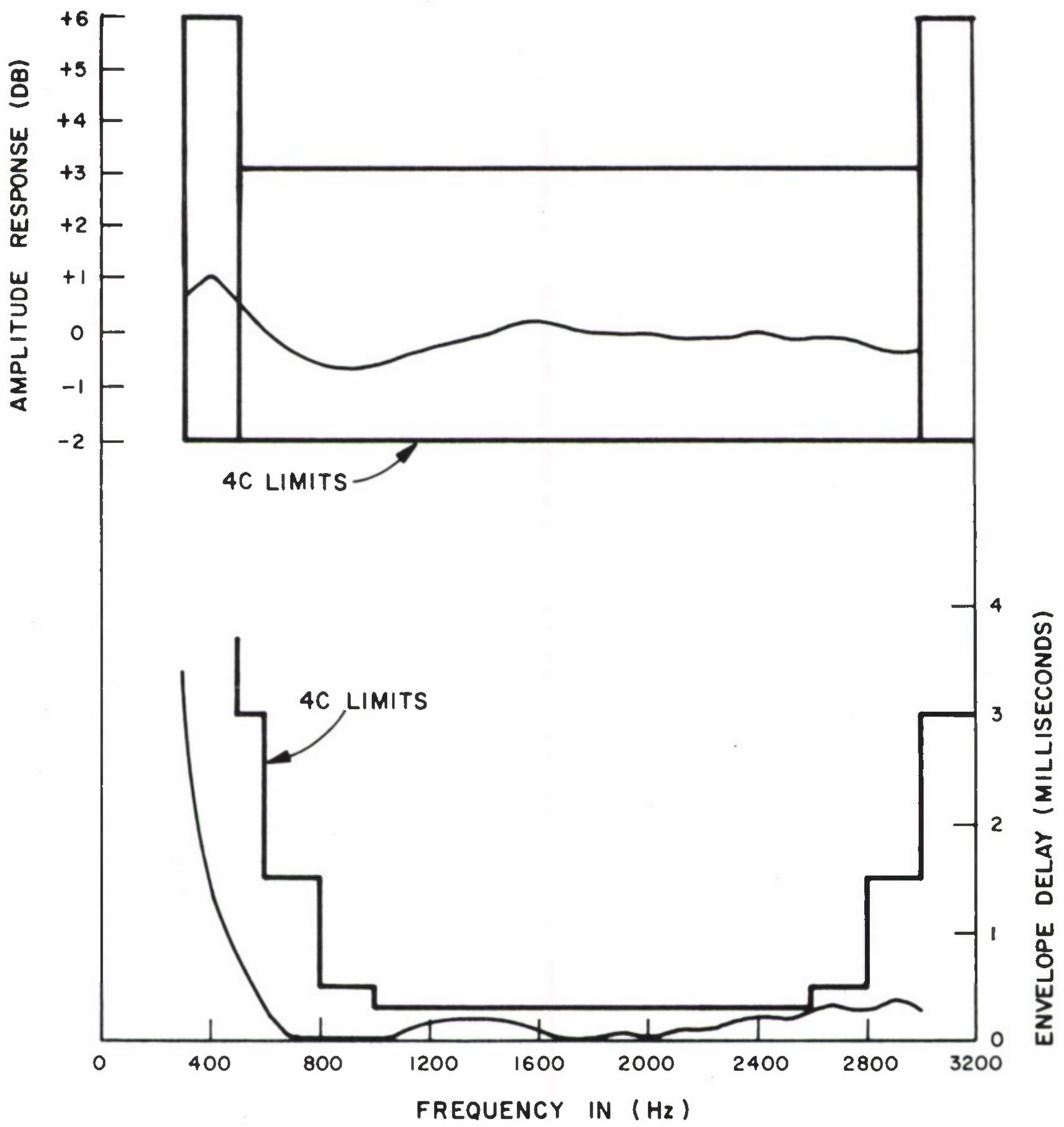

Figure 3A. Submarine Cable Channel Characteristics Antigua-Cape Kennedy Loop Channel 4

