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AUTOMATED PERFORMANCE MONITORING AND ASSESSMENT FOR DCS DIGITAL SYSTEMS

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As an aid in evaluating technical control techniques, an emulation facility that automatically performs the status monitoring, performance assessment, and fault isolation transmission control functions as they apply to the digital Defense Communications System (DCS) has been developed. This emulation facility is a multicomputer system which automatically monitors and isolates faults for digital transmission equipments. The status monitoring and performance assessment functions

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are performed by two processors, the Adaptive Channel Estimator (ACE) and an LSI 11/03, the composite being referred to as the CPMAS-D unit. When the software residing in the CPMAS-D unit detects a monitor point transition, it transmits the monitor point information to the CPMAS Emulator, a PDP 11/60 minicomputer. These messages, called exception reports, enable the CPMAS Emulator to perform its prime mission: fault isolation.

A unique fault isolation algorithm has been developed for test with this emulation facility. The algorithm consists of three discrete steps. First, the equipment alarms are mapped into their effect upon each transmission path (link, supergroup, group, or channel). Second, the stations with the faulty equipment are located by deleting the impact of sympathetic alarms. Third, the faulty equipment is identified using the equipment alarm status.

Testing of the fault isolation algorithm is enhanced by an emulated network consisting of up to 16 stations, 2048 equipments, and two nodal control areas. Monitor point simulators and T1-4000 multiplexers, which provide simulated and real inputs to two CPMAS-D units, are also part of the emulation facility. Technical control terminals are provided to evaluate man/machine operation in an automated technical control environment.

ACKNOWLEDGEMENT

This program was performed for the Rome Air Development Center with Mr. Charles Meyer as the responsible Contracting Officer's representative. All those at GTE Sylvania associated with the program wish to acknowledge the support and helpful guidance of Mr. Meyer. We also wish to acknowledge the assistance of Mr. Robert Meyer of Clarkson College and Mr. David Perreault of Boston University for their technical review and guidance to GTE Sylvania in support of Mr. Charles Meyer.

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SUMMARY

This final report documents the successful technical effort provided by the Sylvania Systems Group, Eastern Division, to the Rome Air Development Center (RADC) to accomplish the program objectives of design, development and test of the Automated Performance Monitoring and Assessment System for DCS Digital Systems. The effort on this program, also known as CPMAS-Communications Performance Monitoring and Assessment System, was performed from February 1978 to January 1980 as the option phase of RADC Contract F30602-76-C-0433. Using the digital DCS, i.e., the DCS that will utilize DRAMA radios and multiplexers as the microwave communications backbone, performance assessment techniques and a fault detection/isolation algorithm were designed and tested.

Contained in this final report is a detailed description of CPMAS and the functions that were implemented during the CPMAS option phase. This option phase was preceded by a six-month study phase, during which alternative approaches for performance assessment and fault detection/isolation were evaluated. The results of the study phase have been documented in a Final Technical Report dated 28 April 1977.[1] Highlights of that phase include an evaluation of the DCS Digital Transmission System with the view toward deriving sizing information for a representative 16-station network, which was subsequently used as a basis during the option phase for evaluating nodal level algorithms. Additionally, parameters were evaluated for assessing performance of the DCS, which led to the development and test of an Adaptive Channel Estimator (ACE) for assessing link performance, and the development and test of CPMAS-D, a unit that acquires performance information. If performance is out of tolerance, the CPMAS nodal level processor, a PDP 11/60, is notified. During the study phase various approaches for fault detection and isolation of the DCS were also evaluated, and the resultant implemented algorithm is discussed in Section 2.3 of this report.

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[1] "Automated Performance Monitoring and Assessment for DCS Digital Systems," 28 April 1977.

This program examined future concepts and techniques for automating the transmission control functions for DCS digital communication facilities. These facilities are characterized by low- and high-speed data circuits, voice access through PCM encoding, multiple stages of time-division multiplexing, digital modulation, and both microwave line-of-sight and troposcatter transmission.

As an aid in evaluating transmission control techniques, an emulation facility has been developed that automatically performs the status monitoring, performance assessment and fault isolation transmission control functions as they apply to the digital DCS. This emulation facility is a multicomputer system which automatically monitors and isolates faults for digital transmission equipments. The status monitoring and performance assessment functions are performed by two processors, the Adaptive Channel Estimator (ACE) and an LSI 11/03, the composite being referred to as the CPMAS-D unit. When the software residing in the CPMAS-D unit detects a monitor point transition (alarm to/from non-alarm) it transmits the monitor point information to the CPMAS Emulator, a Digital Equipment Corporation (DEC) PDP 11/60 minicomputer. These messages, called exception reports, enable the CPMAS Emulator to perform its prime mission: fault isolation.

A unique fault isolation algorithm (Section 2.3) has been developed for test with this emulation facility. The algorithm consists of three discrete steps. First, the equipment alarms are mapped into their effect upon each transmission path (link, supergroup, group, or channel). Second, the stations with the faulty equipment are located by deleting the impact of sympathetic alarms. Third, the faulty equipment is identified using the equipment alarm status.

Testing of the fault isolation algorithm is enhanced by an emulated network consisting of up to 16 stations, 2048 equipments, and two nodal control areas. Monitor point simulators which provide simulated inputs to two CPMAS-D units are also part of the emulation facility. Nodal and Sector technical control terminals are provided to evaluate man/machine operations in an automated technical control environment.

An Adaptive Channel Estimator (ACE) field test was conducted at the Rome Air Development Center (RADC) test facilities so that the ACE development unit could be evaluated as a means of assessing performance of high-speed digital radio transmission systems. Also, the fault-isolation algorithm was tested using the previously described emulation facility. The test data and subsequent technique evaluations are discussed in Sections 3 and 4.

To accomplish the objective of the CPMAS program, tasks were performed as shown in Figure 1, CPMAS Task Flow. Initially the majority of the effort was performed in the system's engineering process of ensuring the efficacy of the previous study effort and subsequently generating the hardware/software design requirement documents. Using these documents as a baseline the ACE, CPMAS-D, and Emulator hardware and software were implemented and tested on a unit basis. The Adaptive Channel Estimator, very early in the program, was tested at RADC so that the design could be finalized, based on actual field test data, identified as ACE Preliminary Field Test in Figure 1. At GTE Sylvania the total system underwent extensive integration tests using, as a source of network status, the monitor point simulator and the emulated 16-station network in the PDP 11/60. All deliverable items were then successfully installed and checked out at RADC and the requisite documentation completed. Based on the results of this program, recommendations for future research and development are identified in Section 6. The seven areas recommended for future R&D are: (1) CPMAS emulation facility tests, (2) Sector level fault isolation, (3) CONUS link tests, (4) operational environment tests, (5) CPMAS and ATEC interface, (6) CPMAS baseline reexamination, and (7) ACE investigation.

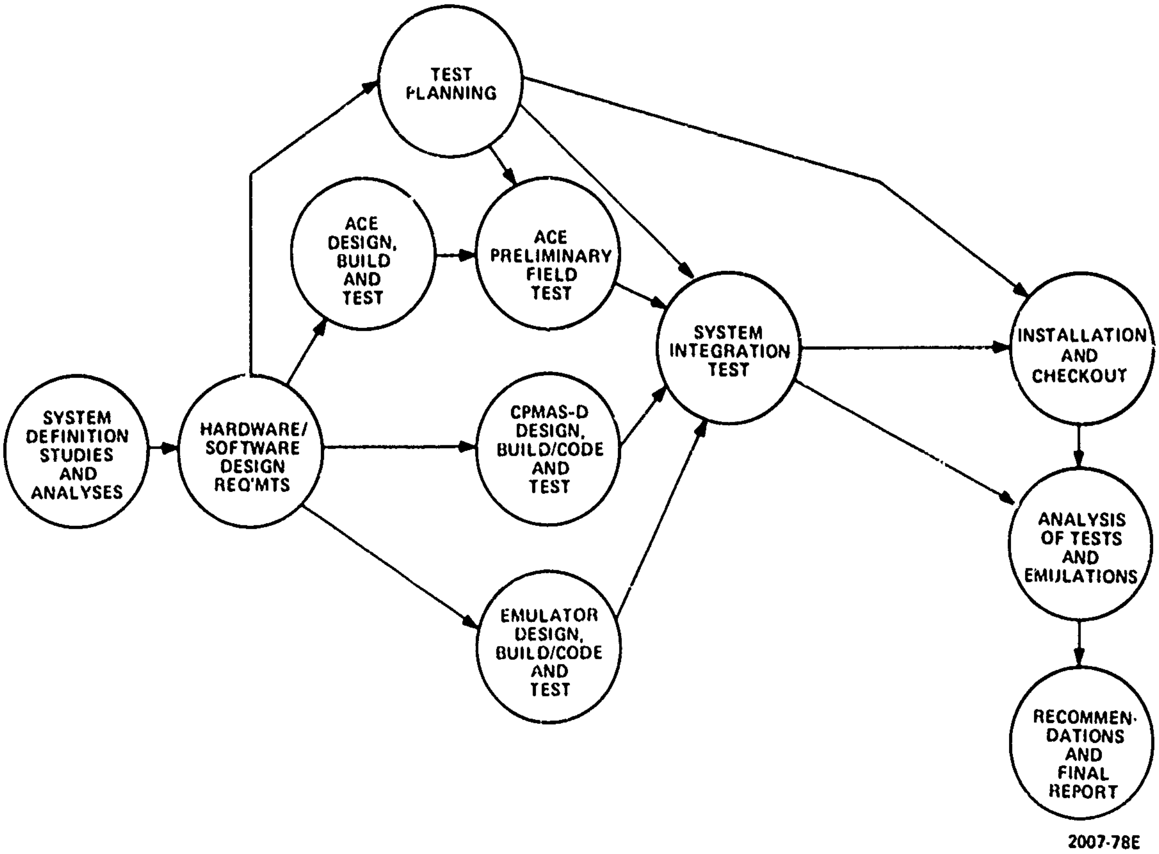

Figure 1. CPMAS Task Flow

EVALUATION

In direct response to Department of Defense requirements, this effort fostered the investigation of (1) a general fault isolation algorithm for digital communications networks, and (2) a theoretically superior digital radio performance assessment technique based on channel estimation. The technology emanating from this program is adaptable to any digital communications network and is computer implementable. Preliminary testing indicates that both the fault isolation algorithm and the radio performance monitor have excellent potential to provide material improvements in existing and future communications networks.

This effort was conducted under RADC technology program objective (TPO) I entitled C^3; subthrust A, entitled Support C^3; and sub-sub-thrust 1.C., Communications, System Control.

Important work is continuing on both the fault isolation algorithm and the adaptive channel estimation (ACE) technique. Verification and extensive performance data gathering on the fault isolation capability will be undertaken in-house at RADC employing the contract delivered emulator for exercising the algorithm. Review of the ACE capacities is being undertaken by MITRE Corporation. The ultimate application is to provide enhancements which may readily be integrated into the ESD SPO's Automated Technical Control (ATEC) System program in the mid 1980 time period.

