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FINAL REPORT OF CATEGORY II TESTING ON THE PHILCO HF AND WIRELINE DATA MODEMS AND TEST SET

JANUARY 1968

R. E. Greim
F. N. Nelson, Jr.

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
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Contract AF19(628)-5165

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FOREWORD

This report was prepared by the Communications Techniques Subdepartment 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 Electronic Systems Division, Laurence G. Hanscom Field, Bedford, Massachusetts. Captain J. J. Centofanti 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.

Clement Y. Horrigan
for OTIS R. HILL, Colonel, USAF
Director of Aerospace Instrumentation
Program Office

ABSTRACT

This document describes Category II field testing of AN/USC-12 HF radio modem equipment, AN/GSC-20 wire-line modem equipment and the AN/USM-235 digital test set. Most of this testing was done during November and December 1966 between Cape Kennedy AFS and the Antigua, W.I. range station; however, a few interface tests were done at a later date subject to the availability of certain test facilities. The results of this test program are included with appropriate comments.

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SECTION I

INTRODUCTION

Background

The Air Force National Range Division's (NRD) digital communications requirements indicated a need for high speed digital data modems for use on wireline and radio circuits. As a result, a contract (AF36(300)-21510) was let to Philco Corporation (C and E Division) of Willow Grove, Pa. for the design, fabrication and production of data modems. The procurement called for wireline modems (AN/GSC-20), HF radio modems (AN/USC-12) and modem test sets (AN/USM-235). The Category I tests were completed during the fall of 1966 and the Category II field testing commenced on 21 November 1966. The latter tests were conducted on the Air Force Eastern Test Range (AFETR) with terminals at Cape Kennedy Air Force Station (CKAFS) and Antigua Air Station (ETR Station 9.1) on Antigua, West Indies. The purpose of these tests was to determine the quantitative performance of the modems and test sets in as near an operational configuration as possible.

The Category II Test Program was under the technical direction of Air Force Systems Command Electronics Systems Division (ESD) and the tests were conducted by The MITRE Corporation. The following agencies supported the test program: NRD, ETR (ETEC, ETOIC) and the Range Contractors (Pan American Airways/Guided Missile Range Division and Radio Corporation of America/Service Company). The tests were conducted under Internal Test Directive (ITD) 025.

Personnel of The MITRE Corporation had the responsibility of implementing the test equipment, conducting the field tests, and reducing and evaluating the data.

The Philco Corp. provided an engineer at each site throughout the entire test period. The engineers were responsible for initial operational setup and necessary maintenance.

Objectives

The principle objective in the conduct of these tests was to determine how well these new equipments performed in an operational environment using range transmission facilities. In addition, it was also desired to check out performance of the modems in system configurations and interface connections with other range equipment and facilities. These objectives are reflected in the five phases of the program defined in Internal Test Directive 025 as follows:

- Phase I - AN/USC-12 tests over an HF link
- Phase II - AN/GSC-20 tests on subcable channels (Note: Phases I and II were done concurrently)
- Phase III - A tandem loop-around test using the facilities of Phases I and II
- Phase IV - Compatibility test with telemetry, cryptographic and other range equipments
- Phase V - Compatibility test with other modems and transmission facilities

Secondary Objectives (Phases IV and V)

The following are the secondary objectives in order of importance:

a) Conduct tests to identify the existence of interface compatibilities between the modems and various ETR data sources and sinks.

b) Conduct tests to determine the quantitative performance of the modems on intra- and extra-range communications circuits.

c) Measure the transmission facility characteristics of the HF and subcable circuits.

AN/GSC-20 WL Modems

The AN/GSC-20 wireline (WL) modem is a four-phase, time differential, PSK system which uses four tones to achieve data transmission rates up to 2400 b/s. The tones are spaced 600 Hz apart beginning at 900 Hz and ending at 2700 Hz. Each tone channel is keyed at 300 symbols per second (baud) with each symbol containing two bits of information. Therefore, the transmitted symbol duration is 3.33 milliseconds. Bit timing synchronization at the receiver is accomplished by deriving a timing signal (at the symbol rate) from the envelopes of the four channels. This 300 Hz timing signal is then compared to a locally generated signal and digital logic brings the two signals into synchronism.

The phase detection is accomplished by a digital integration technique. To minimize the effects of intersymbol interference, only the center one-third of the keying interval is used in determining the phase difference between the two waveforms. A gate interval is initiated by an upward zero-crossing of the received tone waveform. The number of clock pulses counted during the gate interval is determined by the next upward zero-crossing of the reference waveform which terminates the gate interval. The number of gate intervals varies from 1 at the lowest tone to 4 at the highest tone. The digital phase numbers derived during the intervals are then averaged to determine the phase difference between the local reference and the received waveforms. This phase difference (in digital form) is then subtracted from the phase difference of the previous keying interval and this time differential phase is converted into the two binary digits dictated by the coding scheme.

The variety of input data rate options make this a versatile modem. The input rates may range from one 300 bps channel up to one 2400 bps with a total of 24 combinations of 300 bps, 600 bps, and 1200 bps that total no more than 2400 bps.

AN/USC-12 HF Modem

This modem is identical to the WL modem in principle of operation. However, twelve information tones are used to achieve 2400 bps operation. Each tone is keyed at 100 symbols per second (with 2 bits/symbol) resulting in a 10 millisecond keying interval. A 3.3 ms interval in the center of the symbol provides the gating interval for phase detection purposes. This longer symbol length is necessary to accommodate the multipath effects of HF radio. The phase-keyed tones are spaced 200 Hz apart beginning at 700 Hz extending to 2900 Hz. An unmodulated tone at 500 Hz is transmitted with the phase-keyed tones to provide for frequency translation correction up to a maximum frequency offset of $\pm$ 75 Hz.

This modem has an out-of-band diversity capability. The digital phase number of the two received paths are averaged prior to the binary decision, thus resulting in an equal-weight combining technique.

A variety of data rate input options, in addition to an in-band diversity (frequency) option, are provided which make this a very versatile modem from an operational standpoint. The minimum data rate input is 300 bps with a total of 35 optional combinations of 300, 600, and 1200 bps which do not exceed the 2400 bps total. As can be seen, this provides multiple, simultaneous data rate options in lieu of single serial 2400 bps operation.

Included in its salient features are rapid bit synchronization with a sync squelch provision, doppler correction and extensive use of integrated circuits and digital techniques.

AN/USM-235 Test Set

The USM-235 test set is used in conjunction with the modems in order to test them back-to-back or act as a signal source for checking remote modems and/or circuits. The test set includes a switch selectable, 23 or 24 bit, pseudo-random, digital test pattern transmitter, and an independent pattern matching receiver for error detection purposes. Other features are multiple mode operation including various master/slave combinations and a metering function for checking modem supply voltages and output levels. The test set obtains its necessary operating voltages and bit timing from the master modem. Test run lengths of 10^4, 10^5, 10^6 bits or continuous operation are switch selectable from the front panel. A TEST COMPLETE lamp lights on the front panel when a given test length has been completed. A SYNC indicator lamp lights on the front panel when the received pattern is in synchronism with the Test Set comparator generator after a start, which initiates the test run. START and STOP push-button switches are provided on the front panel, along with associated lamps, which control test operation. A RESYNC toggle switch is also provided to select either automatic or manual synchronization of the data pattern. A bit error lamp is used for visual error indication and an OUTPUT jack is provided to connect the bit error pulse to external monitoring equipment.

SECTION II

TEST CONCEPT

Scope

The scope of this text was to provide an evaluation of the performance of the Philco AN/GSC-20 wireline and AN/USC-12 HF modems in an operational environment. This is reflected in the average error rates measured over various test periods. Performance of the HF modem, relative to times of day and radio frequencies used, is also included. Discussions of the equipment operation and system configurations for compatibility testing with other equipment are also included.

This section describes how the objectives were accomplished. Details on the methods and utilization of the instrumentation and circuits are also included.

Description of Tests

Phases I and II

During these phases, an HF radio circuit (Phase I) and a subcable circuit (Phase II) were used to simultaneously transmit independent serial data patterns (at 2400 or 1200 bits per second) over the respective nominal 3 Kc channels from Antigua to CKAFS.

At Antigua, the timing signals from the individual modems (AN/USC-12 and AN/GSC-20) were used to generate the serial data patterns from their respective test sets and the data patterns were applied to the modems for transmission to CKAFS.

At CKAFS, the HF signal was received in space diversity, demodulated by the AN/USC-12 and the serial pattern obtained. This pattern was matched against a locally-generated version (derived from the AN-USM-235) and the error pattern obtained. Errors were totalized by an electronic counter, printed on paper tape and recorded along with the modem timing and frame marker signals on two channels of a 14-channel magnetic tape recorder.