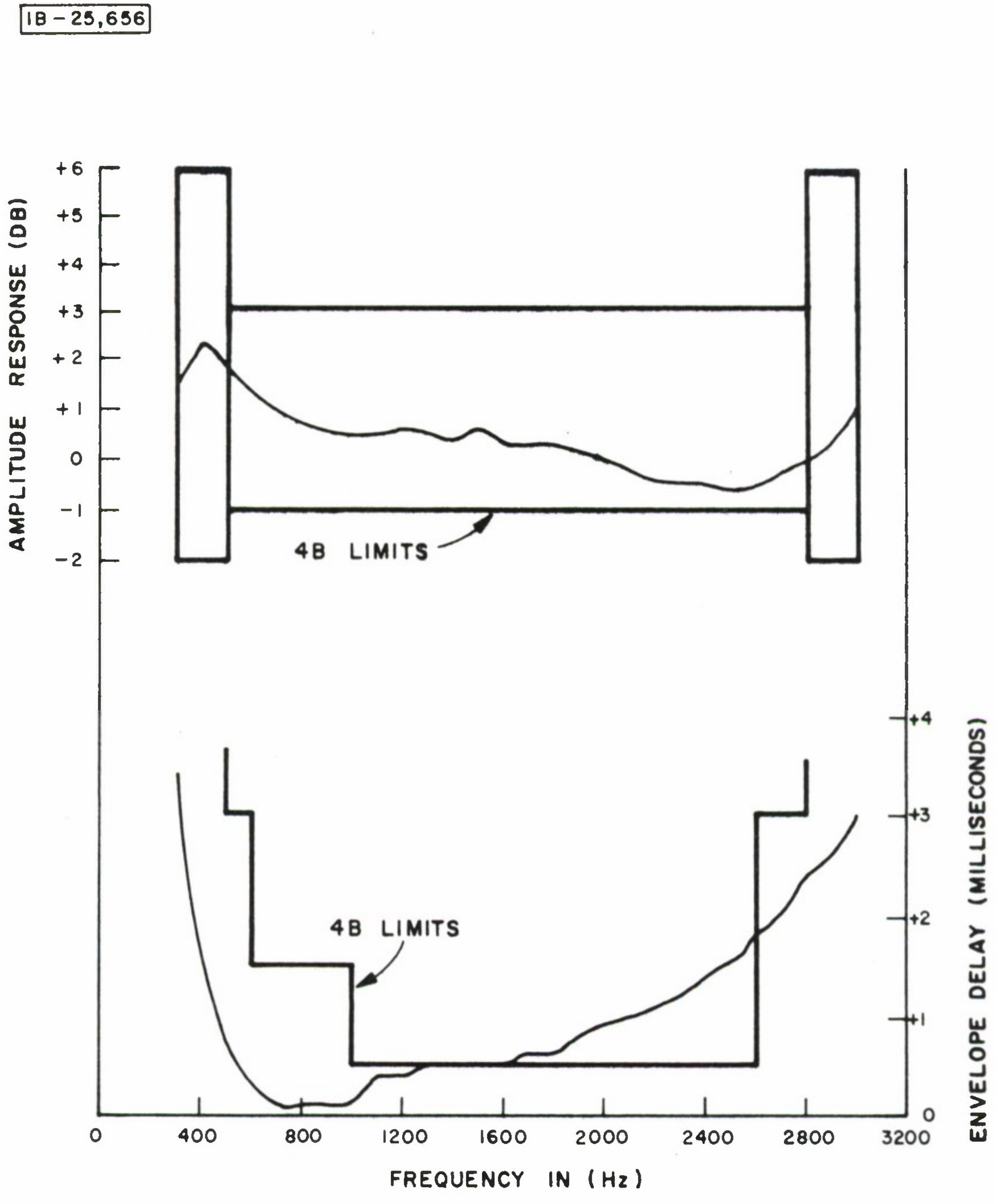

Figure 3B. Submarine Cable Channel Characteristics Antigua–Cape Kennedy Loop Channel 12