Charles Meyer
CHARLES N. MEYER
Project Engineer

SECTION 1

INTRODUCTION AND SUMMARY

Sylvania Systems Group, Eastern Division, is pleased to submit this final report documenting the successful technical effort provided to the Rome Air Development Center (RADC) to accomplish the program objectives of design, development, and test of the Automated Performance Monitoring and Assessment System for DCS Digital Systems. The effort on this program, also known as CPMAS-Communications Performance Monitoring and Assessment System, was performed from February 1978 to June 1980 as the option phase of RADC Contract F30602-76-C-0433. Using the digital DCS, i.e., the DCS which will utilize DRAMA radios and multiplexers as the microwave communications backbone, performance assessment techniques and a fault detection/isolation algorithm were designed and tested.

1.1 INTRODUCTION

This final report contains a detailed description of CPMAS and its functions which were implemented during the CPMAS option phase. This option phase was preceded by a six-month study phase, during which alternative approaches for performance assessment and fault detection/isolation were evaluated. The results have been documented in a Final Technical Report dated 28 April 1977.[1] Highlights of that phase include an evaluation of the DCS Digital Transmission System with the view toward deriving sizing information for a representative 16-station network which was subsequently used as a basis during the option phase for evaluating nodal level algorithms. Additionally, parameters were evaluated for assessing performance of

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[1] "Automated Performance Monitoring and Assessment For DCS Digital Systems," 28 April 1977.

the DCS, which led to the development and test of an Adaptive Channel Estimator (ACE) for assessing link performance, and the development and test of CPMAS-D, a unit that acquires performance information and, if performance is out of tolerance, the CPMAS nodal level processor, a PDP 11/60, is notified. During the study phase various approaches for fault detection and isolation of the DCS were also evaluated, and the resultant implemented algorithm is discussed in Section 2.3 of this report.

1.2 SUMMARY

This program examined future concepts and techniques for automating the transmission control functions for DCS digital communication facilities. These facilities are characterized by low- and high-speed data circuits, voice access through PCM encoding, multiple stages of time-division multiplexing, digital modulation, and both microwave line-of-sight and troposcatter transmission.

As an aid in evaluating transmission control techniques, an emulation facility that automatically performs the status monitoring, performance assessment, and fault isolation transmission control functions as they apply to the digital DCS has been developed. This emulation facility is a multicomputer system which automatically monitors, and isolates faults for digital transmission equipments (power generators, RF distributions, digital radios, second level multiplexers, first level multiplexers, submultiplexers, and key generator units). The status monitoring and performance assessment functions are performed by two processors, the Adaptive Channel Estimator (ACE) and an LSI 11/03, the composite being referred to as the CPMAS-D unit. When the software residing in the CPMAS-D unit detects a monitor point transition (alarm to/from non-alarm) it transmits the monitor point information to the CPMAS Emulator, a Digital

Equipment Corporation (DEC) PDP 11/60 minicomputer. These messages, called exception reports, enable the CPMAS Emulator to perform its prime mission; fault isolation.

A unique fault isolation algorithm has been developed for test with this emulation facility. The algorithm consists of three discrete steps. First, the equipment alarms are mapped into their effect upon each transmission path (link, supergroup, group, or channel). Secondly, the stations with the faulty equipment are located by deleting the impact of sympathetic alarms. Third, the faulty equipment is identified using the equipment alarm status.

Testing of the fault isolation algorithm is enhanced by an emulated network consisting of up to 16 stations, 2048 equipments, and 2 nodal control areas. Monitor point simulators which provide simulated inputs to two CPMAS-D units are also part of the emulation facility. Nodal and Sector technical control terminals are provided to evaluate man/machine operations in an automated technical control environment.

An Adaptive Channel Estimator (ACE) field test was conducted at the Rome Air Development Center (RADC) test facilities so that the ACE development unit could be evaluated as a means of assessing performance of high-speed digital radio transmission systems. Also, the fault-isolation algorithm was tested using the previously described emulation facility. The test data and subsequent technique evaluations are discussed in Sections 3 and 4.

1.3 DELIVERABLE ITEMS

Figure 1-1, CPMAS Feasibility System, shows the hardware items delivered under the contract. They are specifically:

a. 2 each, Monitor Point Simulators
b. 2 each, CPMAS-D units
c. 2 each, ACE units
d. 2 each, T1-4000 multiplexers
e. 1 each, CPMAS Emulator.

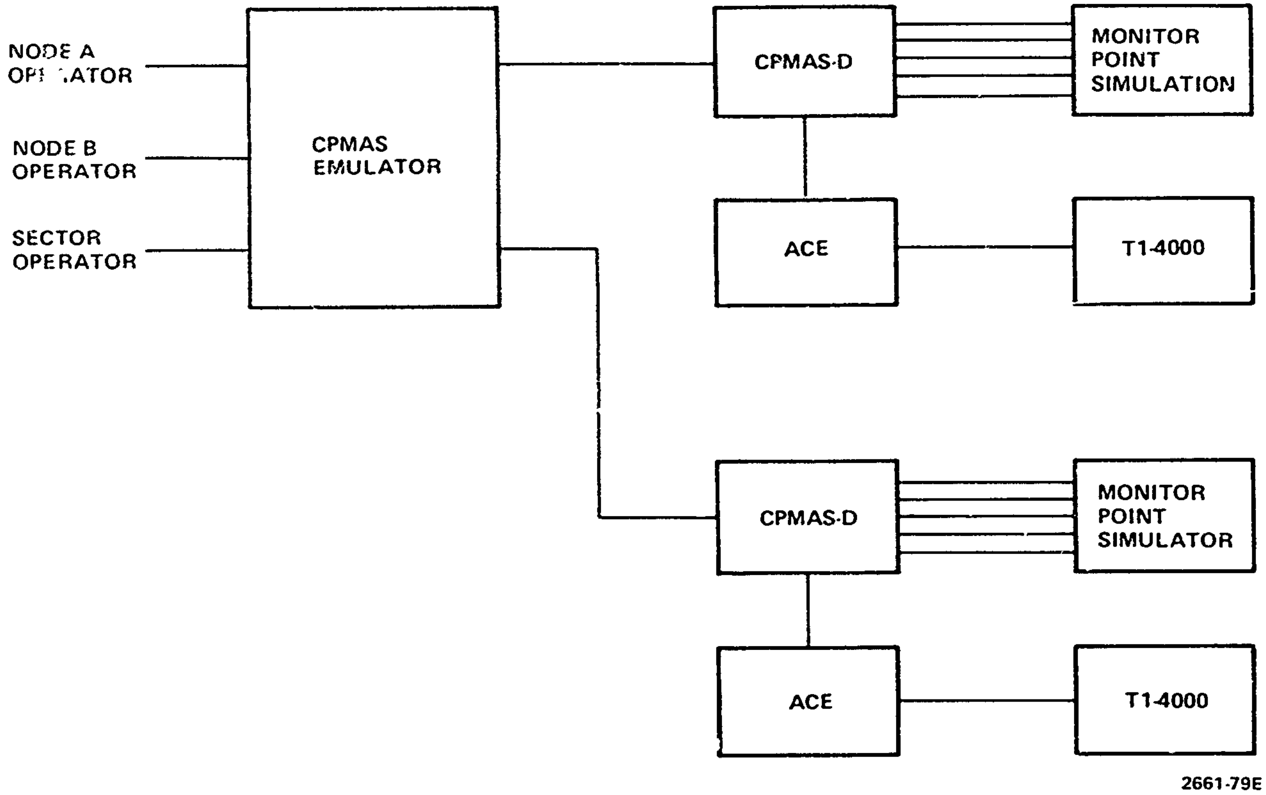


Figure 1-1. CPMAS Feasibility System

The CPMAS Emulator, which provides the nodal functions, consists of a Digital Equipment Corporation PDP 11/60 System (Figure 1-2) which consists of:

a. CPU
b. 124k words of main memory
c. 2 each, 7-megaword disk pack disks
d. 1 - 256k word fixed-head disk
e. 1 - 250k byte floppy disk
f. 1 magnetic tape unit
g. 1 line printer
h. 2 each, Keyboard/CRT units.

The hardware items are discussed in Section 2.

All PDP 11/60 software is written in FORTRAN IV PLUS, as is CPMAS-D software, except for a very small percentage which is in DEC MACRO 11 language. The ACE algorithms are implemented in programmable read only memory (PROM) modules. CPMAS functions are identified in the block diagram of Figure 1-3, which shows the interrelationship among the four major items; namely, the monitor point simulator, ACE, CPMAS-D and the CPMAS Emulator. CPMAS Emulator functions are implemented in software, as are the CPMAS-D functions except for the monitor interface, which is hard-wired logic. The test bed simulator is also hard-wired logic. In Section 2 CPMAS software is discussed further.

In Tables 1-1 and 1-2 are listed the Specification Documentation and Test Documentation which have been delivered. These documents contain the detailed descriptions of CPMAS requirements and test results and should be referenced if that detail is required.

1.4 TASK FLOW

To accomplish the objective of the CPMAS program, tasks were performed as shown in Figure 1-4, CPMAS Task Flow. Initially the majority of the effort was performed in the system's engineering process of ensuring the efficacy of the previous study effort and subsequently generating the hardware/software