In a similar fashion, the subcable demultiplexed signal was demodulated by the wireline modem (AN/GSC-20) and the serial patterns matched against another locally-generated version. Resultant errors were then totalized, printed out and recorded as for the HF channel.

Phase III

During this phase, to achieve tandem operation of the HF and wireline modems, a serial data stream was generated by an AN/USM-235 Test Set at CKAFS and applied to the AN/GSC-20 wireline modem for transmission to Antigua via the subcable.

At Antigua, the demultiplexed modem audio signal was demodulated by the wireline receive modem and the output digital data pattern fed to the AN/USC-12 HF modem for retransmission to CKAFS. The received timing of the wireline modem was used as transmit timing for the HF modem. Then, at CKAFS, the serial data stream derived from the HF modem was processed as in the individual test runs of Phase I.

Phase IV

The tests conducted during this phase were to determine the interface compatibility between the selected modem (either HF or Wireline) and various range data sources and sinks (e.g., telemetry, radar, secure equipment, etc.). Data patterns used for error checking purposes were dictated by the data sources to be interfaced with. The data was transmitted from Antigua to CKAFS.

Phase V

The tests in this phase consisted of local loop tests conducted to determine the digital interface compatibility of the AN/USC-12 and AN/GSC-20 modems with other range data modems. This phase also included tests to determine the operational performance of the wireline modem when transmitting over circuits having Schedule 4B transmission facility characteristics.

SECTION III

TEST CONFIGURATION

Test Circuits

In order to conduct the tests on the two types of modems, an HF radio circuit and a submarine cable circuit were set up between Antigua, whose prime function was to be the transmitting terminal, and Cape Kennedy, the receiving terminal.

The HF radio circuit, designated, P-27, was utilized during Phases I and III of the test program. The decision as to which HF frequency would be used for test operation was based upon the following factors:

1) What is the proper operating frequency based upon the Central Radio Propagation Laboratory (CRPL) prediction for that period?

2) What is the nearest range operating frequency to the predicted one?

3) If this frequency currently being used for range operations and, if not, how is the interference situation?

If the prime frequency was unavailable then a slightly lower frequency, if available, would be used for test purposes. The CRPL frequency predictions appear in later illustrations.

The testing of the wireline modem (AN/GSC-20) was conducted between the two terminals by using the range submarine cable circuits. Depending upon the amount of range testing and operations, various cable channels were allocated for test purposes. During Phase II, an uprange channel (Antigua to CKAFS) was used and during the tandem operation of the two modems in Phase III, a downrange channel was used. There are eight stations along the cable which serve as data entrance or data drop-off points, thus, the modem audio signal is frequency multiplexed and demultiplexed seven times by the subcable multiplex equipment during transmission to Cape Kennedy.

Voice communications between the two test terminals was available primarily on a subcable circuit, however, an HF radio voice channel was utilized when there was a lack of subcable channels.

Phases I and II

During Phases I and II of the test program, the Antigua terminal transmitted the digital data to CKAFS using the HF and wireline modems on the radio and subcable circuits. This configuration is illustrated in Figure 1. The digital data generated by the AN/USM-235 Test Sets was applied to the respective data modems. After transmission via their respective circuits, the signals were received at Cape Kennedy and demodulated by the AN/USC-12 and AN/GSC-20 modems. The received digital data was applied to the individual test sets for error measuring purposes. Since sufficient test instrumentation was available, simultaneous testing was possible. The errors that occurred on the circuits, were totalized in electronic counters and the cumulative total printed out by digital printers on a one minute basis coincident with the time of day. Simultaneously, the error signals were recorded on magnetic tape with their respective bit timing signals to provide data for fine-grained error distribution analysis.

Phase III

During Phase III, the functions of the wireline modems at the two sites were reversed. The digital data was generated by the wireline modem test set at CKAFS and transmitted to Antigua where the received digital data was applied to the HF modem for transmission back to Cape Kennedy via HF radio. This configuration verified the tandem operation capability of the two modems. As in Phases I and II all error measurements were conducted at Cape Kennedy. The equipment configuration during this phase is also indicated in Figure 1 by the dotted lines.

Phase IV

The purpose of this phase was to determine the interface compatibility of the modems with range digital data equipment and voice encryption devices.

First, the wireline modem was used to determine its compatibility with the SPAC (Signal Programmer and Conditioner) unit of the telemetry station at Antigua and with the RTTDS (Real Time Telemetry Data System) located in the Tel IV building on Merritt Island. Test messages generated by the SPAC were transmitted by the wireline modem via the subcable and demodulated by the wireline modem at Tel IV. The digital data output was then checked for validity by the RTTDS. As is indicated in Figure 2, the equipment configuration, the timing of the Antigua wireline modem was provided by the

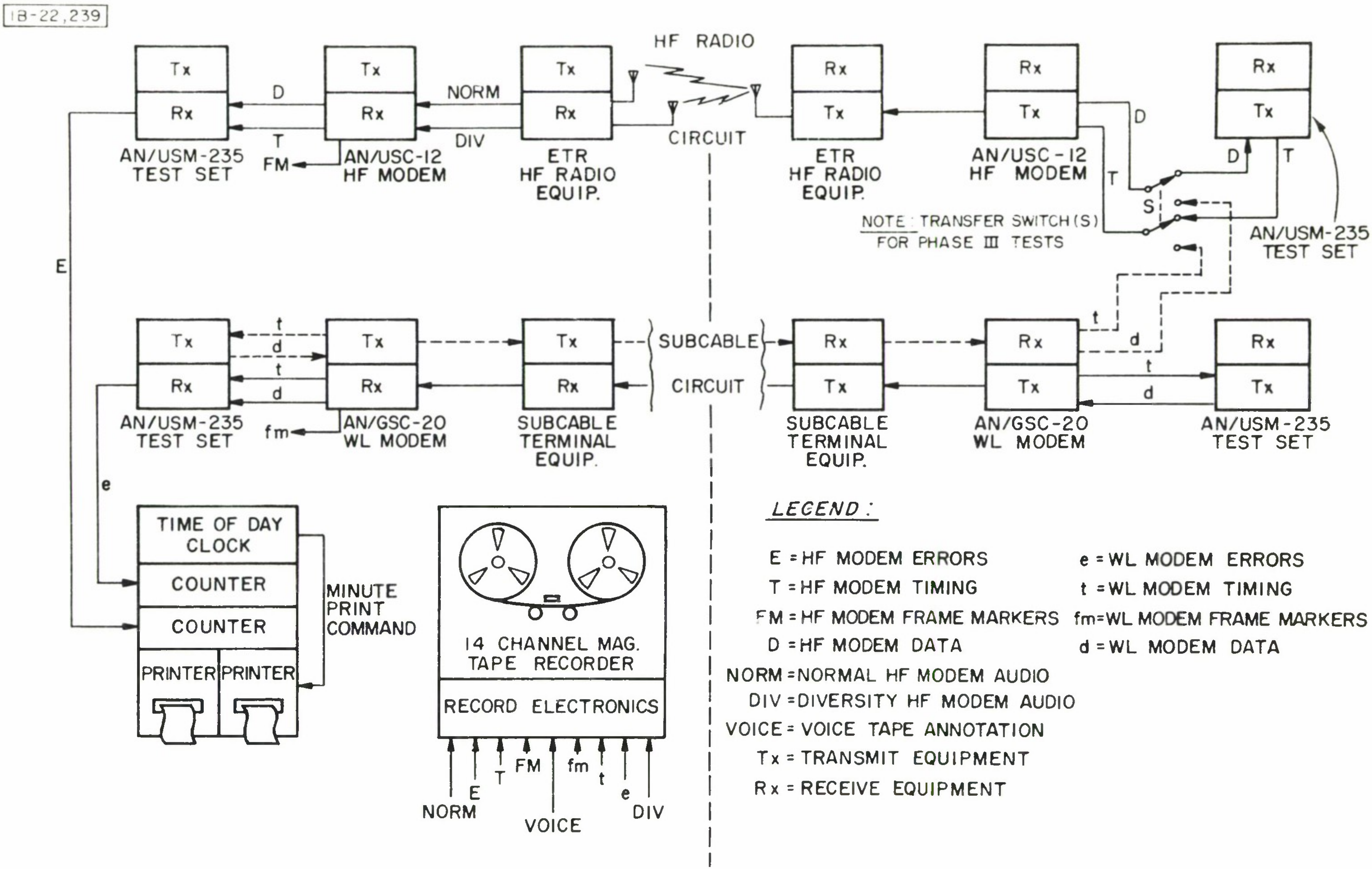

Figure 1. TEST CONFIGURATION (PHASES I - III)

SPAC unit and the RTTDS unit was driven by the receiver modem timing.