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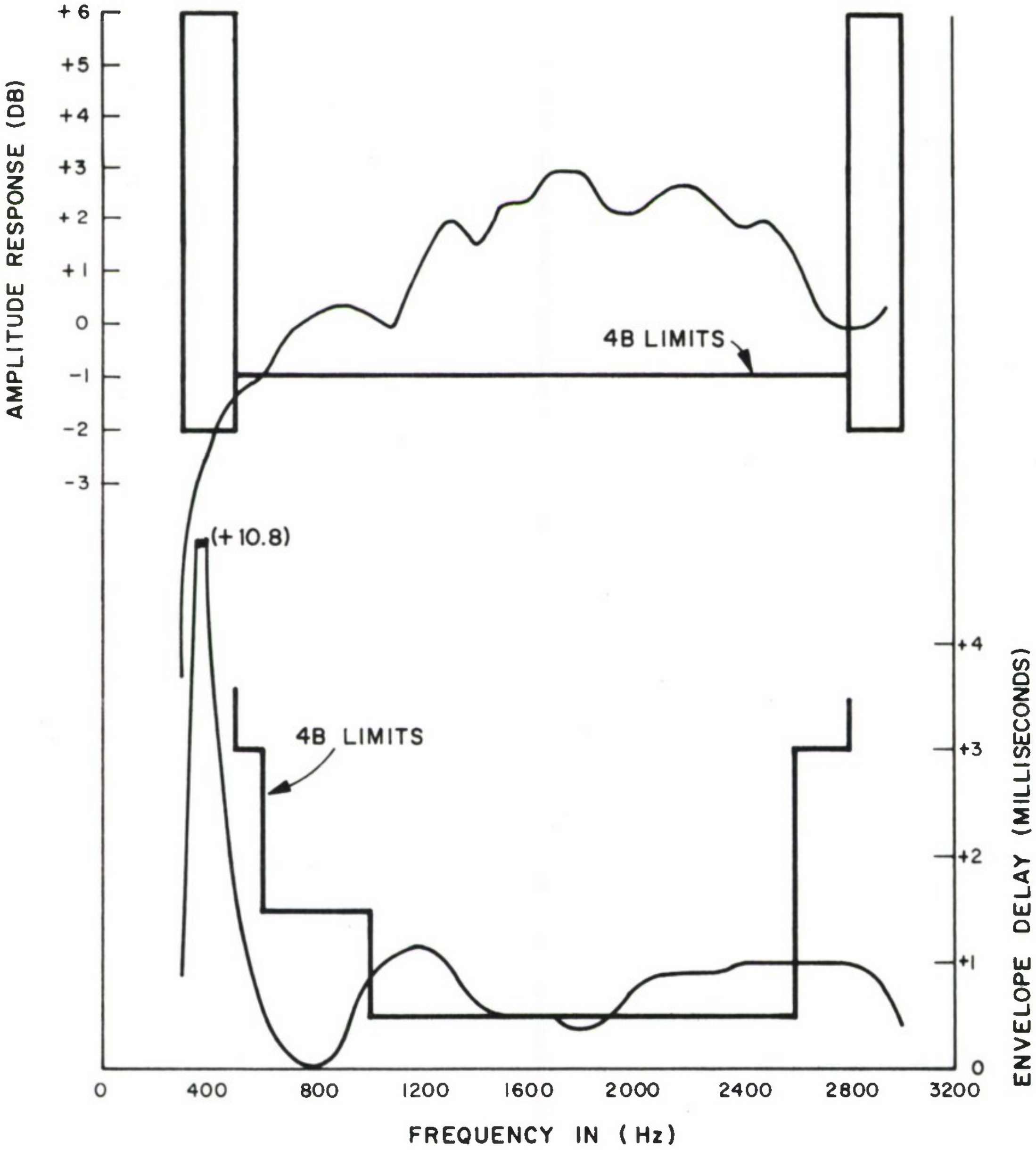

Figure 3C. Submarine Cable Channel Characteristics Antigua-Cape Kennedy Loop Channel 5 the delay characteristics of the transmission media. An important point to note here, is the fact that the modem must be equalized internally for each circuit routing used.