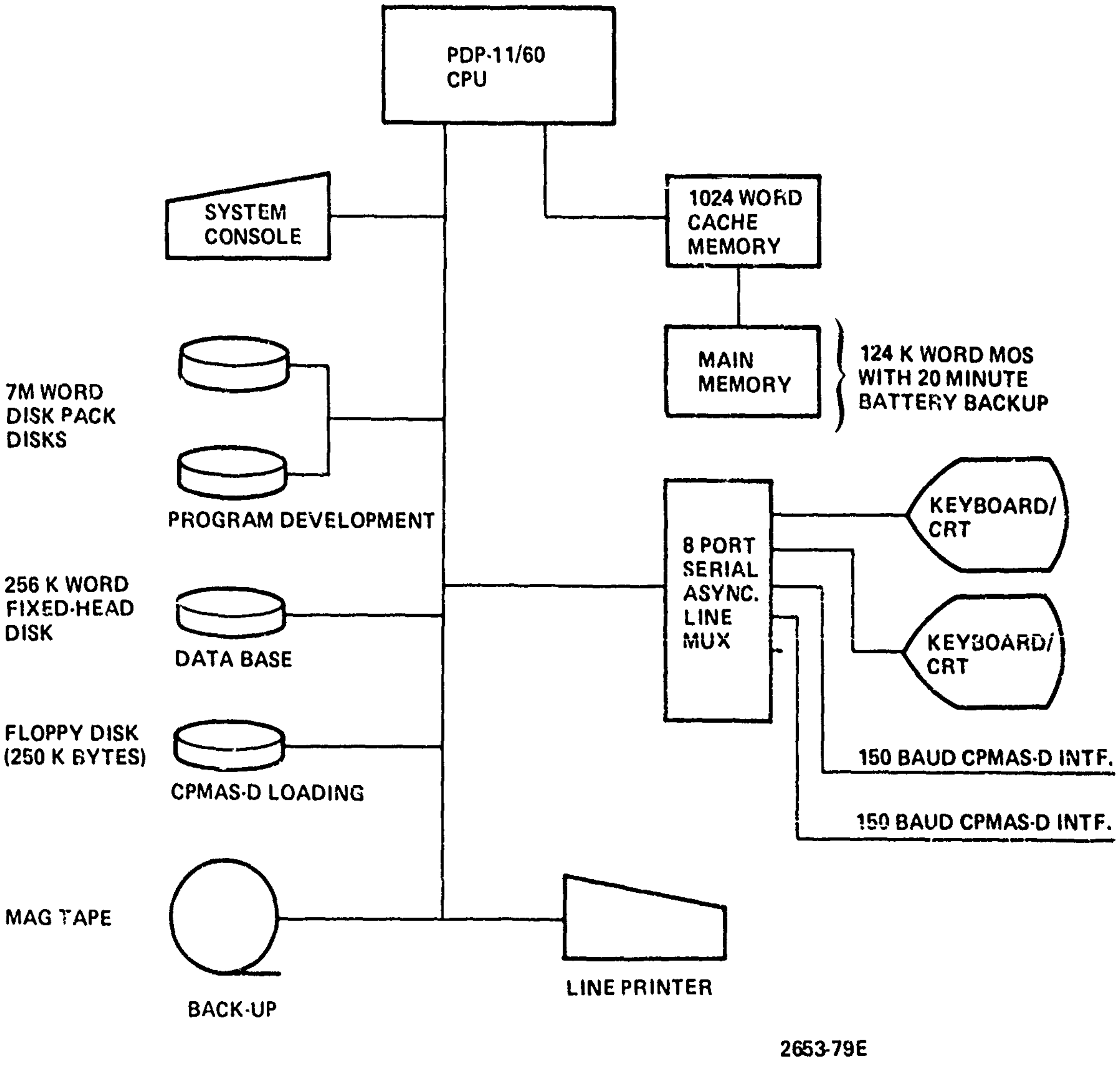
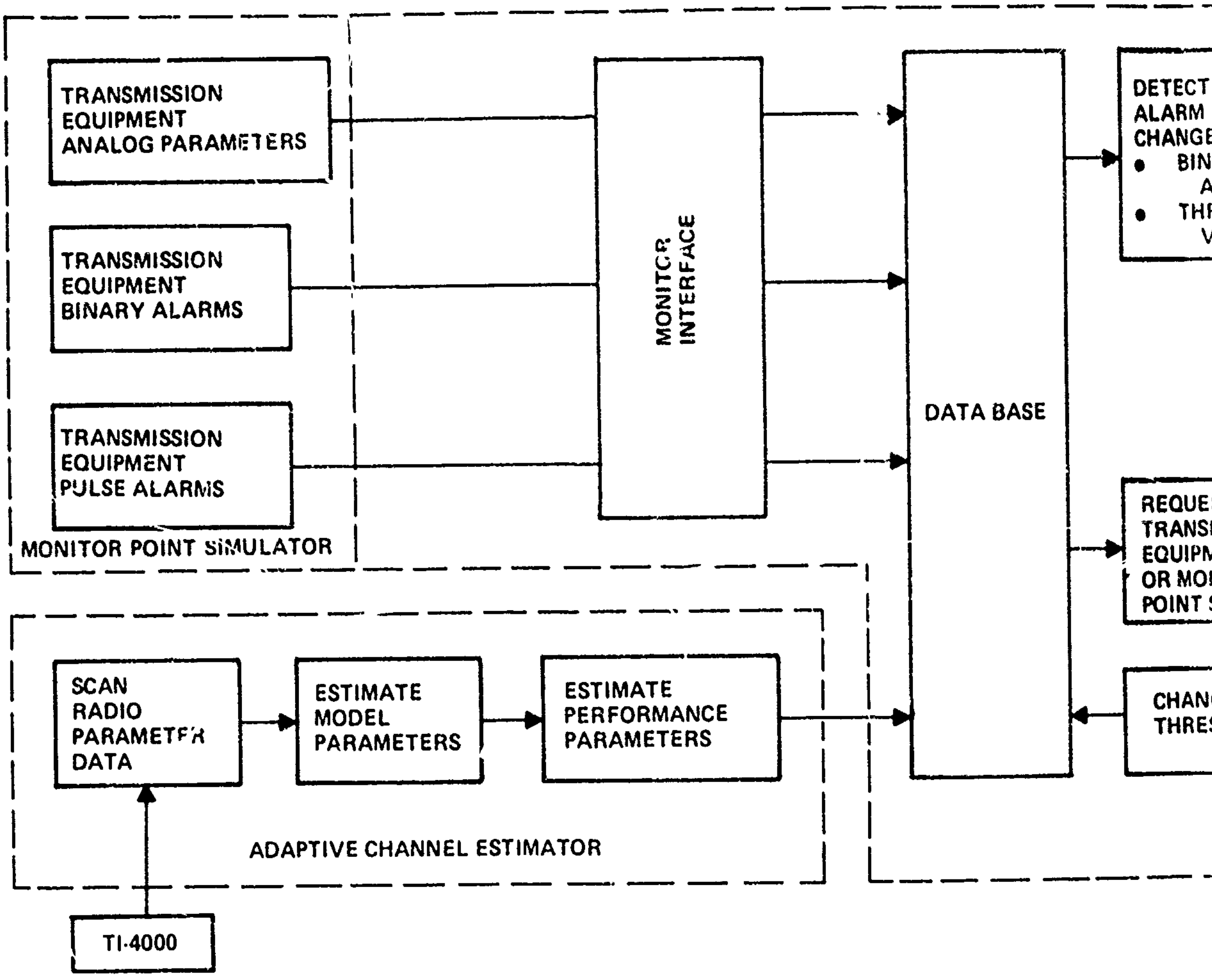


Figure 1-2. CPMAS Emulator Processor Configuration


TRANSMISSION EQUIPMENT ANALOG PARAMETERS
TRANSMISSION EQUIPMENT BINARY ALARMS
TRANSMISSION EQUIPMENT PULSE ALARMS
MONITOR POINT SIMULATOR
MONITOR INTERFACE
DATA BASE
DETECT
ALARM
CHANGE
• BIN
A
• THR
V
REQUE
TRANS
EQUIPM
OR MO
POINT
CHAN
THRES
SCAN RADIO PARAMETER DATA
ESTIMATE MODEL PARAMETERS
ESTIMATE PERFORMANCE PARAMETERS
ADAPTIVE CHANNEL ESTIMATOR
TI-4000

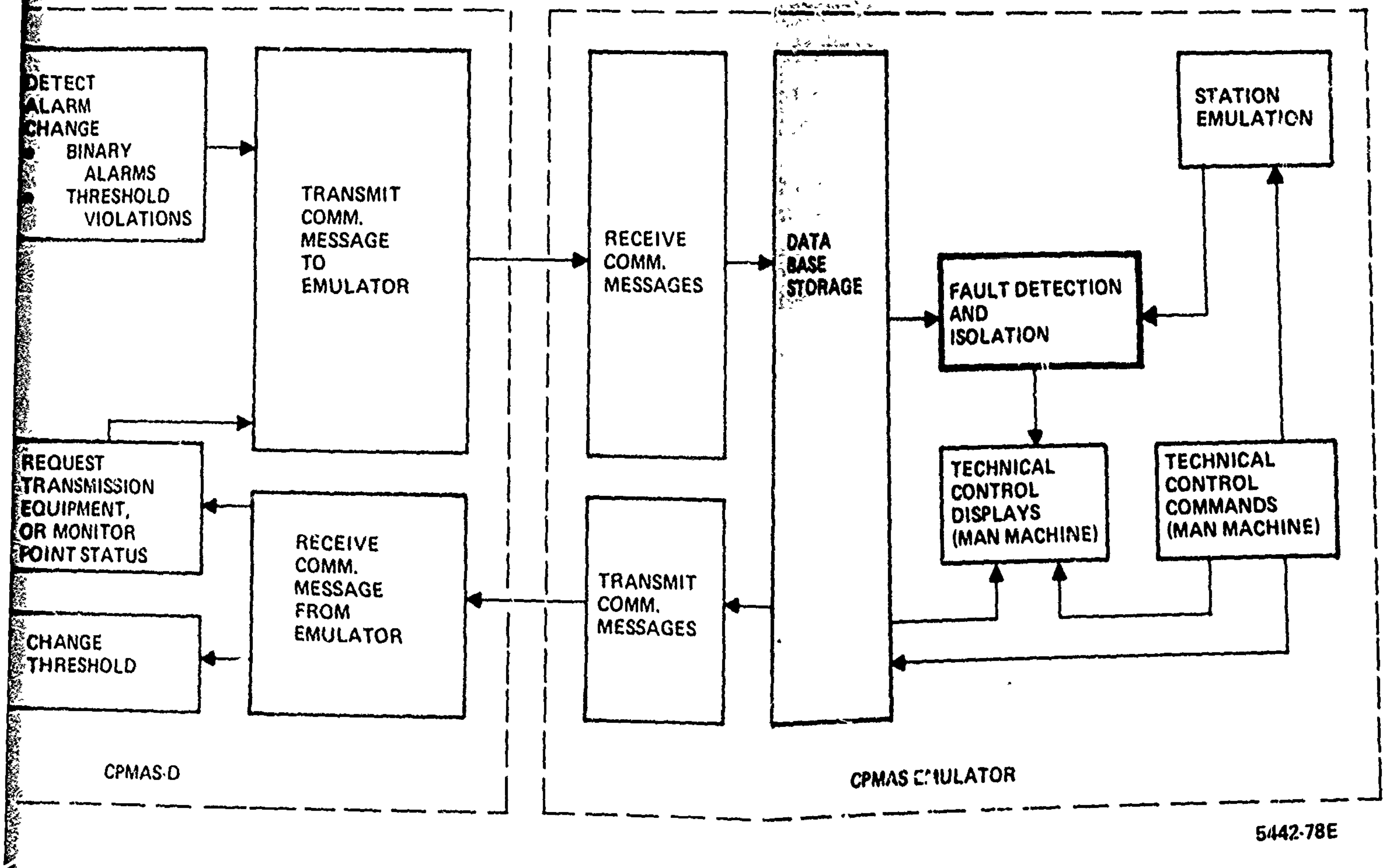


Figure 1-3. CPMAS Functional Diagram

2

TABLE 1-1. SPECIFICATION DOCUMENTATION

Item	Title	ID No.
1	Adaptive Channel Estimator Requirements Specification	166-001
2	CPMAS-D Feasibility Model	166-002
3	CPMAS-D Software Requirements Specification	166-003
4	CPMAS Emulator Equipment Requirements Specification	166-004
5	CPMAS/Emulator Computer Program High Level Design Specification	
6	CPMAS/Emulator Computer Program Development Specification	166-625-77

TABLE 1-2. TEST DOCUMENTATION

Item	Title	ID No.	Date
1	Site Survey Report for Adaptive Channel Estimator (ACE) Field Test	166-625-65	Sept. 1978
2	Adaptive Channel Estimator (ACE) Test Plan/Procedure		Sept. 1978
3	Adaptive Channel Estimator (ACE) Test Report		Mar. 1979
4	CPMAS/System Integration Test Plan/Procedures		23 July 1979
5	CPMAS/System Integration Test Report		