Another test was conducted to verify the compatibility of the wireline modem with a voice encryption (digitizing) device. At Antigua, prerecorded rhyming tapes were played into a KY-585 Vocoder and the vocoder digital output applied to the modem for transmission to CKAFS. At the Cape, the digital output of the modem was fed to the receiving vocoder and its audio output was recorded. Voice communications between sites were also attained using the telephone handsets supplied with the vocoder equipment. This equipment configuration is shown in Figure 3.

Compatibility of the modem with data encryptographic equipment (KG-13) and digital data multiplexing/demultiplexing equipment (Rixon DTMU) was also tested. These tests were also conducted locally at Cape Kennedy and the test configuration used is shown in Figure 4.

Phase V

The test conducted during this phase involved the verification of the digital interface between the AN/USC-12 and AN/GSC-20 modems and other data modems that are used on the range. Also included in this phase were tests of the GSC-20 operation on Schedule 4B telephone circuits.

Since the digital outputs of the AN/USM-235 Test Sets are not to MIL-188B specifications, it was necessary to set up the modems in a back-to-back configuration to achieve the necessary input/output MIL-188B interfaces for the other modems. These configurations are shown in Figures 5 and 6.

The operation of the wireline modem on a Schedule 4B-quality telephone circuit was tested later on a looped basis between the Goddard Space Flight Center (GSFC) and the Cape and the configuration is shown in Figure 7.

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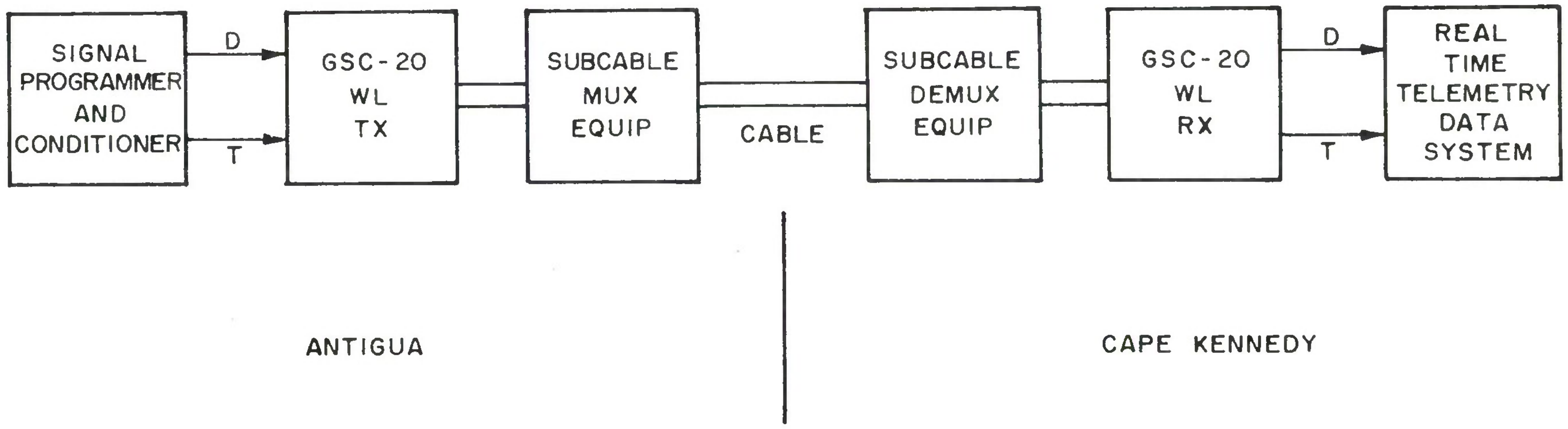