An AN/USM-235 test set operating with a 23-bit test pattern was mixed with an external test pattern generator to form a 345-bit test word. The 345-bit test word was then fed into the AN/GSC-20B modem which was operated at 4800 bps. The composite audio line output signal from the AN/GSC-20B modem was transmitted over a southbound submarine cable 4 kHz channel to Antigua where it was loop connected (without regeneration) and transmitted back to the CKAFS X-Y Building over a northbound cable 4 kHz channel into the AN/GSC-20B modem demodulator. The AN/USM-235 test set measured the bit errors at the output of the modem, and the bit errors were accumulated on a counter.

PHASE JITTER TEST

The phase jitter characteristics measurements were performed as follows (Figure 4). A 1 kHz test signal was inserted into a southbound submarine cable 4 kHz channel to Antigua where it was loop connected and transmitted back to the CKAFS X-Y Building over a northbound cable 4 kHz channel. A dual trace oscilloscope was utilized to compare the transmitted signal with the received signal, and to measure the resultant phase jitter. In addition, the transmitted and received signals were applied to an audio phase detector capable of measuring peak phase jitter up to ± 90 degrees. The output of the phase detector was analyzed utilizing an audio spectrum analyzer to establish the spectral components of the phase jitter.

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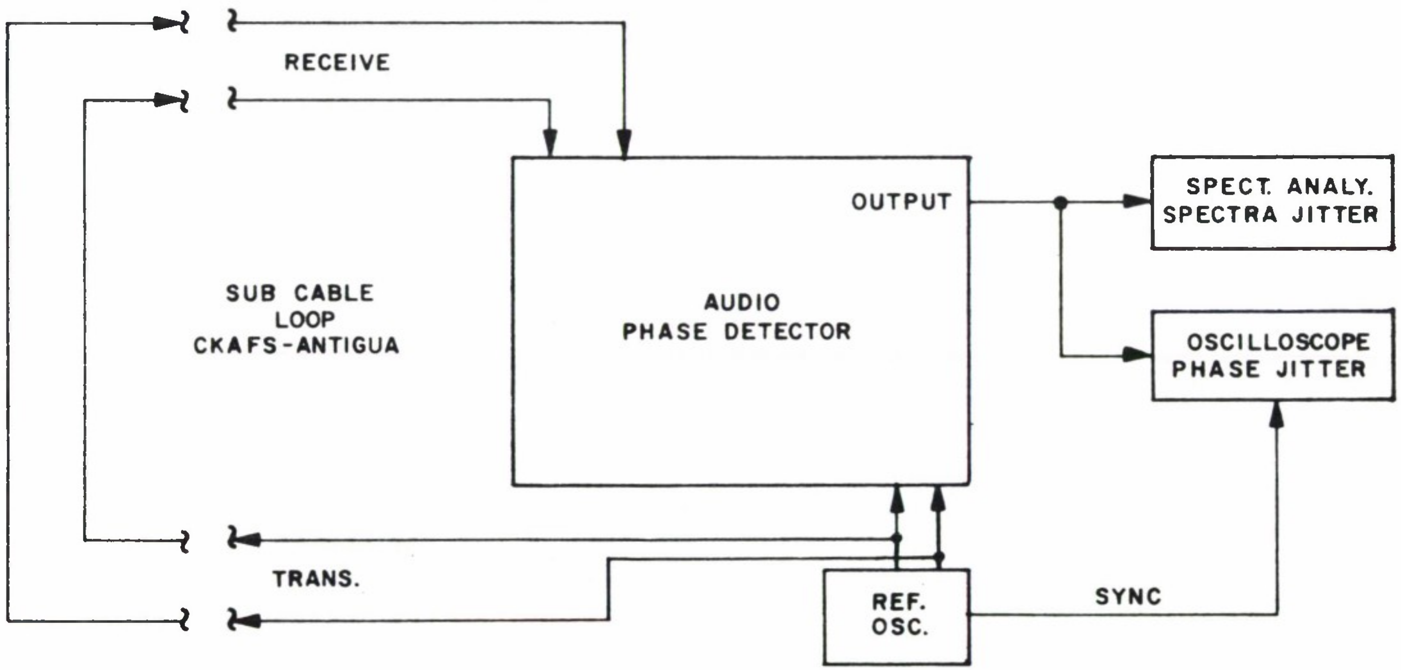