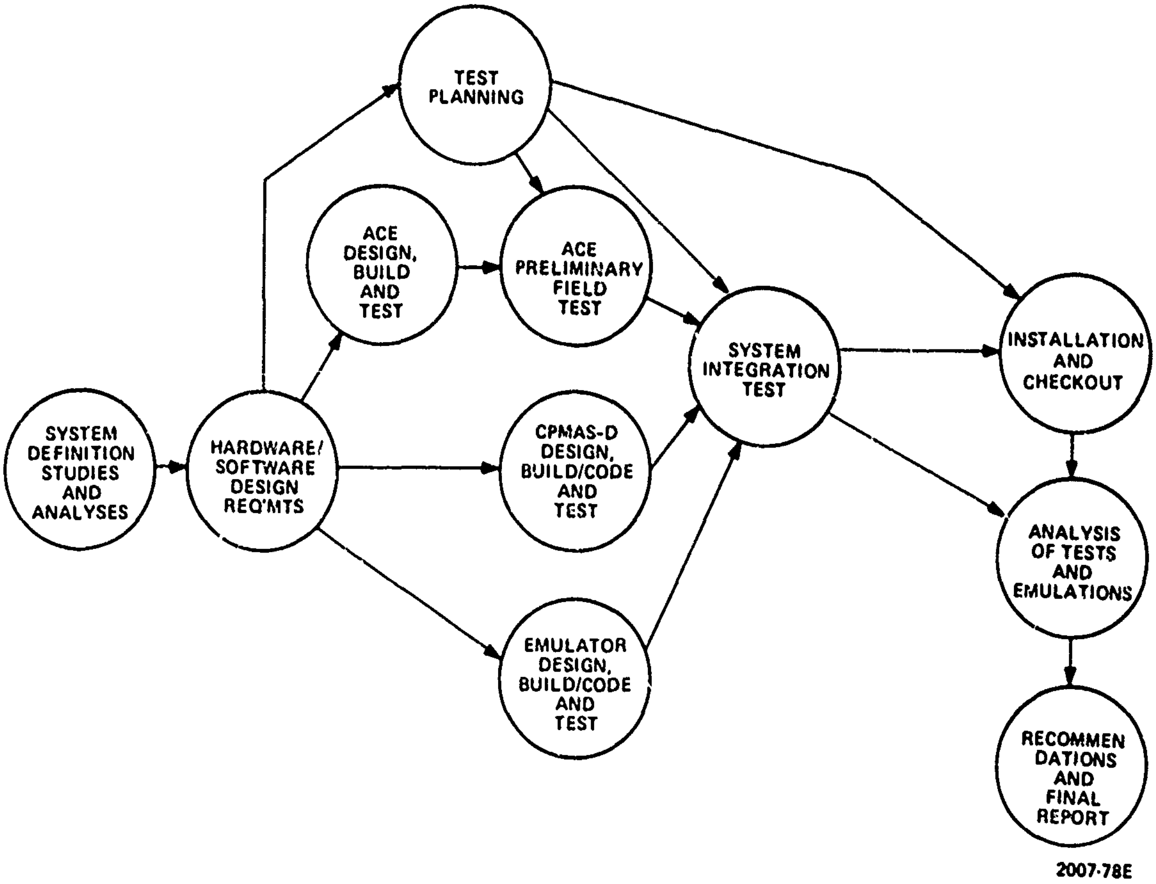


Figure 1-4. CPMAS Task Flow

design requirement documents, identified as items 1, 2, 3 and 4 in Table 1-1. Using these documents as a baseline the ACE, CPMAS-D, and Emulator hardware and software were implemented and tested on a unit basis. The Adaptive Channel Estimator, very early in the program, was tested at RADC so that the design could be finalized based on actual field test data-identified as ACE Preliminary Field Test in Figure 1-4. At GTE Sylvania the total system underwent extensive integration tests using as a source of network status, the monitor point simulator, and the emulated sixteen station network in the PDP 11/60. All deliverable items were then successfully installed and checked out at RADC and the requisite documentation completed. The required test documentation is listed in Table 1-2. Based on the results of this program, recommendations for future research and development are identified in Section 6.

SECTION 2

CPMAS DESCRIPTION

As an aid in evaluating technical control techniques, an emulation facility that automatically performs the status monitoring, performance assessment, and fault isolation transmission control functions as they apply to the digital Defense Communications System (DCS) has been developed. This emulation facility is a multicomputer system which automatically monitors, and isolates faults for digital transmission equipments (power generators, RF distributions, digital radios, second level multiplexers, first level multiplexers, submultiplexers, and key generator units). The status monitoring and performance assessment functions are performed by two processors, the Adaptive Channel Estimator (ACE) and an LSI 11/03, the composite being referred to as the CPMAS-D unit. When the software residing in the CPMAS-D unit detects a monitor point transition (alarm to/from non-alarm) it transmits the monitor point information to the CPMAS emulator, a PDP 11/60 minicomputer. These messages, called exception reports, enable the CPMAS Emulator to perform its prime mission, fault isolation.

A unique fault isolation algorithm has been developed for test with this emulation facility. The algorithm consists of three discrete steps. First, the equipment alarms are mapped into their effect upon each transmission path (link, supergroup, group, or channel). Secondly, the stations with the faulty equipment are located by deleting the impact of sympathetic alarms. Third, the faulty equipment is identified using the equipment alarm status.

Testing of the fault isolation algorithm is enhanced by an emulated network consisting of up to sixteen stations, 2048 equipments, and two nodal control areas. Monitor point simulators and T1-4000 multiplexers, which provide simulated and real inputs to two CPMAS-D units, are also part of the emulation facility. Technical control terminals are provided to evaluate man machine operation in an automated technical control environment.

2.1 BACKGROUND

The Defense Communications System (DCS) is the strategic long-haul network of the Department of Defense providing both dedicated and common-user services. Due to the criticality of the information carried by the DCS and its overall role in command and control communications, system control of the DCS is an important 24-hour function. System control as practised in the military environment comprises three general categories:

a. Transmission Control - Status monitoring, performance assessment, fault isolation, restoration, and coordination of long-haul dedicated circuits and common-user trunks.

b. Traffic Control - Traffic routing and flow control of the common-user networks.

c. Network Control - Configuration management and restoral control of all DCS resources.

This program examined future concepts and techniques for automating the performance assessment and fault isolation transmission control functions for DCS digital communication facilities. These facilities are characterized by low- and high-speed data circuits, voice access through PCM encoding, multiple stages of time-division multiplexing, digital modulation, and both microwave line-of-sight and troposcatter transmission.

As presently planned, the DCS system control will be structured into five hierarchical levels:

a. Worldwide - DCA Operations Center (DCAOC)

b. Theater - Areas and Region Operation Centers (ACOC/RCOC)

c. Sector - (formerly identified as Facility Control Offices)

d. Nodal - major DCS Technical Control Facility

e. Station - control of equipment and transmission at a specific DCS station.

The two upper levels, Worldwide and Theater, are DCS operated and staffed, while the lower three levels are MILDEP operated and staffed thus providing DCS system control support and satisfying O&M requirements. The relationship of the five levels of the system control hierarchy and anticipated communication links for coordination, status, and control for effecting Transmission Control, Network Control, and Traffic Control of the DCS is depicted in Figure 2-1.

The Automated Technical Control (ATEC) System planned for deployment at DCS stations will consist of an instrumentation subsystem and computer-based control subsystems designed to automate functions supporting the DCS transmission control and network control functions. Installation of ATEC System components will be made at the lower three levels of the DCS SYSCON subsystem hierarchy. Level 3, the sector level, will be provided with a computer-based control subsystem (SCS) located at designated Facility Control Offices (FCO) within the world-wide DCS. Subordinate Intermediate Control Offices (ICO) at designated major nodal stations (Level 4) of the DCS will also be provided with a computer-based control subsystem (NCS). The automated monitor/test instrumentation collectively identified as the ATEC systems Measurement Acquisition Subsystem (MAS) will be installed at Level 5 where appropriate to the communications equipment environment and the monitor/test requirements. This level includes communications facilities of the DCS Stations, i.e., the switching centers of the AUTOVON, AUTODIN, and AUTOSEVOCOM, the tech control or patch and test area where digital and analog circuits are accessible, and at the transmission equipment areas/sites where the TDM/FDM and Digital/Analog nodes are located.

The DCS comprises a network of communications stations which are linked by terrestrial and satellite transmission systems that provide interconnections among users of the switching centers of AUTOVON, AUTODIN, and AUTOSEVOCOM. Dedicated

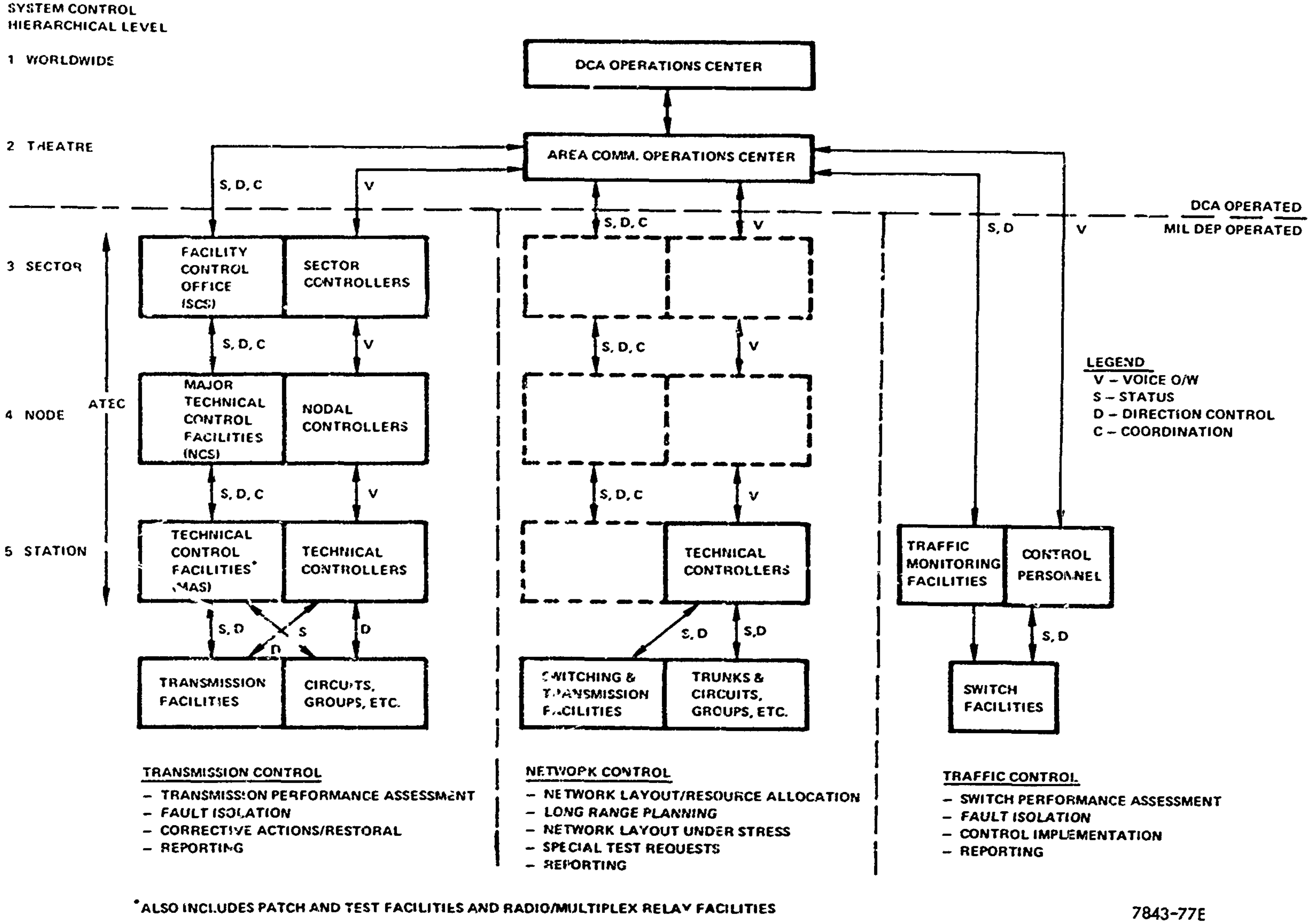


Figure 2-1. DCS System Control

users and networks also access the DCS world-wide transmission system through the communications stations. The communications services provided to switched and dedicated users are primarily VF communications; i.e., clear voice or secure voice, clear data or secure data. When required, wideband communcations are provided.