Figure 2. TELEMETRY EQUIPMENT - WIRELINE MODEM CONFIGURATION

IA- 22,227

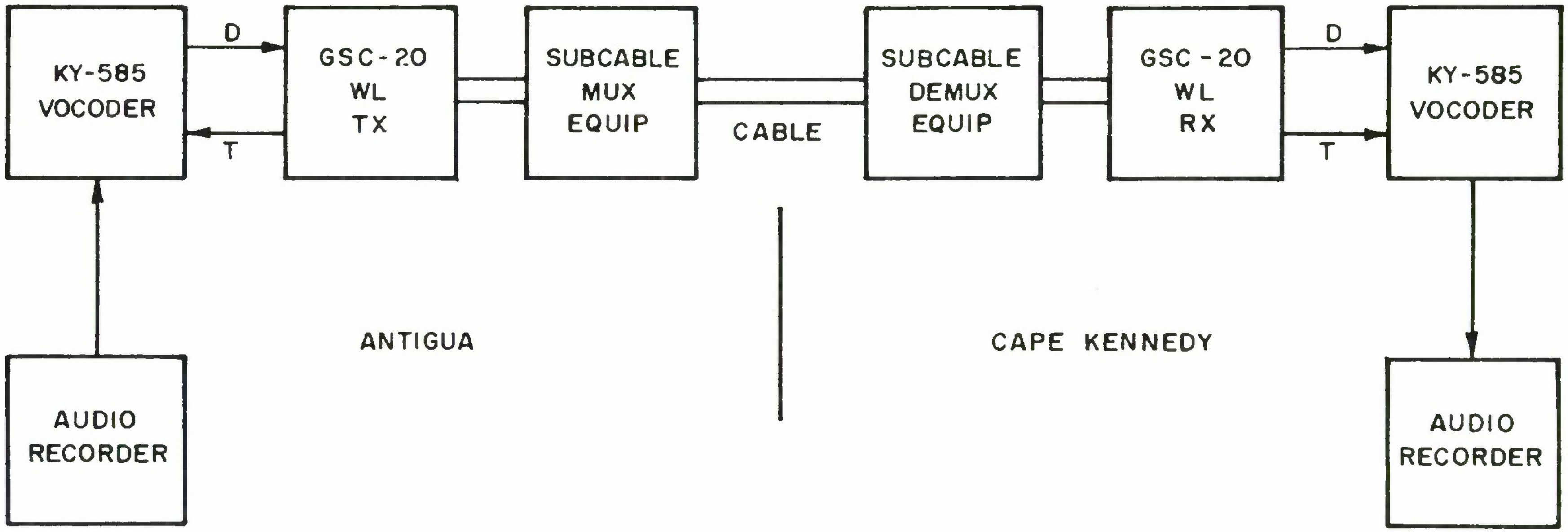

Figure 3. VOCODER/WIRELINE MODEM INTERFACE CONFIGURATION

IA-22,229

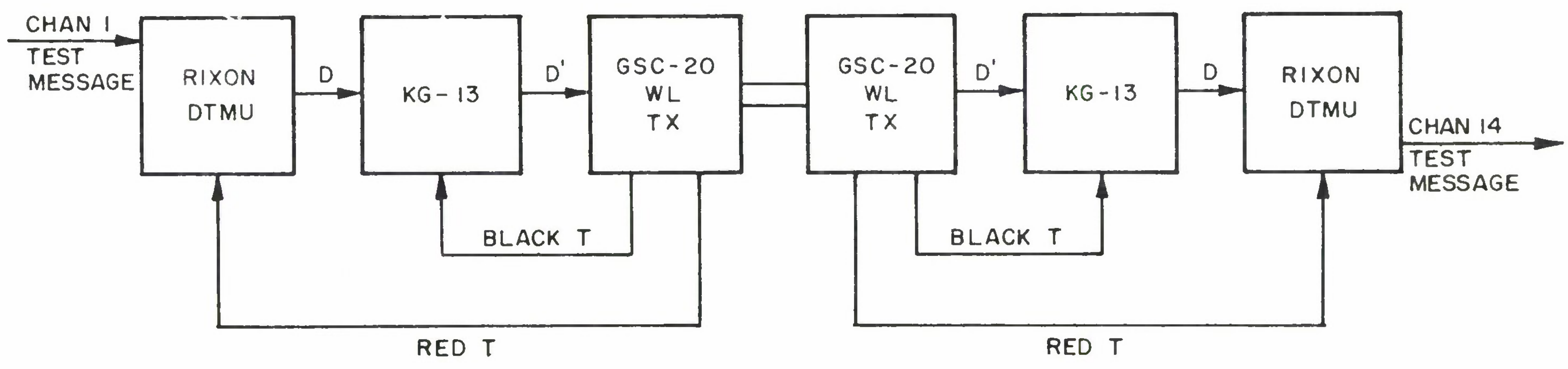

Figure 4. MULTIPLEX-CRYPTO EQUIPMENT/WIRELINE MODEM INTERFACE CONFIGURATION

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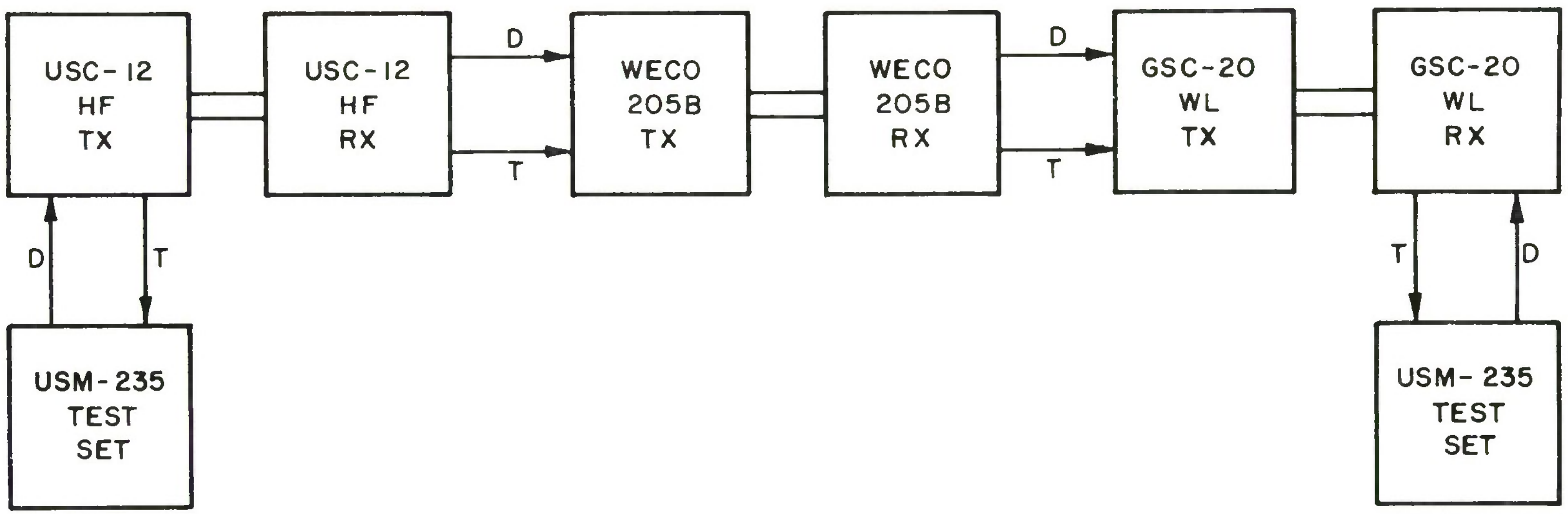

Figure 5. WESTERN ELECTRIC/PHILCO MODEMS INTERFACE CONFIGURATION

IA-22,231

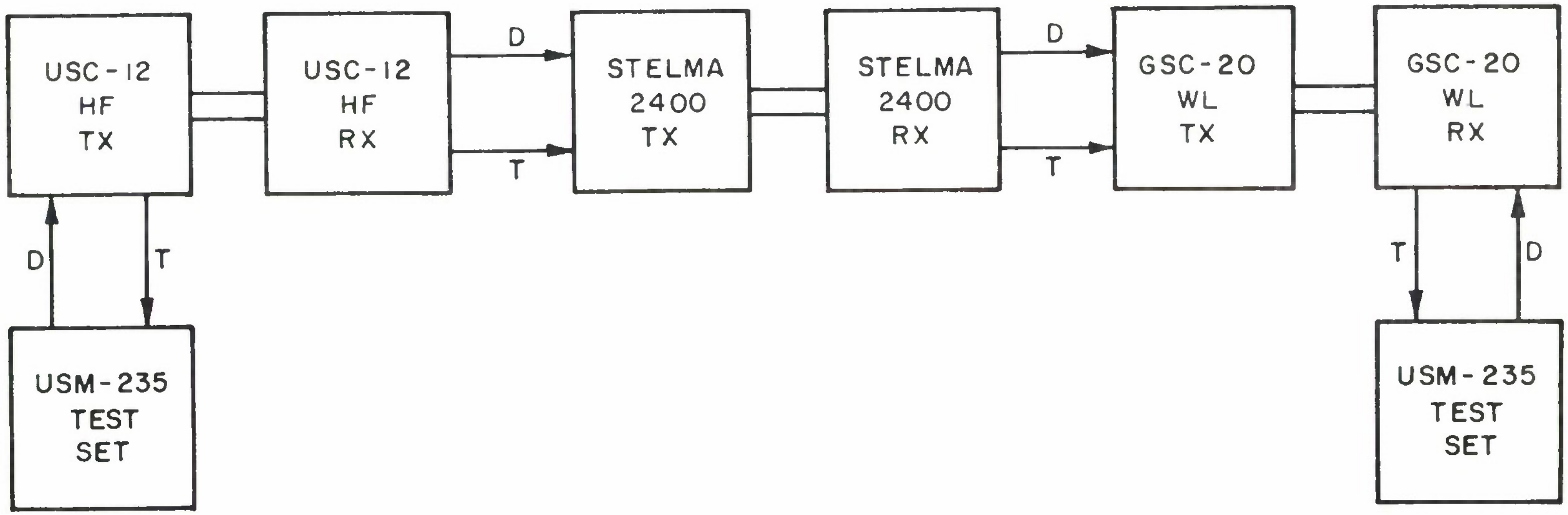

Figure 6 STELMA/PHILCO MODEMS INTERFACE CONFIGURATION

IA-22,232

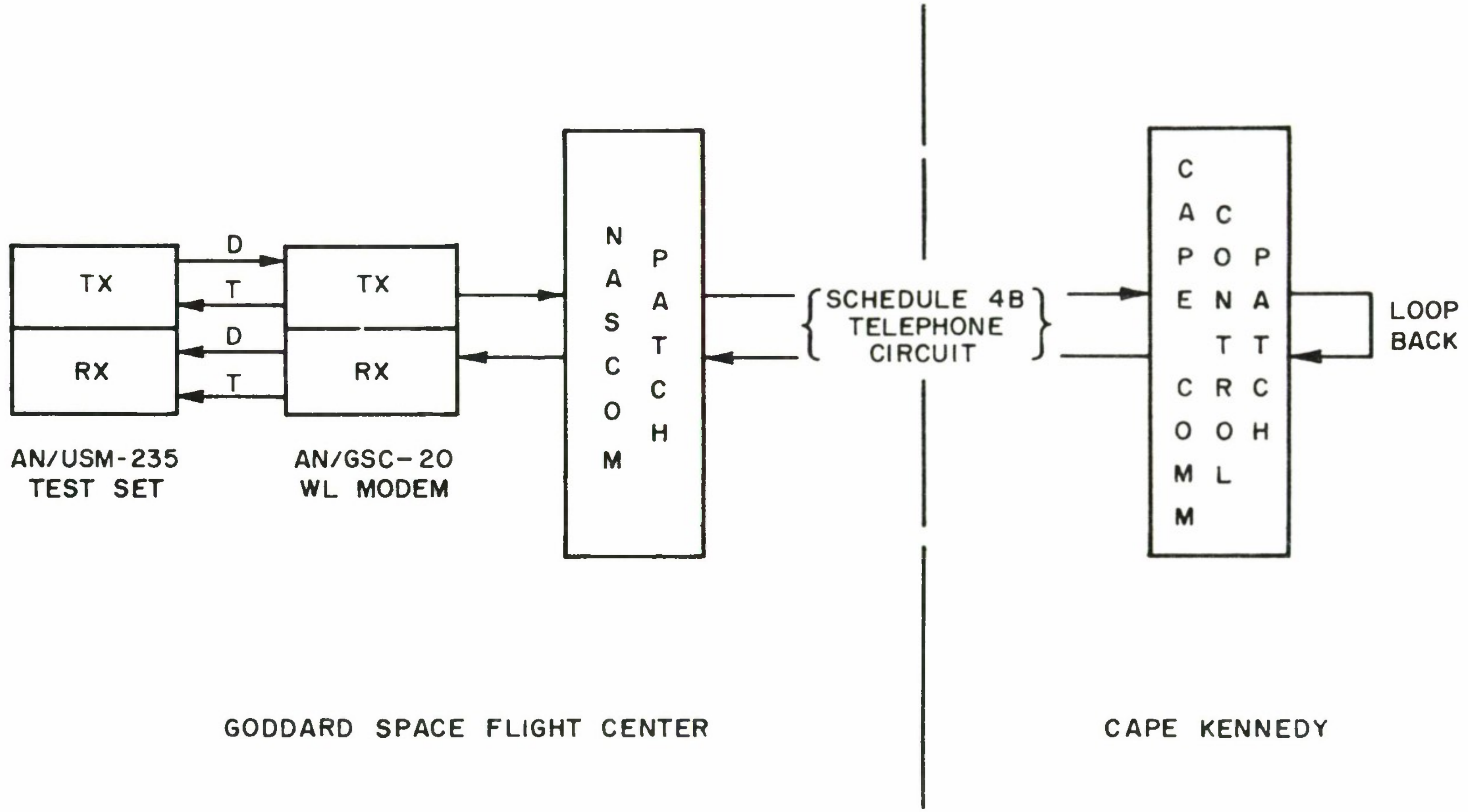

Figure 7. SCHEDULE 4B CIRCUIT TEST CONFIGURATION

SECTION IV

CONDUCT OF THE TESTS

During the test period, testing was conducted on a seven day per week basis unless pre-empted by actual live range operations. The subcable and radio circuits were generally available during the greater part of each day although the majority of the testing was concentrated in the daylight and evening hours.