Figure 4. Jitter Characteristics Measurements Test Configuration

SECTION III

DESCRIPTION OF TEST RESULTS

HF MODEM TEST

The results of the four HF data modem tests are presented in Table II. Each test run consisted of a total of 10^6 bits transmitted at a rate of 2400 bps utilizing a 23 bit test pattern. During the test period the inputs from the normal and diversity receivers were observed on an oscilloscope to ensure that coincidental fading of the two signals did not occur and that proper space diversity of the receiver antennas was maintained. In addition, the switching between normal and diversity tones in the AN/USC-12A was monitored.

A comparison of bit error rate performance of the AN/USC-12A modem relative to the AN/USC-12 modem is shown in Figure 5. The average improvement shown is derived relative to the equal weight diversity performance measured on the AN/USC-12 modem. The theoretical improvement curve was derived on the basis of two independent Rayleigh fading channels and error free diversity switching decisions.

CAT II TEST

The results of the four wireline data modem tests are presented in Table III. All test runs were conducted for 10^6 bits at 4800 bps utilizing a 345 bit pattern with the exception of test 4. The modem transmit level was -6 DBM. It should be noted that run number 1, series 1, of wireline test number 2 was voided because of the large number of errors (1790) apparently due to a modem failure. The modem fault was corrected and the testing resumed. Test 4 utilized the same line configuration as Test 3,

Table II

Summary of Error Rate Performance
AN/USC-12 and AN/USC-12A

HF Test I — DATE 6/26/68
Freq 25.161 MHz

Run No.	Time Started	USC-12 Errors	USC-12A Errors	USC-12 BER	USC-12A BER
1	1517	640	49	6.4×10^{-4}	4.9×10^{-5}
2	1525	783	85	7.83×10^{-4}	8.5×10^{-5}
3	1532	1494	126	1.49×10^{-3}	1.26×10^{-4}
4	1540	2540	252	2.54×10^{-3}	2.52×10^{-4}
5	1549	394	10	3.94×10^{-4}	1×10^{-5}

HF Test 2 — DATE 6/27/68

Freq 25.161 MHz

Run No.	Time Started	USC-12 Errors	USC-12A Errors	USC-12 BER	USC-12A BER
1	1021	1443	176	1.44×10^{-3}	1.76×10^{-4}
2	1028	1351	207	1.35×10^{-3}	2.07×10^{-4}
3	1036	251	15	2.51×10^{-4}	1.5×10^{-5}
4	1043	736	255	7.36×10^{-4}	2.55×10^{-4}
5	1050	1029	79	1.03×10^{-3}	7.9×10^{-5}

Table II (Continued)

HF Test 3 DATE 6/27/68

Freq 25.161 MHz

Run No.	Time Started	USC-12 Errors	USC-12A Errors	USC-12 BER	USC-12A BER
1	1400	2550	367	2.55×10^{-3}	3.67×10^{-4}
2	1407	1889	225	1.89×10^{-3}	2.25×10^{-4}
3	1415	2439	413	2.44×10^{-3}	4.13×10^{-4}
4	1423	1561	273	1.56×10^{-3}	2.73×10^{-4}
5	1430	1517	204	1.52×10^{-3}	2.04×10^{-4}