The present DCS transmission subsystem is predominately analog and utilizes a frequency division multiplexing (FDM) hierarchy built upon the 4-kHz VF channel. This FDM equipment is compatible with that used by the various common carriers, tactical systems, and NATO, and may be interfaced at any level in the hierarchy. Digital data transmission through the analog FDM hierarchy is accomplished by converting the data, via modems, to quasi-analog form (see MIL-STD-188-100, Section 4.1.2.3.3). Narrow-band data ($\leq$ 9600 b/s) can be handled by modems placed at the VF channel level. Wideband data requires modems operating at the group or supergroup level.

The European DCS transmission subsystem will be converted from analog to digital operation through the DEB upgrade and the pilot digital transmission upgrade FKV Project. New digital links will be added and certain analog links will be converted to digital; that is, FDM equipment and analog radios will be replaced by TDM equipment and digital radios, respectively. The transmission upgrades utilize a PCM/TDM hierarchy and are compatible at the T1 level and at several baseband rates. DEB Stage I uses a hierarchy similar to that used in FKV with the exception that digital data access is via the CY-104 (the T1WB1 is not required) equipped with special digital data port cards.

Existing terrestrial transmission in the Pacific is essentially all FDM utilizing U.S. Government-owned LOS radio subnetworks and cables, with some dependence on other local military networks for alternate backup routing. DCS transmission strategy calls for a time-phased conversion of the Pacific LOS networks to digital transmission. This will not be a backbone type architecture that characterizes the corresponding European DCS upgrade since the DCS Pacific network consists of isolated,heavy traffic nodes separated by large distances. These nodes are interconnected by submarine cable and satellites.

The DCS transmission environment considered as the baseline for this program is the digital microwave transmission and multiplex equipment deployed under Stages II through IV of the DEB Program and characterized by DRAMA equipment.

In order to be responsive to the monitoring and performance assessment requirements of this hybrid DCS, including its all-digital segments, the Communications Performance and Assessment for DCS Digital Systems (CPMAS) program was undertaken. The CPMAS program has developed an emulation facility on which the present fault detection/isolation algorithm, and other new algorithms, can be tested in a controlled environment. Because no algorithm having the necessary sophistication to perform adequate fault isolation will be sufficiently simple to enable verification by inspection, or analytically, that it works properly, then this facility will prove to be a valuable tool in evaluating contemporary fault isolation algorithms. The emulation facility will allow testing and verification of an algorithm under controlled conditions, including those which might only occur in the field environment during a near catastrophe. Testing an algorithm in the field under such conditions would be unacceptable to the operation organization.

2.2 SYSTEM OVERVIEW

As previously mentioned the CPMAS emulation facility is a multicomputer system which automatically monitors and isolates faults for digital transmission systems. Figure 2-2 shows the equipment comprising the CPMAS emulation facility. The CPMAS Emulator, namely a Digital Equipment Corporation (DEC) PDP 11/60 and associated peripherals performs the nodal and sector level technical control functions. The two CPMAS-D units, including

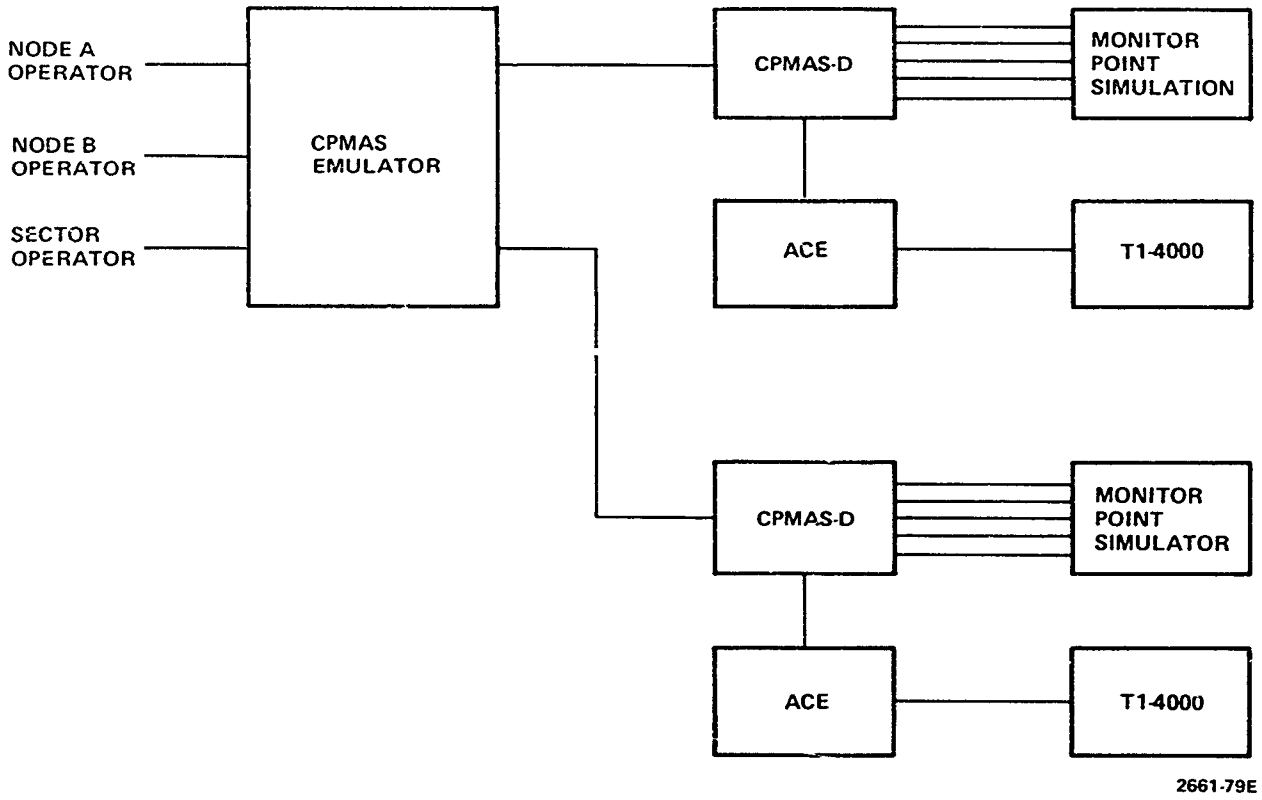


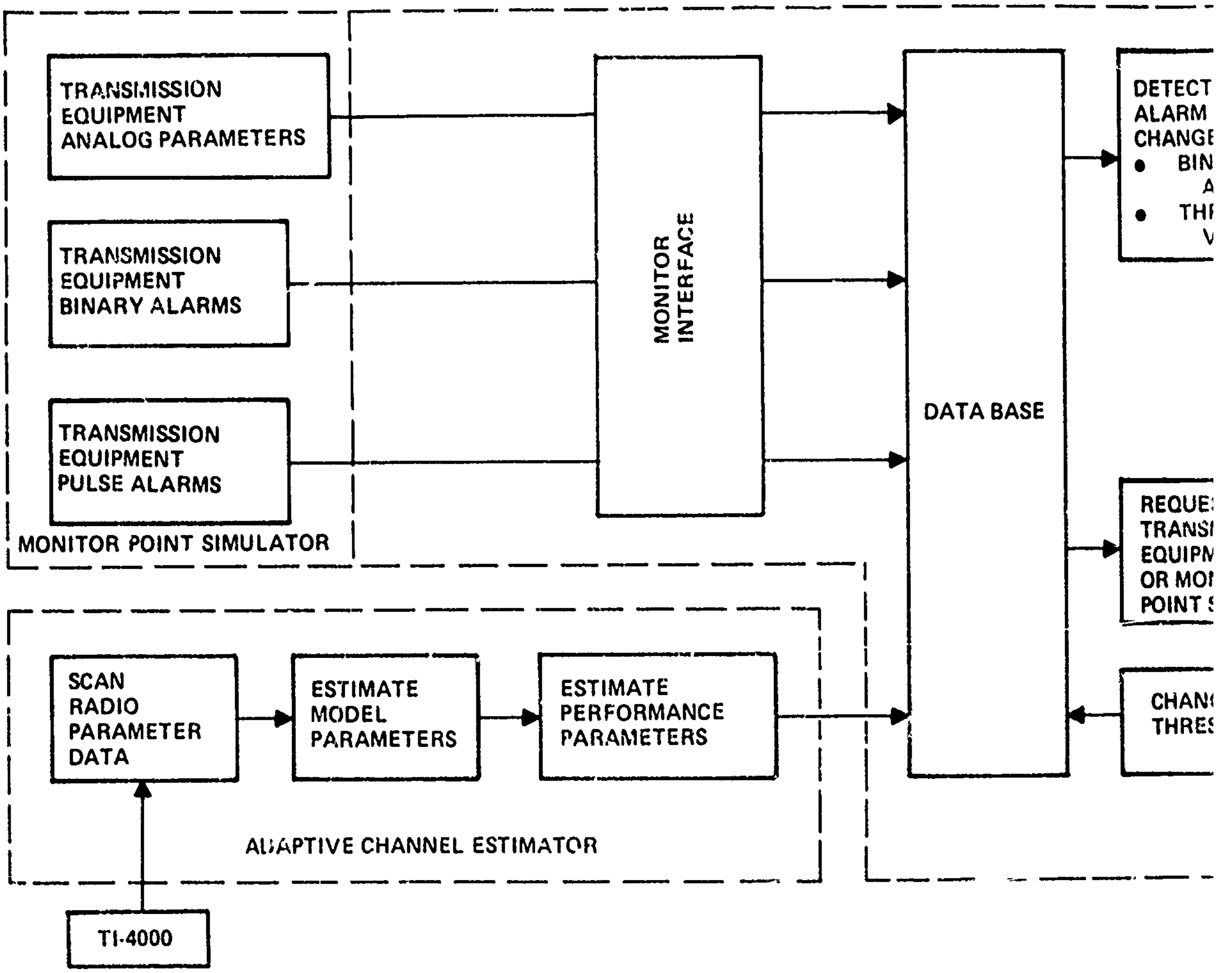
Figure 2-2. CPMAS Emulation Facility

the ACE units, perform the station level technical control functions. Monitor point simulators provide simulated monitor point status, which is scanned by the CPMAS-D units. Two VIDAR T1-4000 multiplexers operating at 12.5526 Mbps provide the ACE units with signals to be monitored. However, the CPMAS-D units do not monitor the status of the T1-4000 multiplexers since an expanded set of monitor points based upon the digital radio and multiplexer acquisition (DRAMA) equipment is processed by the fault detection/isolation algorithm.