A total of 70 hours of operational test data was accumulated during Phases I and II. An additional eight hours was utilized during Phase III. The remaining phases required approximately 50 hours to set up and test.

The lack of facilities prevented the conduct of some tests originally programmed for inclusion within the Category II test program. These items include tests involving AUTOVON circuits and range radar data equipments. Tests utilizing Emergency Bank facilities were also omitted due to the planned phase-out of this equipment.

SECTION V

DATA REDUCTION

As previously mentioned, minute-by-minute cumulative error totals of both modems were provided by the digital printers. The error data of each minute on the HF modem paper tape printouts were formatted on punched computer cards. The cards were then processed in a digital computer whose program was capable of providing the cumulative distribution of error rates based upon various time interval sizes (1 minute, 10 minute, etc.) A ten minute sample size was chosen since it would provide sufficient data points to characterize the operational performance of the HF modem.

Because of the large number of error-free 10 minute intervals within the wireline modem paper tape printouts, the cumulative distribution of the error performance was manually calculated.

SECTION VI

TEST RESULTS

Cumulative Error Rate Performance (HF)

The AN/USC-12 modem performance (Figure 8) exhibited an average bit error rate of approximately 6×10^{-4} under a variety of conditions, i.e. high and low mean signal strengths, no fading, deep fading, marginal circuit conditions, etc. In addition, optimum frequency choice was not always selected since the secondary objectives of the test program involved collection of error patterns under a wide variety of circuit conditions.

There were no problems in achieving modem synchronization or framing synchronization for the USM-235 test set. Diversity operation was observed and it was noticed that on the lower operating frequencies the fading on the diverse paths appeared to be too well correlated for good diversity action which suggests antenna orientation and spacing problems at these frequencies. Observations of diversity action at frequencies where the diverse path fading was sufficiently independent yielded error rate improvements of about two to one. This data was meagre and although it provided a qualitative feeling for the diversity effectiveness it was not sufficiently conclusive to present herein.

Cumulative Error Rate Performance (WL)

The AN/GSC-20 modem performance, shown in Figure 9, exhibited error rates of 1×10^{-6} or less in 90% of the 10 minute samples examined and the majority of the 90 minute runs were error-free. This data was taken on a relatively good circuit as indicated in the submarine cable characteristics of Figure 10, however, tests on regularly scheduled telephone wirelines produced somewhat higher error rates as indicated in later results. Considering the versatility of this equipment, it should prove to be an excellent performer under a wide variety of situations. Up to 2 milliseconds of delay equalization can be accomodated on the four tones, and careful adjustment will assure good performance.

Effects of Operating Frequencies on HF Modem

The procedure used by the range personnel in the selection of the proper HF frequencies to be used during each day is mainly based upon monthly propagation predictions received from the Central Radio

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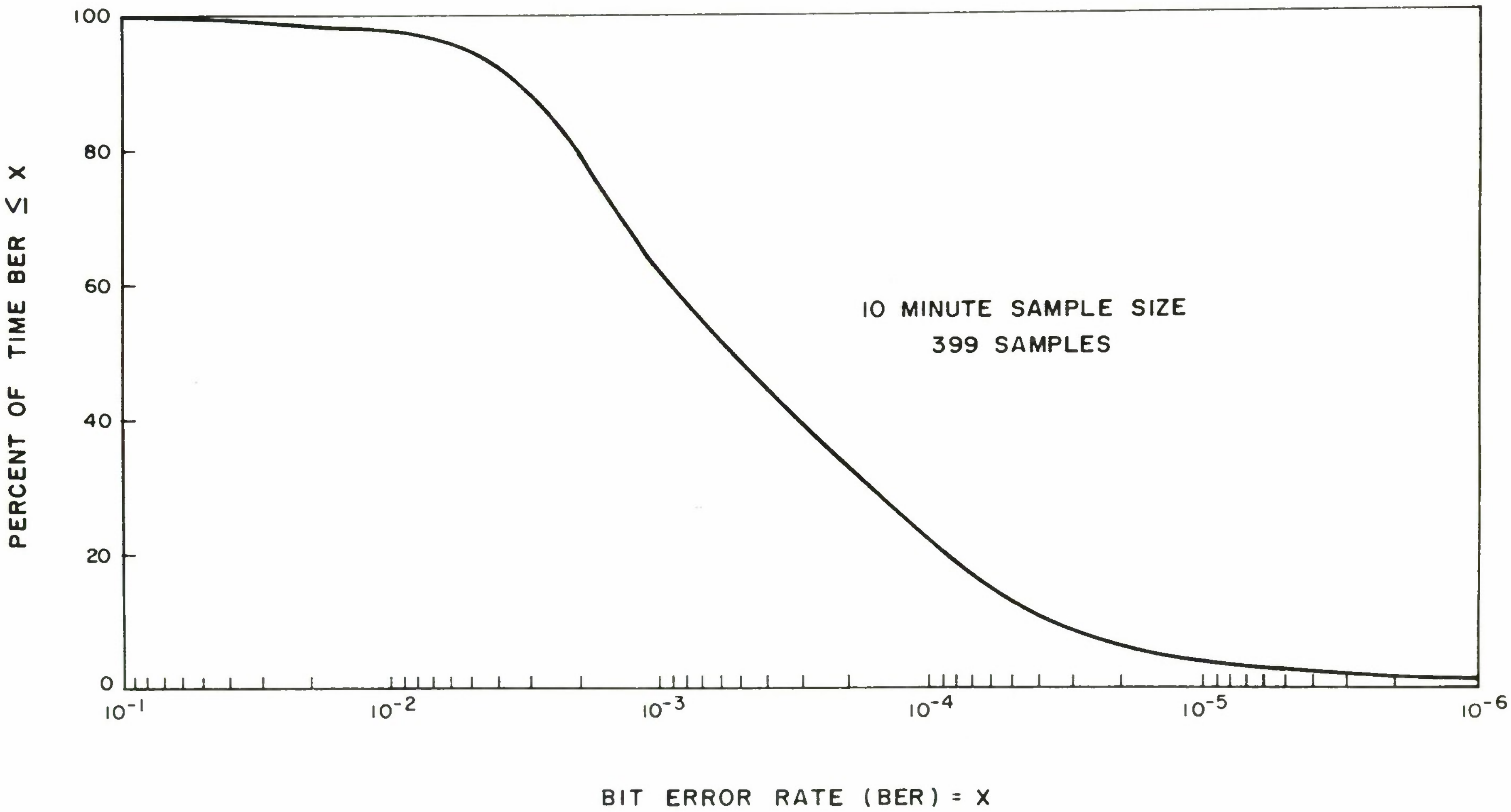