HF Test 4 DATE 6/27/68

Freq 15.564 MHz

Run No.	Time Started	USC-12 Errors	USC-12A Errors	USC-12 BER	USC-12A BER
1	2039	2709	343	2.71×10^{-3}	3.43×10^{-4}
2	2046	3045	425	3.05×10^{-3}	4.25×10^{-4}
3	2053	3576	860	3.58×10^{-3}	8.60×10^{-4}
4	2112	4233	1394	4.23×10^{-3}	1.40×10^{-3}
5	2119	4654	1884	4.65×10^{-3}	1.88×10^{-3}

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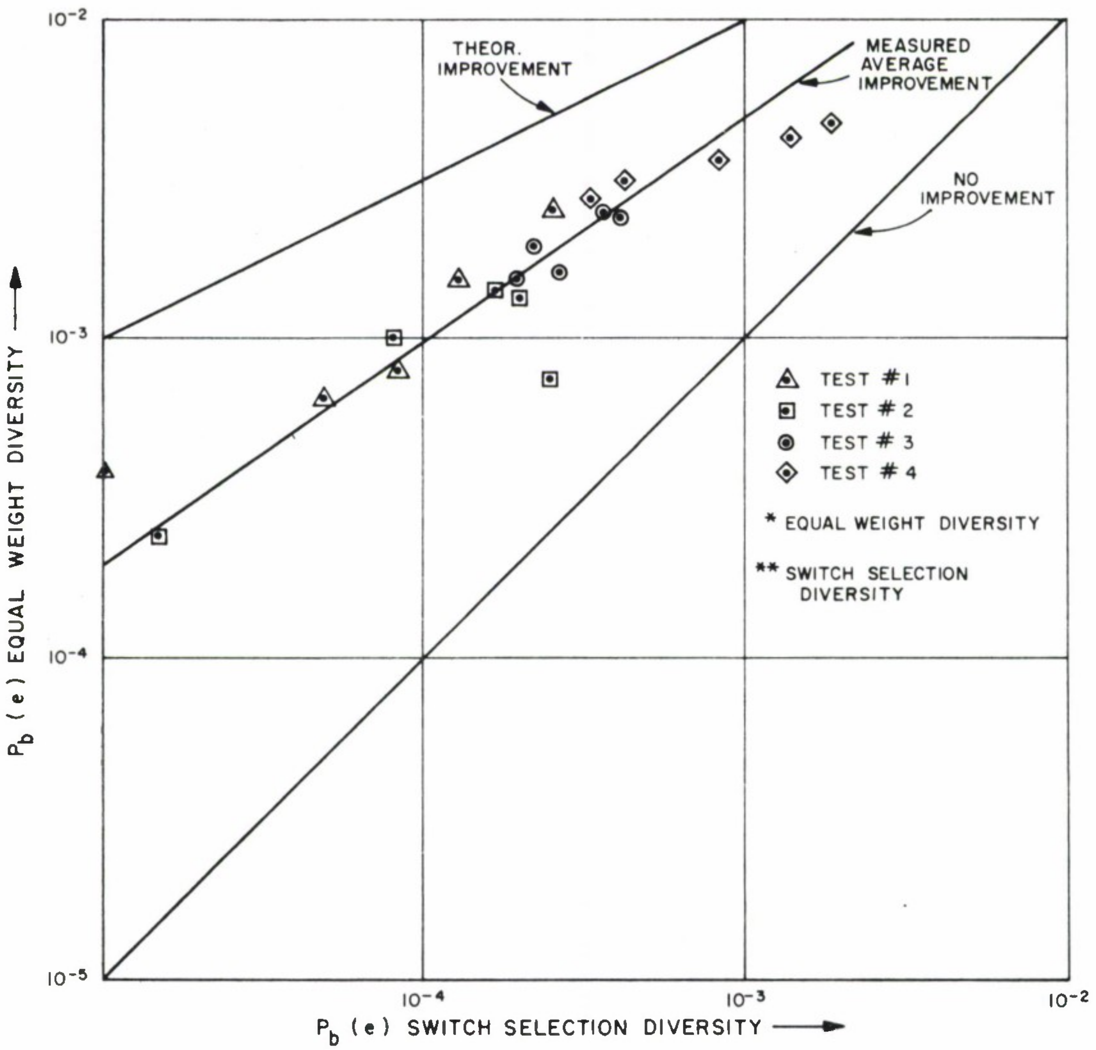