Communications between each CPMAS-D unit and the CPMAS emulator consists of two simplex (one transmit, one receive) 150-baud asynchronous communications channels. All telemetry functions of the CPMAS emulation facility is accomplished using the above mentioned 150-baud channels. In particular, the telemetry function accomplishes all communications protocol and integrity verification requirements: calculation and comparison of longitudinal redundancy characters, receive message buffering, transmission of ACK or NAK characters, and verification of proper message length and header.

Figure 2-3 presents the functional flow of the CPMAS emulation facility. The CPMAS Emulator performs four main functions: fault detection/isolation, man/machine, station emulation, and message processing.

The primary function of the CPMAS Emulator is the execution of the CPMAS fault detection and isolation algorithm. The detection and isolation of faults in a DCS communications network is complicated by the generation and propagation of sympathetic alarms. Sympathetic alarms propagate downstream from the real fault following the network connectivity and hierarchical structure and are triggered at non-faulted equipment as a result of signal anomalies caused by faulted up-stream equipment. The function of a fault detection/isolation algorithm is to locate the faulty equipment by discarding the sympathetic alarm reports.


TRANSMISSION EQUIPMENT ANALOG PARAMETERS
TRANSMISSION EQUIPMENT BINARY ALARMS
TRANSMISSION EQUIPMENT PULSE ALARMS
MONITOR POINT SIMULATOR
MONITOR INTERFACE
DATA BASE
DETECT
ALARM
CHANGE
• BIN
A
• THI
V
REQUE
TRANSI
EQUIPM
OR MOI
POINT
CHAN
THRES
SCAN RADIO PARAMETER DATA
ESTIMATE MODEL PARAMETERS
ESTIMATE PERFORMANCE PARAMETERS
ADAPTIVE CHANNEL ESTIMATOR
TI-4000

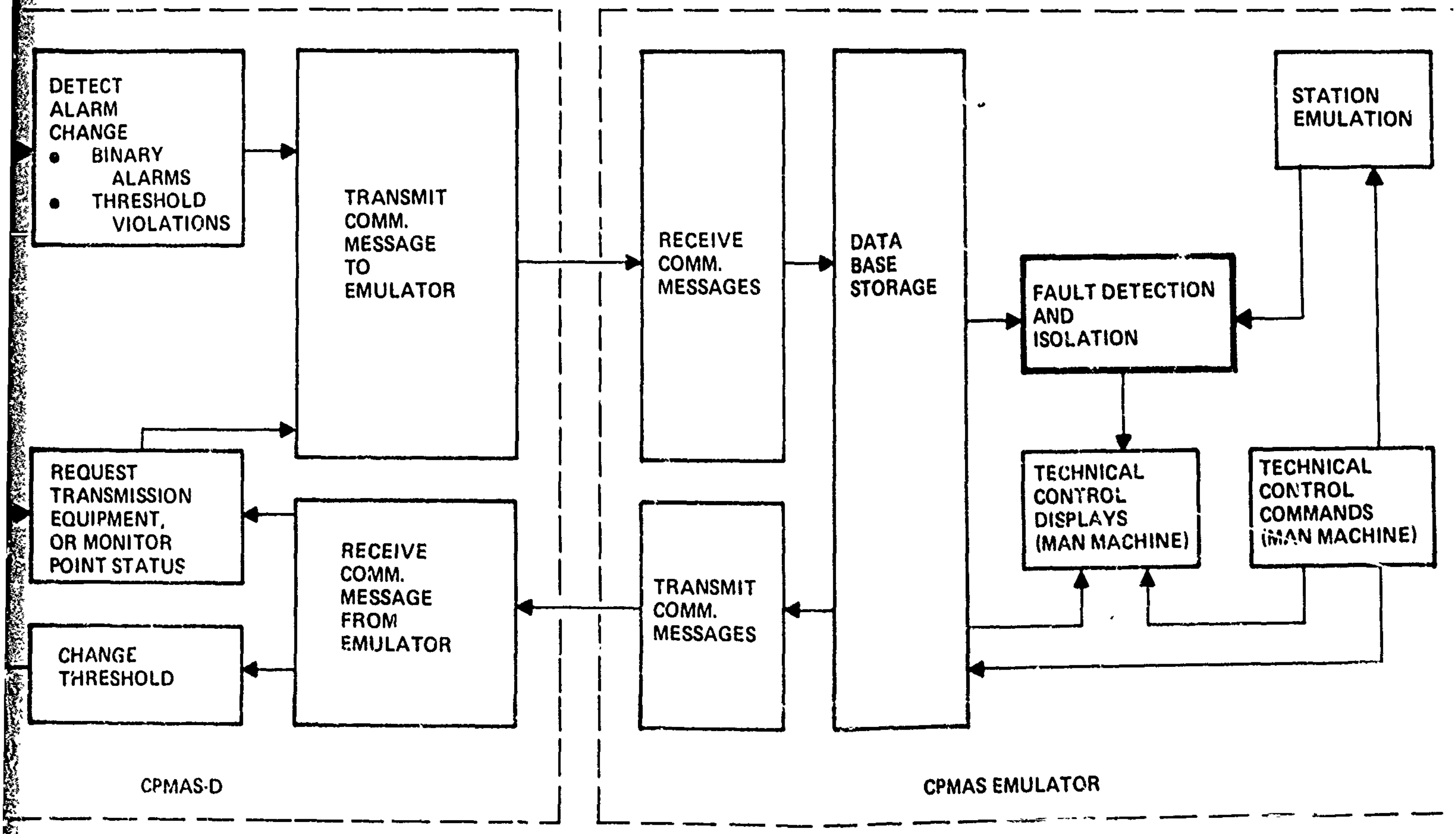


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Figure 2-3. CPMAS Emulation Facility Functio
Flow

2

A unique fault detection/isolation algorithm has been developed for use in the CPMAS emulation facility. The algorithm uses a global network approach that examines the status of the entire network and simultaneously isolates all faults. This approach allows faults to be quickly isolated and results in an isolation time that is relatively insensitive to fault loading. A detailed description of the CPMAS fault detection/isolation algorithm and a discussion of its performance will be presented below (Section 2.3).

A CPMAS man/machine capability is provided so that technical control man/machine operation can be evaluated and detailed status information can be conveniently accessed for subsequent evaluation. CPMAS man/machine operation consists of technical controller commands, information prompts, and information displays. A detailed discussion of the CPMAS man/machine function is presented in Section 2.4.

The station emulation CPMAS Emulator function provides the emulation user with the capability to exercise the CPMAS emulation facility with an expanded network. Fault scenario data can be generated for hypothetical digital transmission system models. These models can contain up to sixteen stations, two nodal areas, and 2048 equipments.

The message processing CPMAS emulator function performs the telemetry function at the CPMAS Emulator, i.e., it accomplishes all communications protoc [illegible]. integrity verification.

The CPMAS-D Unit, exclusive of the ACE unit, performs the station level CPMAS functions of performance monitoring, performance assessment, and telemetry. The CPMAS-D monitor interface function monitors binary alarms, analog parameters, pulse parameters, and ACE parameters by a sequential scan technique. These parameters are representative of one diversity digital radio, one redundant PCM/TDM second level multiplex unit, one PCM/TDM first level multiplex unit, and one submultiplex unit. The data base function stores scan address and previous scan parameter states for all monitored points and four threshold values (red low, amber low, amber high, and red high) for all analog and pulse parameters as well as six ACE parameters. Performance assessment consists of the detection of changes in alarm state or threshold crossings. The telemetry function processes messages for transmission (exception reports caused by monitor point state changes, and responses to monitor immediate and threshold status requests) and received messages in the manner of the CPMAS Emulator telemetry function.

The ACE operates as a major component of the CPMAS-D unit. The ACE provides a means of measuring the quality of microwave line-of-sight radio links employing either three-level partial response or quadrature phase shift keying modulation techniques. The ACE employs a quadratic channel model to adaptively estimate, using a least mean squared error technique, bit error rate, signal-to-noise ratio, and signal-to-distortion ratio for one or two radio basebands. The ACE iteratively estimates the radio channel characteristics by sampling the radio data detector input signal and comparing the sample to an estimated data detector input signal in order to generate an error function. The error function is used to iteratively update the channel model until an accurate channel model is obtained. The model parameters are then used to calculate the radio channel performance parameters. The ACE unit will be described in greater detail below.

The monitor point simulator provides the signals which drive the CPMAS-D unit performance monitor function. These signals are binary alarms which represent hard transmission equipment faults, analog voltages, intermittent binary signals (pulses), and radio baseband signals which represent performance monitor parameters. These may be thresholded to assess the performance of the transmission equipment and/or network.

2.2.1 CPMAS Emulator

The CPMAS Emulator performs the nodal level CPMAS functions, namely, fault detection/isolation, man/machine, station emulation, and message processing. Generation and maintenance of the CPMAS Emulator data base is also performed to ensure that the most recent data is provided to the operational software.

The CPMAS Emulator is a Digital Equipment Corporation (DEC) PDP 11/60 and employed a general purpose multi-user, multi-task operating system known as RSX-11M developed by DEC. All of the Emulator software has been developed using DEC's FORTRAN IV PLUS.

2.2.1.1 CPMAS Emulator Software

As shown in the simplified system block diagram (Figure 2-4), CPMAS Emulator software is grouped into five major categories, which relate directly to (A) collecting information for fault detection and isolation, (B) performing the network level fault detection and isolation, (C) displaying fault detection and isolation results, (D) generating and maintaining the data base required to run the fault detection and isolation process and (E) performing station emulation for all stations in the network model without CPMAS-D units to monitor equipment, as well as stations equipped in excess of the CPMAS-D monitoring data base.

2.2.1.1.1 Message Processing - Collecting information for the Fault Detection and Isolation process requires four subprograms for Message Input Processing: (LIST1, LIST2, OMSGN1, and OMSGN2) and two for Message Output Processing: (OMSGT1 and OMSGT2). As shown in the message processing block diagram (Figure 2-5) all message traffic from the CPMAS-D units are collected by the subprograms in Message Input Processing. Once a message has passed integrity verification it is routed to either the equipment fault summarizer task, OEFS, or to the man/machine display subprogram, ONODLB, in whose network area the CPMAS-D units are located.