Figure 8. AN/USC-12 HF MODEM PERFORMANCE

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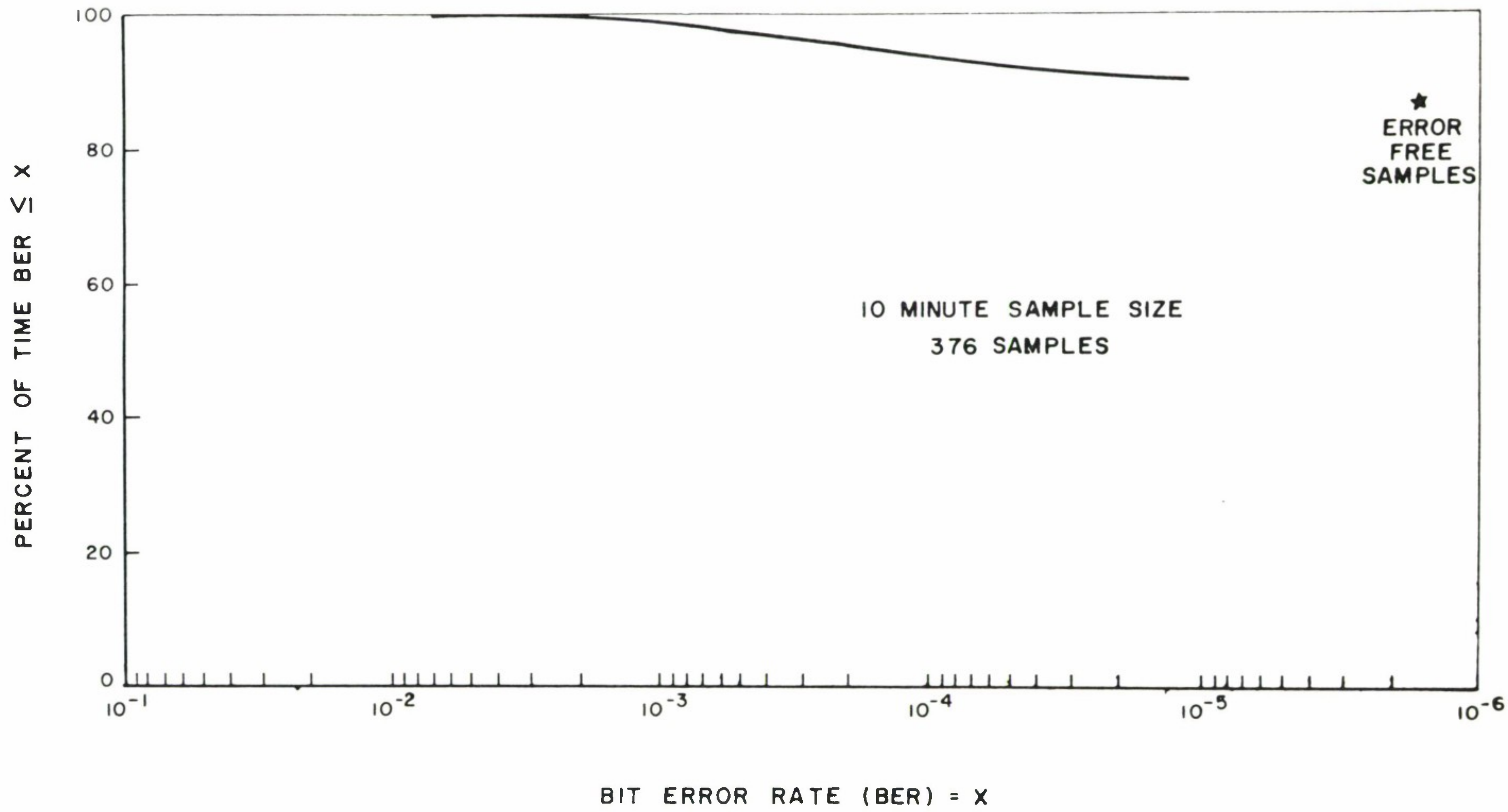

Figure 9. AN/GSC-20 WIRELINE MODEM PERFORMANCE

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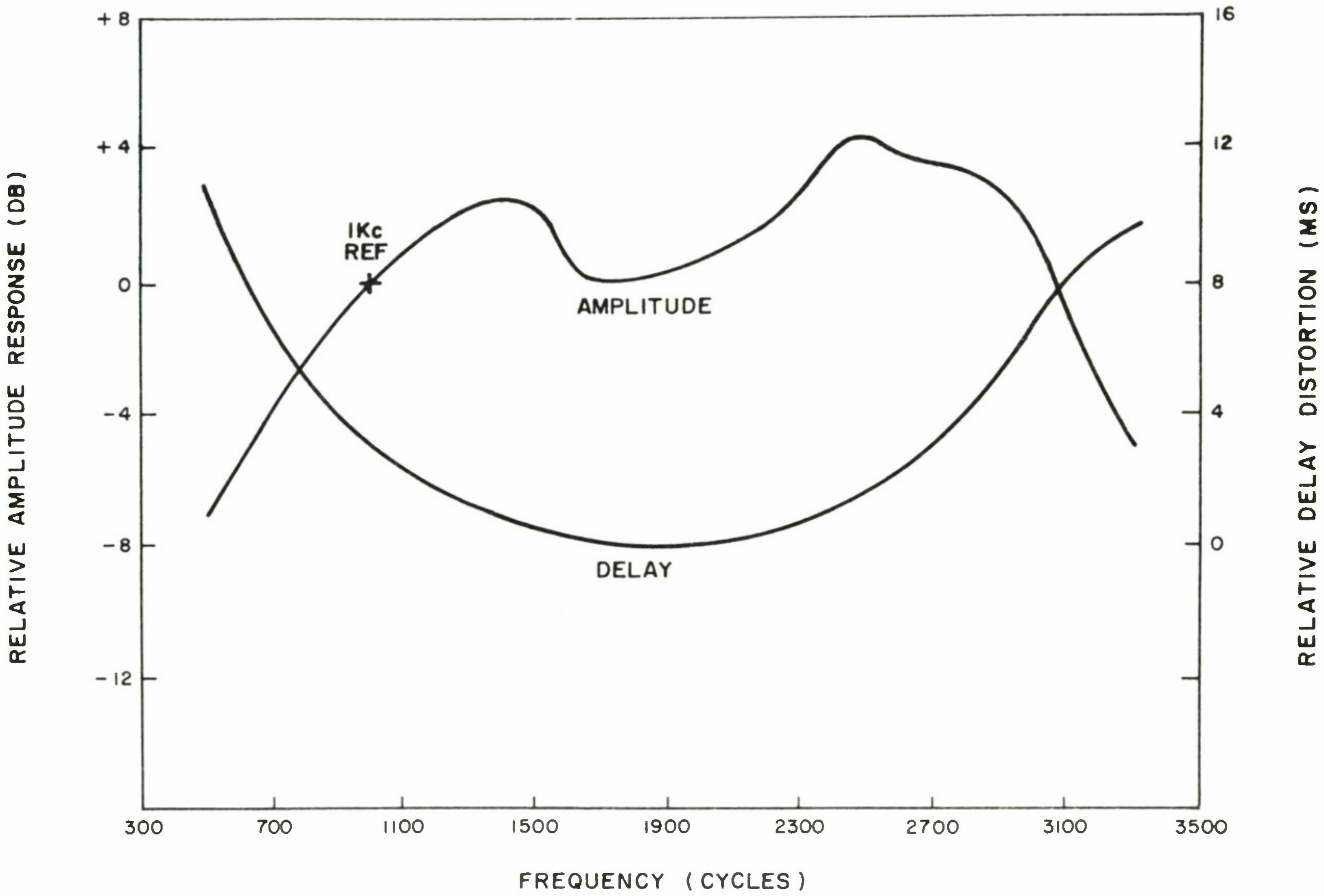

Figure 10. SUBCABLE CHANNEL CHARACTERISTICS
ANTIGUA - CAPE KENNEDY CHANNEL 4 LOOPED

Propagation Laboratory (CRPL) of the National Bureau of Standards. These predictions indicate the optimum working frequencies (FOT) and lowest usable frequencies (LUF) throughout the day between the designated circuit terminals.

These predictions are only rough guidelines for frequency selection and the frequency assignment nearest the FOT is normally used if interference is not present. Ideally, oblique ionospheric sounder equipment should be used to provide real-time propagation data relative to short-term variations which are characteristic of the ionosphere.

In general, modem performance improves as the operating frequency approaches the FOT since this minimizes the multipath and absorption effects. Figures 11 thru 13 are plots illustrating the effect of operating frequency on modem performance. Since the predictions are only an estimate of the propagation medium and the frequency assignments limited making operation near the FOT not always possible, then no clear-cut results can be extrated, although trends are indicated.

In Figure 11, the effect of operating frequency upon modem performance is fairly well correlated since the performance does degrade as the FOT drops below the operating frequency. In Figure 12 the performance improves as the FOT drops down to the operating frequency and since the slope of the FOT curve is very steep, the performance degrades quickly as the FOT falls below the operating frequency. Figure 13 shows the performance versus the most frequently used operating frequency during the tests and some improvement is indicated where the FOT approaches the operating frequency, especially from 1800 to 0000 EST.

Philco Modem Telemetry Equipment Interface

Tests were conducted to verify the interface compatibility of the wireline modem and the SPAC (Signal Programmer and Conditioner) unit at Antigua (transmit terminal) and the modem and the RTTDS (Real Time Telemetry Data System) unit located at the Tel IV building (receive terminal) on Merritt Island.