Figure 5. Bit Error Rate Comparisons For AN/USC-12* and AN/USC-12A** Modems

Table III

Summary of Error Rate Performance

AN/GSC-20B

Wireline Test 1 DATE 6/26/68

Channel 4 Express

Series	Run No. 1	Run No. 2	Run No. 3	Run No. 4	Run No. 5	Average Error Rate	BER
1	1	14	7	4	4	6.0	6×10^{-6}
2	17	48	0	0	0	13	1.3×10^{-5}
3	1	1	0	5	3	2	2×10^{-6}
4	1	10	4	1	0	3.2	3.20×10^{-6}
5	0	0	0	1	2	.6	6×10^{-7}

Wireline Test 2 DATE 6/27/68

Channel 12 Express

Series	Run No. 1	Run No. 2	Run No. 3	Run No. 4	Run No. 5	Average Error Rate	BER
1	Deleted	188	245	254	185	218	2.18×10^{-4}
2	188	192	190	213	239	204	2.04×10^{-4}
3	245	174	200	283	479	276	2.76×10^{-4}
4	303	223	238	333	541	327	3.27×10^{-4}

NOTE:

Most of the errors were in the 900-Hz Channel because of the amount of delay adjustment necessary to compensate for the delay differential between 900 Hz and 2700 Hz.

Table III (Continued)

Wireline Test 3 DATE 6/27/68

Channel 5

Series	Run No. 1	Run No. 2	Run No. 3	Run No. 4	Run No. 5	Average Error Rate	BER
1	443	316	317	493	459	405	4.05×10^{-4}
2	354	321	147	197	182	240	2.40×10^{-4}
3	137	329	292	176	162	219	2.19×10^{-4}
4	148	273	324	419	304	293	2.93×10^{-4}

Wireline Test 4 DATE 6/27/68

Channel 5

Series	Run No. 1	Run No. 2	Average Error Rate	BER
1	529	607	568	5.68×10^{-4}

NOTE:

Same configuration as Test 3 but using a 23 bit word.

Observed that most errors were associated with the 45° phase shift of the 900 Hz tone.

but it was operated with a 23 bit pattern rather than the 345 bit pattern. The purpose of the test was to obtain a comparison between operation with a 23 bit pattern and a 345 bit pattern.

The results obtained indicate approximately equal performance for the short test sequence as for the long test sequence. This is rather surprising since this contradicts the experimental test results observed at Philco-Ford, where the error rate observed for the short test pattern (23 bit) was considerably better (more than an order of magnitude) than that obtained for the long (345 bit) test pattern for similar test conditions and transmission media.

PHASE JITTER TEST

The results of the phase jitter measurements indicate that nine degrees peak or 50 microseconds of phase jitter (at 1 kHz) exists on channel four on the submarine cable from CKAFS to Antigua with a loop around at Antigua. Figure 6 illustrates the internal noise frequency spectrum of the analyzer without the 1 kHz signal (A) and the phase jitter frequency spectrum present on the line with the 1 kHz signal (B). As can be seen from Figure 6B, the phase jitter displays discrete frequency components as multiples of 60 Hz. This is due to the residual 60 cycle power supply and stray pickup of signals which are modulating the translation oscillators of the frequency multiplex terminals (FCC-17) of the submarine cable transmission system.