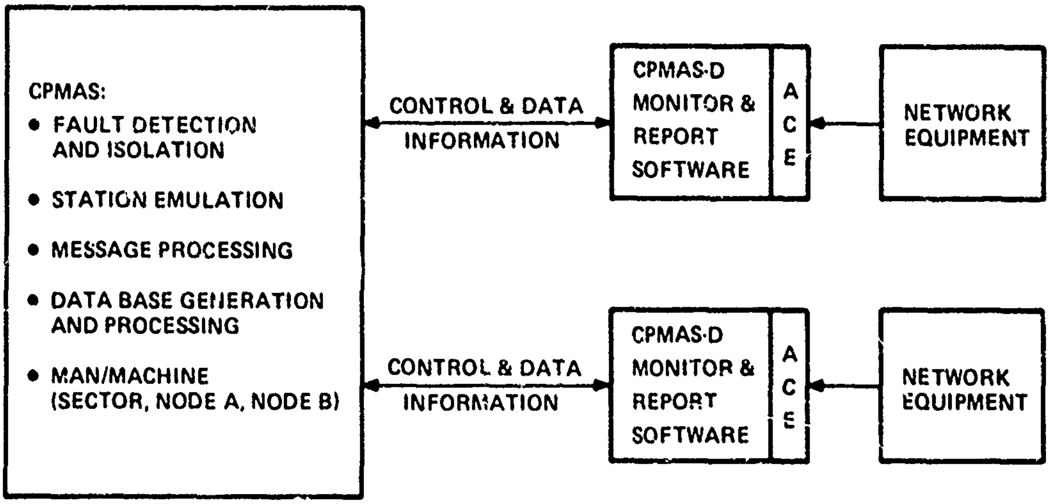

Figure 2-4. Simplified System Block Diagram

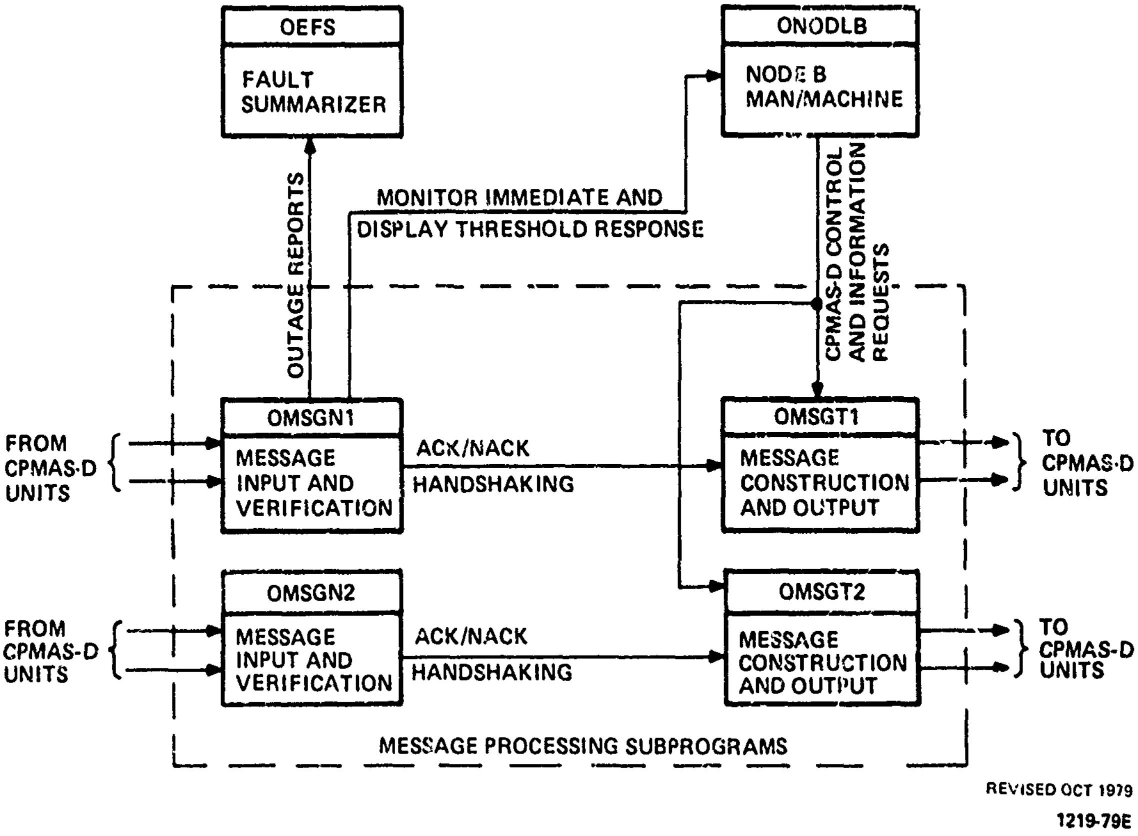

Figure 2-5. Message Processing Block Diagram

The subprograms in the Message Output Processing are responsible for performing all message communication to the CPMAS-D units. They operate in conjunction with Message Input Processing to provide the "handshaking" with the CPMAS-D units and also transmit messages, on request, from the man/machine subprogram ONODLB. These requests are used to alter or acquire CPMAS-D data base information used in the fault monitoring process. The Input Message Processing subprograms LIST1 and LIST2 are assigned the highest processor priority, within the CPMAS Emulator, to insure adequate response to the 150 baud CPMAS-D communication lines.

2.2.1.1.2 Fault Detection and Isolation Processing - The subprograms performing the fault detection and isolation functions, as well as their interfaces, are shown in Figure 2-6 These processes consist of four discrete steps and are developed as discrete subprograms. The first is called the equipment fault summarizer, OEFS, whose function is to parse the exception reports from the CPMAS-D units and translate these reports into their corresponding network impact (e.g., link, supergroup, etc.). To perform this process, two pieces of information are required: (A) the generic mapping of each equipment alarm to a hierarchy level (e.g., group 3) and (B) the specific hierarchical level on which the outage is being reported (e.g., station ABC, link M0109, supergroup 2, group 3). The specific outage level is determined by accessing the equipment alarm data base through subprogram ODBCNT. Subprogram OEFS processes the equipment alarms and delivers the link and local and housekeeping outages to the other fault detection and isolation subprogram (see OEFS Figure 2-6). First, the derived network impact data base is updated for later use by OSLFI, the station level fault isolation subprogram. This portion of the fault detection and isolation data base is maintained in a summary table containing the hierarchical outages for each link in the network. Secondly, the alarms received are stored in the updated equipment data

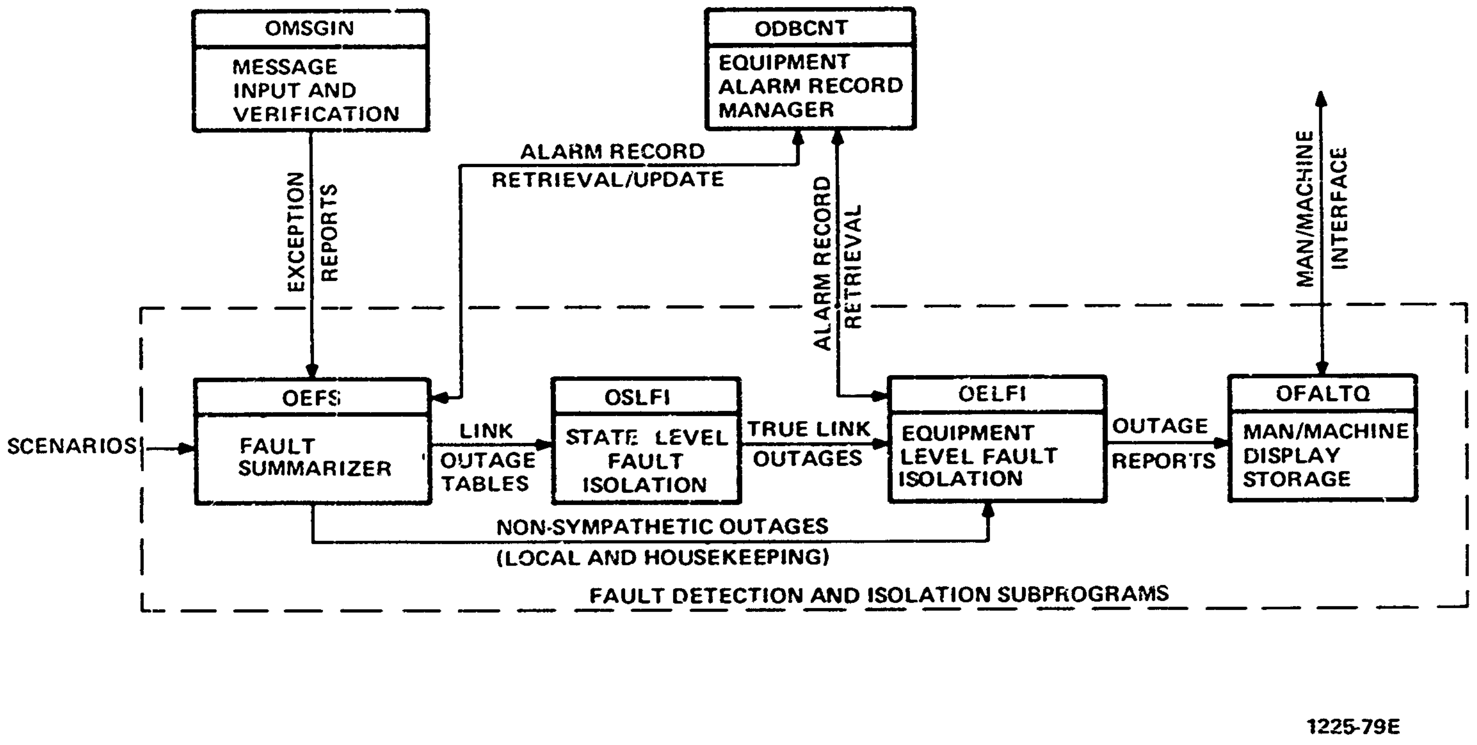

Figure 2-6. Fault Detection and Isolation Block Diagram

base via subprogram ODBCNT for later use by OELFI, the equipment level fault isolation subprogram. Third, alarms which correspond to non-sympathetic conditions are passed directly to the equipment level fault isolation subprogram, OELFI, as solved problems, requiring no fault detection and isolation processing. These alarms occur in offline/redundant gear such as radios as well as by conditions such as a low fuel alarm occurring in a power generator.

The second step in the fault detection and isolation process consists of deleting all "sympathetic" communication outages, thereby yielding only "true" communication hierarchy outages. This requires locating the communication hierarchy furthest "upstream" at which an outage is reported. This outage is then deemed to be the real fault while all downstream outages are considered sympathetic.

To perform this function the CPMAS Emulator task, OSLFI, uses two pieces of information: (A) a table or list driven data base defining the equipment connectivity throughout the network being modeled and (B) the network communication outage information stored in link summary tables. When OSLFI runs to completion, it reports outages by hierarchical level to the third fault detection and isolation subprogram, OELFI (refer to Figure 2-6).

Subprogram OSLFI is executed every ten seconds (minimum) and is synchronous with respect to subprogram OELFI. Subprogram OSLFI only reports communication outages. Since some outages may be of an intermittent nature, it is necessary to compare previously reported outages to currently reported outages; if a fault previously reported is no longer being reported then it has undergone a transition from fault-in to fault-out. Synchronization with subprogram OELFI allows past and present outages to be compared, to yield the information on intermittent problems.

The third step in the fault detection and isolation process is performed by subprogram OELFI (equipment level fault isolation). As shown in Figure 2-6, this subprogram receives as input all problems already traced to an equipment level (solved problems) as well as unsolved real outage problems (communication outage reports from subprogram OSLFI). Subprogram OELFI passes all solved problems directly to subprogram OFALTQ for display storage. Unsolved problems are traced to their most "upstream" faulted source, of the identical hierarchical level, by retrieving the data base alarm records updated by subprogram OEFS and accessed via subprogram ODBCNT. Once the faulted equipment is traced to its upstream source, it is then reported to subprogram OFALTQ for display storage.

The fourth, and last, fault detection and isolation subprogram (OFALTQ) is responsible for maintaining the 100 most recently active faults in the modeled network. As shown in Figure 2-6, it receives solved outage reports from subprogram OELFI. These reports are compared to previously stored reports and are stored for display if new or transitional. Subprogram OFALTQ is active from system startup, allowing asynchronous man/machine inquiry/response relative to fault detection and isolation. Processing of outage reports, by OFALTQ, is synchronous with respect to completion of subprogram OELFI. Synchronization with subprogram OELFI allows all current equipment outages, received from OELFI, to be compared to the previously stored equipment outages. Any outage previously stored, but not currently reported, is intermittent and is reported to the man/machine subprograms as such.