At Antigua, a spare clock driver circuit was substituted for the normal data driver circuit in order to provide a bi-polar data input signal to the wireline modem. The SPAC unit data signal is normally a uni-polar NRZ signal which is incompatible with the MIL 188B interface of the modem. This minor modification was

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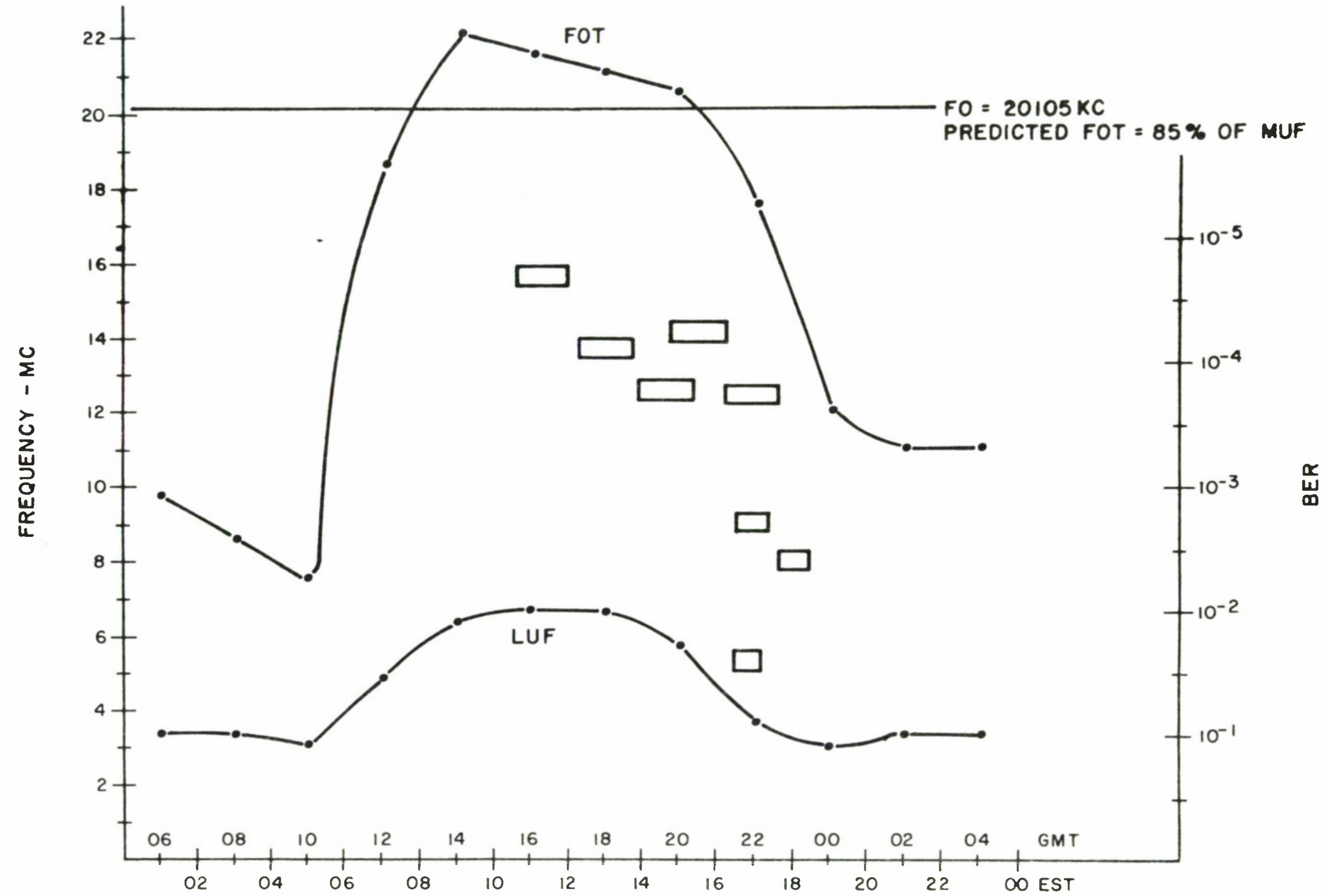

Figure 11. TIME OF DAY VS. PREDICTED FOT/LUF AND BER AT 20 MHz

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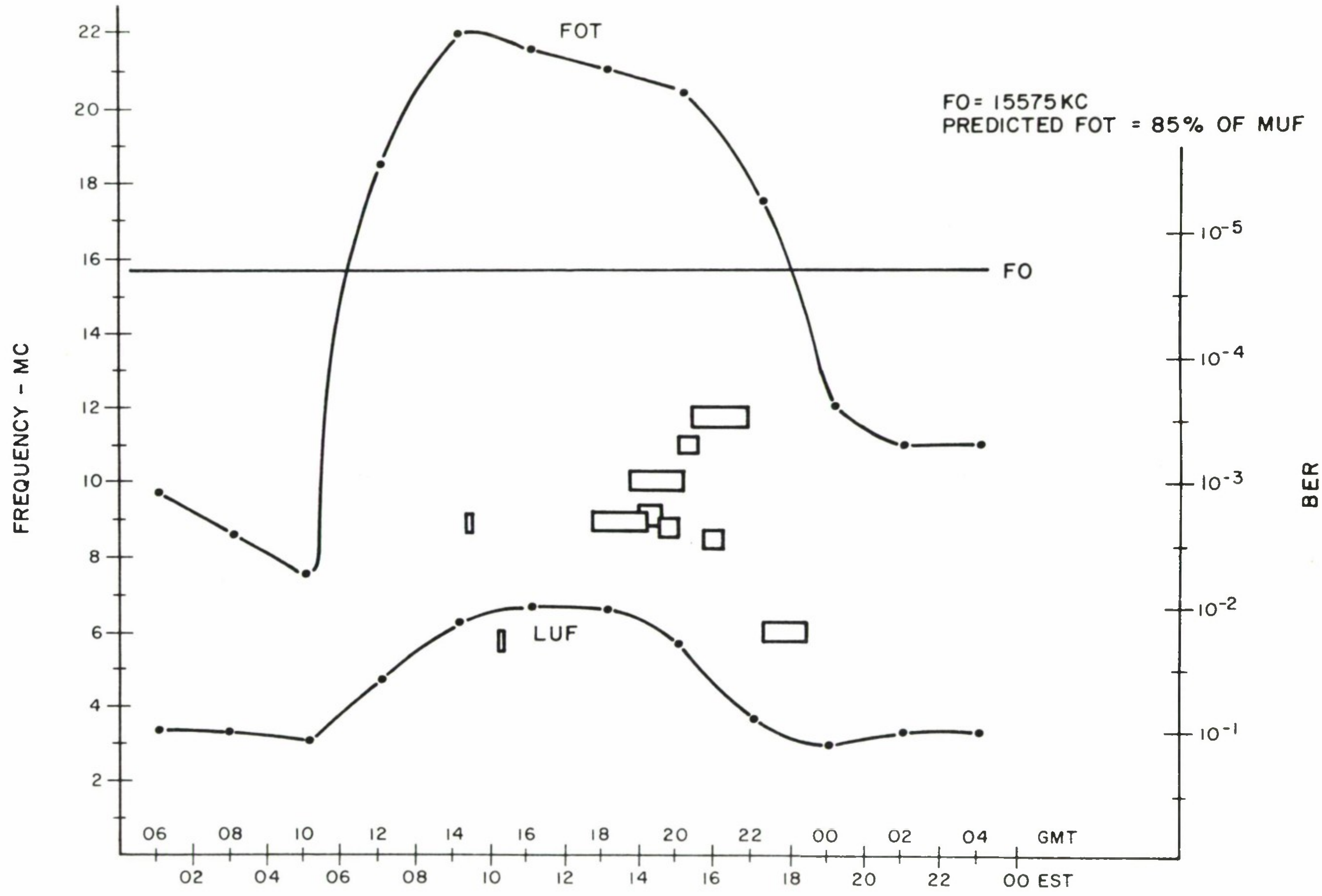