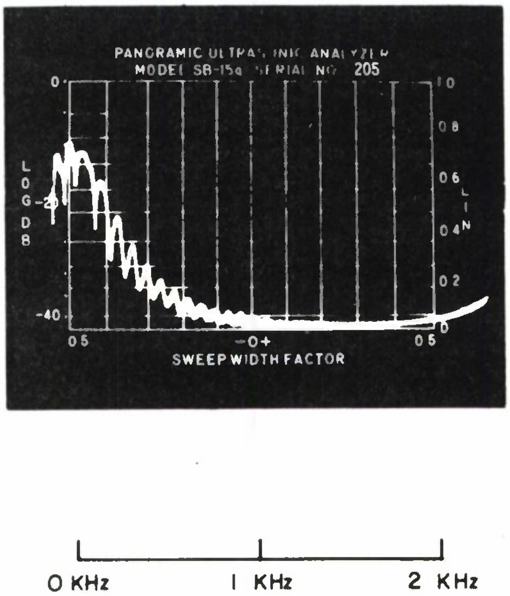

Figure 6. Phase Jitter Response
(a) Spectral Density-Analyzer (Internal Noise)

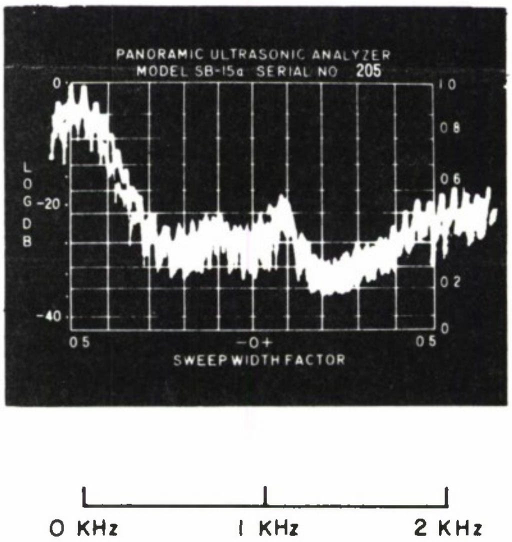

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Figure 6. Phase Jitter Response
(b) Spectral Density-Antigua-Cape Kennedy Loop

SECTION IV

SUMMARY AND CONCLUSIONS

The results of the Tests with the AN/USC-12 and AN/USC-12A HF modems indicates that a definite improvement in the bit error rate is accomplished with the AN/USC-12A modem's hybrid diversity signal processing technique as compared to the AN/USC-12 modem's equal weight diversity signal processing technique. The improvement factor* ranges from approximately 2.5 to 1 during the evening hours to approximately 10 to 1 during the afternoon hours as shown in Table 1. This result is in agreement with the fact that the diversity antenna electrical spacing decreases with lower (evening) frequencies causing the diversity channel fading to become more correlated with respect to the normal receive channel signal fading.

Results of the Cat II tests on the AN/GSC-20B modem indicate that satisfactory operation (bit error rate equal to or less than 10^{-5}) requires the use of well equalized circuits equivalent to schedule 4C. When this modem is operated on circuits of schedule 4B quality, performance will be degraded to an average of 2.5 to 3 x 10^{-4} bit error rate. These results are in agreement with previous simulation tests (and Cat I tests) performed at Philco-Ford facilities using simulated line networks.

The phase jitter measurements indicates that modification of the submarine cable carrier terminals has decreased phase jitter by approximately on-half to a value of nine (9) degrees peak. The frequency spectrum analysis indicates that the phase jitter still possesses discrete components of 60 Hz and multiples thereof.

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* Bit error rate ratio of switch selection diversity to equal weight diversity.

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(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

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13. ABSTRACT

This document describes the results of Category II field testing of the AN/GSC-20B wireline modem, evaluation tests of the AN/USC-12A HF radio modem and the establishment of the phase jitter characteristics of the ETR submarine cable data transmission system after modification. The testing was accomplished at Cape Kennedy AFS during the week of 23 June 1968.

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