Figure 12. TIME OF DAY VS. PREDICTED FOT/LUF AND BER AT 20 MHz

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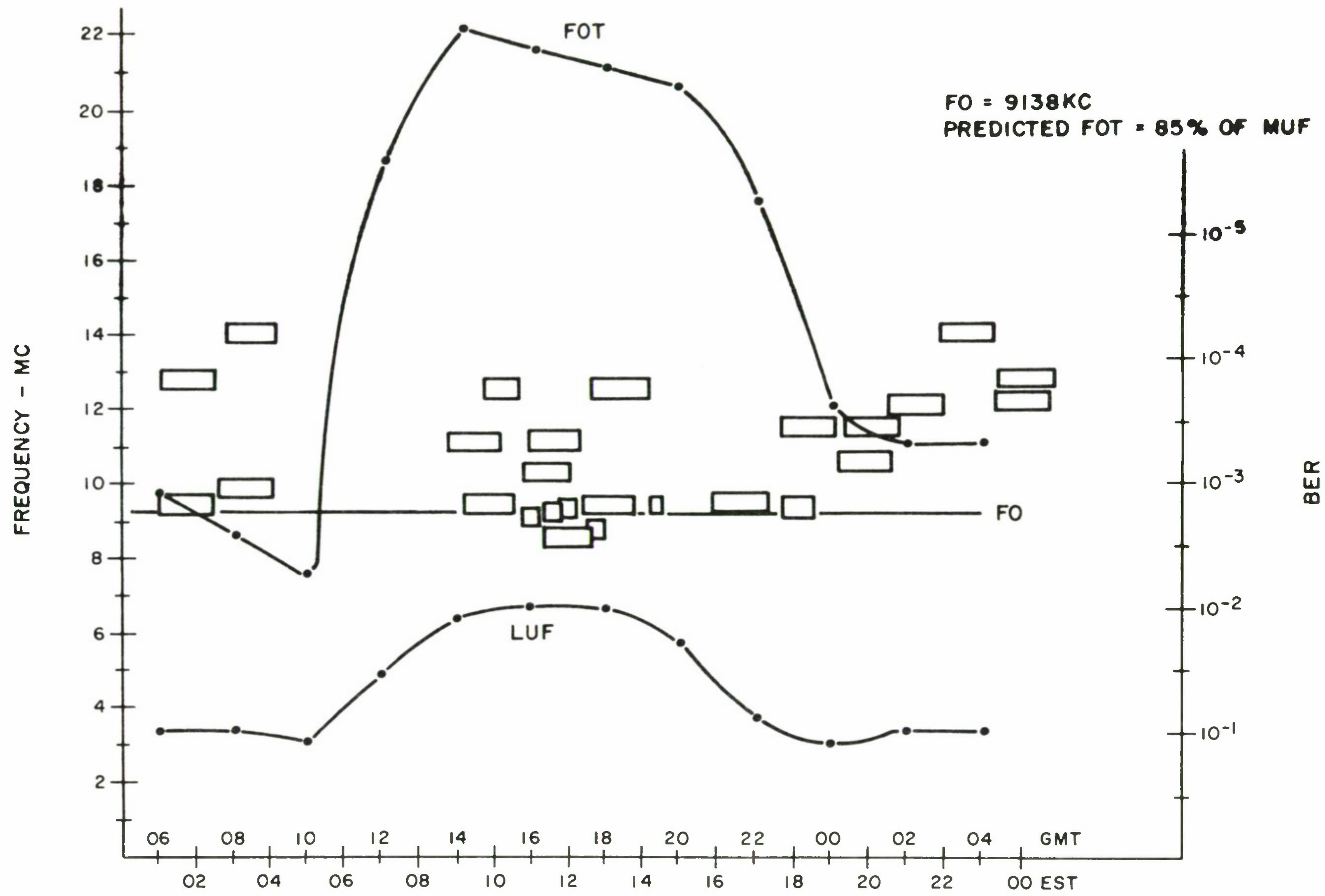

Figure 13. TIME OF DAY VS. PREDICTED FOT/LUF AND BER AT 9.1 MHz

incorporated by range contractor (PAA Engineering) personnel. The timing, provided by the SPAC unit to the modem was no problem since it was a bi-polar signal.

At Tel IV, the digital data output and corrected receiver timing were fed to the RITDS unit. Range contractor personnel then transmitted a number of test messages to verify that the equipments were operating properly. After sending test messages having programmed errors in them, a test run of approximately one hour was made during which no error occurred.

WECo 205B - Philco Modems Interface

In order to provide MIL 188B interfaces on both the transmit and receive sides of the Western Electric 205B wireline modem and utilize the AN/USM -235 Test Sets, it was necessary to operate the HF modem back-to-back with its associated test set on the transmit side of the 205B and operate the wireline modem back-to-back with its test set on the 205B receive side (Figure 5). The 23 bit pseudo-random pattern of the test set was utilized as the test message. A strapping option of the AN/GSC-20 modem was employed to provide the correct phase relationship between the data and timing into the 205B transmitter.

The testing was conducted on a local loop basis at Antigua, since no 205B modems were readily available at Cape Kennedy. The test message was transmitted through the equipment configuration for an hour during which no errors occurred.

Stelma 2400 - Philco Modems Interface

By substituting the Stelma Model 2400 HF modem for the Western Electric 205B, the same equipment configuration was utilized to check the digital interface compatibility between the Stelma and Philco modems. The local loop tests did show that the MIL 188B interfaces of the Philco modems and the RS-232A interfaces of the Stelma modem are compatible as was the case for the 205B tests. This was verified by transmitting the 23-bit pattern at 2400 bits per second through the equipment setup for one hour with no errors.

KY-585-Philco Modem Interface

Tests were also conducted to verify that the Philco Modem interfaced with the KY-585 Vocoder equipment. Rhyming tapes were replayed into the KY-585 audio input at Antigua and then transmitted to Cape Kennedy via the submarine cable. The audio vocoder output was monitored and recorded. The handsets supplied with the vocoders, were also used for voice communications between Antigua and Cape Kennedy. The level of intelligibility was found to be dependent upon the volume of the voice and during the tape recordings the audio input was decreased and resulted in improved intelligibility. The correct timing - data phase relationships must be used in order to ensure proper equipment operation.

Rixon Teletype Multiplex - Wireline Modem Interface

Because of the system configuration at Cape Kennedy, it was impossible to directly interface the wireline modem and Rixon Data Terminal Multiplex Unit (DTMU). Normally, the DTMU equipments are used to transmit secure traffic and buffer amplifiers are used to isolate the timing input signals from the data signals. It was found that the buffer amplifiers would not respond to the rise time of the MIL 188B timing signals generated by the wireline modem.

To determine if the system will operate if non - MIL 188B signals are used, the rise time of the modem timing signals was purposely shortened. After bypassing the Alarm Modules (used to indicate loss of channel identity under normal secure operating conditons), a teletype test word was inserted into one parallel channel of the transmit DTMU. On the receive side, since channel identity is not guaranteed without employing some sort of synchronization device, the sixteen receive DTMU teletype outputs were sampled until the test pattern was located.

Although it seems as though the system will function properly if the DTMU and modem are interfaced directly on a digital logic basis, range contractor personnel have indicated that continued use of the buffer amplifier concept is intended. Therefore, the conclusion of this interface test is that the buffer amplifiers are not compatible with the MIL 188B interface specifications and that they should be modified to respond to the specified signals.

Encryption Equipment - Wireline Modem Interface

Coincident with the Rixon DTMU interface testing, tests were also conducted to verify the compatibility of MIL 188B interfaces of the KG-13 Encryption equipment and the AN/GSC-20 Wireline Modem. By using the non-MIL 188B timing signals in conjunction with the DTMU terminals and supplying standard MIL-188B interface signals to the KG-13, a test message was transmitted through the system on a local basis. The audio connection between the modems was interrupted for a short duration (a few minutes) causing errors in the output test message. After returning the audio connection, the message reappeared in the same DTMU output channel without any errors.

Modem Operation On Typical Schedule 4B Circuits

Since the wireline modem was tested on a submarine cable circuit whose delay and amplitude response characteristics did not comply with those of a Schedule 4B circuit, it was decided that additional performance data on telephone landline circuits would be desirable. Therefore, tests have been conducted on a looped, Schedule 4B circuit between the NASA Goddard Space Flight Center (GSFC) and Cape Kennedy with favorable results.(average error rate of 5×10^{-6}).

SECTION VII

CONCLUSIONS AND RECOMMENDATIONS

AN/GSC-20 Wireline Modem

The results of the averaging of 10 minute samples experienced over the submarine cable circuit are shown in the cumulative performance curve discussed in Section VI. Since 95% of these samples yielded bit error rates better than 1×10^{-5} the performance over this media was found to be excellent. Approximately 86% of the 90 minute runs taken ran error free. This performance is considered quite satisfactory for range circuits of this type and these units should prove to be extremely versatile because of their many data rate options.

Loop tests on actual Schedule 4B circuits made between Goddard Space Flight Center (GSFC) and CKAFS using the GSC-20 and averaging 90 minute runs demonstrated bit error rates approximately 5×10^{-6}. Examination of the detailed Schedule 4B requirements suggest that a circuit just meeting the schedule as far as distortion in the 2600-3000 c.p.s. region is concerned might prove marginal using this modem since the highest signaling tone is at 2700 cps.

AN/USC-12 HF Modem

Cumulative results taken on 10 minute samples of the HF circuit test data show a median error rate rate of approximately 6×10^{-4} which is considered representative for this type of circuit. A study is currently in progress to implement a more efficient diversity combining scheme.

AN/USM-235

The digital test set performed well throughout all tests with both modems. These test sets will provide range personnel with a convenient checking device to rapidly assess modem performance during test and maintenance periods. It is recommended that a modification to the test set be considered which includes an additional test mode pattern of repetitive data cross-overs to facilitate modem alignment. (Alignment is presently accomplished by a special strapping option within the modem.)

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13. ABSTRACT

This document describes Category II field testing of AN/USC-12 HF radio modem equipment, AN/GSC-20 wire-line modem equipment and the AN/USM-235 digital test set. Most of this testing was done during November and December 1966 between Cape Kennedy AFS and the Antigua, W.I. range station; however, a few interface tests were done at a later date subject to the availability of certain test facilities. The results of this test program are included with appropriate comments.

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