2.2.1.1.3 Man/Machine Process - The man/machine processor is used for displaying fault detection and isolation results and controlling the startup/restart of the CPMAS-D units. All contributing subprograms, and informational interfaces are shown in Figure 2-7.

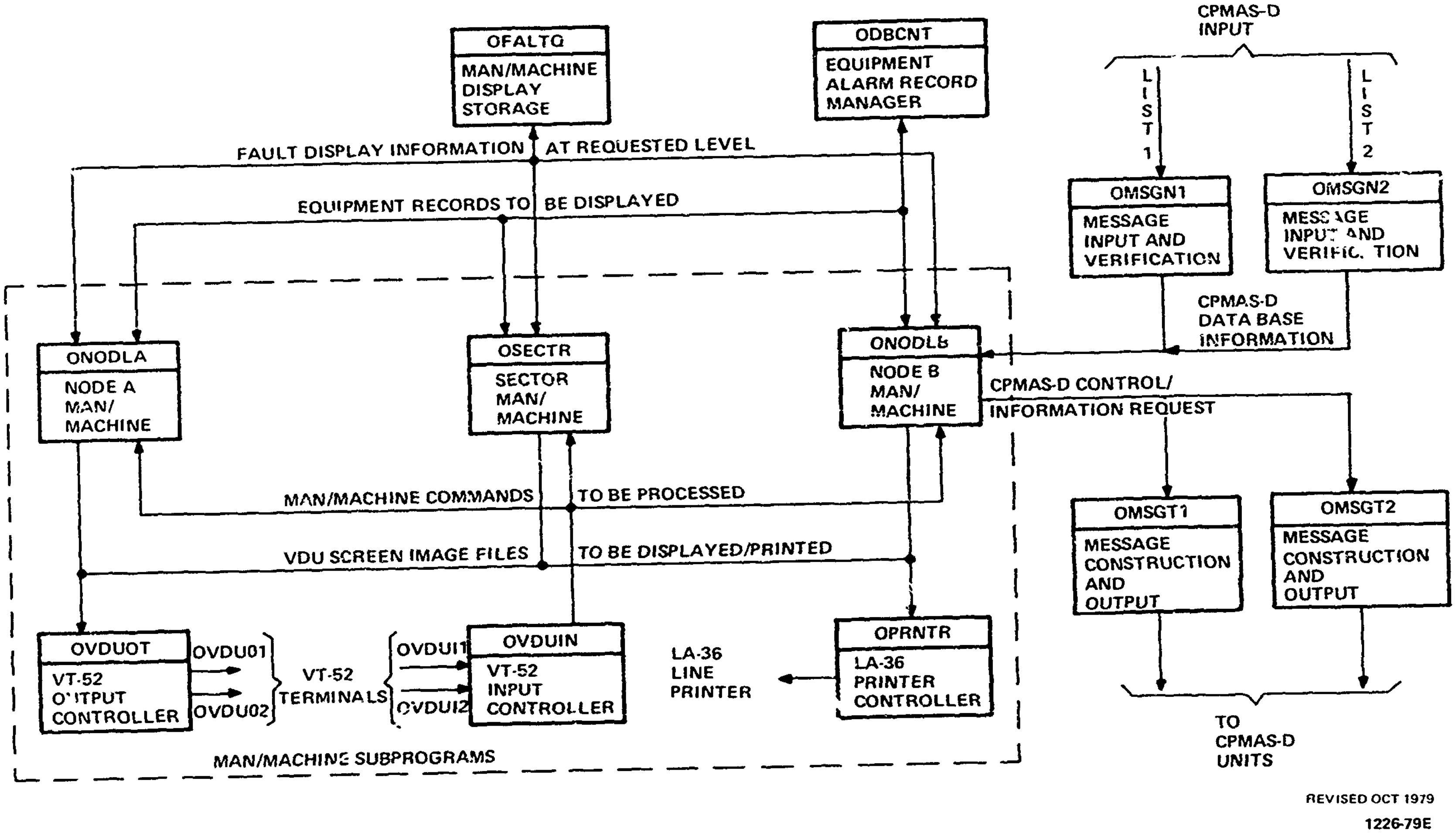

Figure 2-7. Man/Machine Block Diagram

The man/machine subprograms are ONODLA (Node A technical controller), OSECTR (Sector technical controller) and ONODLB (Node B technical controller). These subprograms have similar display capability, varying only in scope (e.g., OSECTR may display all network faults while ONODLA may display only those faults residing in Node A).

As shown in Figure 2-7, subprogram ONODLB has a unique bidirectional interface with the Message Input and Output Processing subprograms. It is via these interfaces that the Nodal B technical controller controls CPMAS-D unit operation (starts/restarts), accesses (display threshold, monitor immediate), and changes (change threshold) the CPMAS-D unit data base. As depicted, subprograms ONODLA, ONODLB, and OSECTR receive the man/machine requests made on the VT-52 terminals monitored by subprograms OVDUI1, OVDUI2 and OVDUIN. They process their requests (accessing the equipment data base via subprogram ODBCNT if necessary) and update their respective displays via subprograms OVDUOT, OVDUI1 and OVDUI2 (VDU output control).

To obtain hard copy of displays, each man/machine processor has print capability, obtained via subprogram OPRNTR and activated via a man/machine print request.

As shown in Figure 2-7, all fault isolation information is acquired via the bidirectional interface to subprogram OFALTQ. This simplifies the informational transfer problems associated with multiple man/machine processors. In addition, access to the equipment data base (via subprogram ODBCNT) is restricted to a read only mode, thereby limiting data base update to the fault isolation subprogram OEFS.

2.2.1.1.4 Data Base Generation and Processing - To accommodate variable network connectivities and variable station equipment complements, two data base generation/access control subprograms are provided within the CPMAS Emulator software system: UDBCEN and ODBCNT. Subprograms UDBGEN and ODBCNT allow the CPMAS

Emulator user to test the fault detection/isolation algorithm within networks containing up to 16 stations, 2 nodes, and 22 links.

Subprogram ODBCNT is the data base controller. As shown in Figure 2-8 two fault detection/isolation subprograms (OEFS, OELFI) and three man/machine subprograms (ONODLA, ONODLB, OSECTR) require access to the equipment alarm information contained in the data base. To facilitate software debugging and eliminate disk file shared access problems, all I/O requests are made through subprogram ODBCNT. This software allows equipment alarm record access by hierarchy or equipment name. Thus the subprogram OEFS and man/machine subprograms may access any equipment alarm information by name, while subprogram OELFI (equipment level fault isolation) has the capability of determining faulted equipment having knowledge of only its hierarchy. Task ORESUM (not shown) acts as an interface link between task ODBCNT and the Tasks with which it communicates.

The major components of the CPMAS data base shown in Figure 2-9 are:

a. Equipment Alarm Records - These records contain the monitor point status of all equipment in the modeled network.

b. Network Scan List - Defines the order in which the paths in a network are analyzed by the station level fault isolation subprogram (OSLFI).

c. Station Channel Switching - Used by subprogram OSLFI to map all communication outage information from one link to all other links emanating from the station.

d. Network Link List - Contains a list of all stations, nodal area designator, and link names. It is used by both station level fault isolation and the man/machine processors to locate other data base information.

e. Station Hierarchy - Demux/Termination Information. Defines, for each link in the network, the paths associated with each link supergroup and group as it traverses a station. It is used to optimize the channel outage mapping process during station level fault isolation.

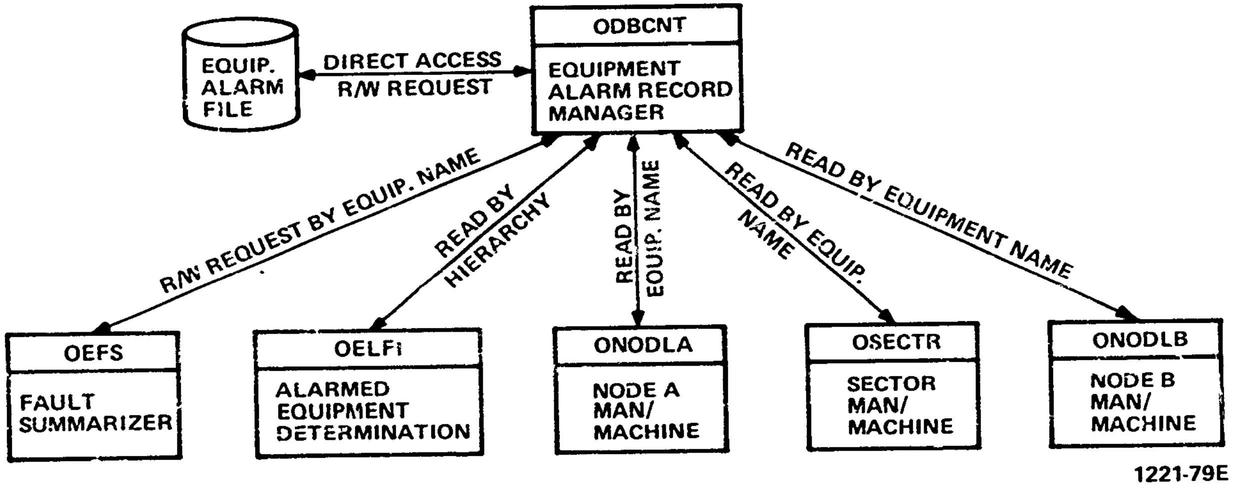

Figure 2-8. Data Base Access Control

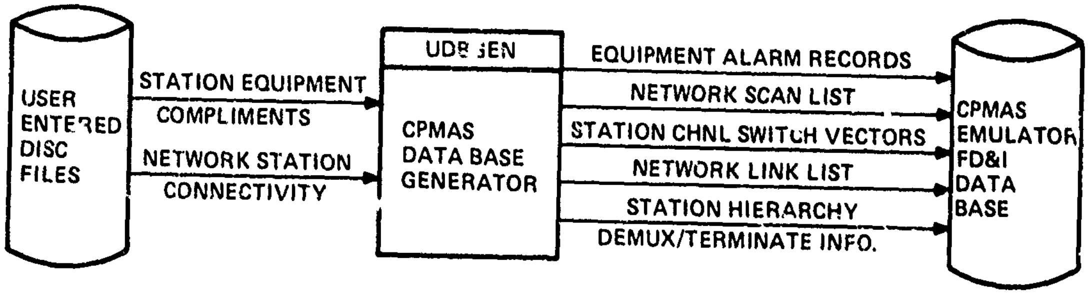

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Figure 2-9. Major Data Base Items

To generate the data base, the subprogram, UDBGEN is run offline. Using the information contained in the User's Manual the user creates/updates the disk files necessary to generate a CPMAS data base using the PDP-11 Editor, EDI. The data base generator subprogram UDBGEN then processes these disk files to provide (A), a listing of all equipment, by name and hierarchy, within the modeled network and (B), all data base files and tables necessary for CPMAS Emulator Program operation.

2.2.1.1.5 Station Error Report Generation - Emulation of station outage reporting is provided to allow for fault detection and isolation outage input from up to 16 stations, rather than limiting input to the 2 stations monitored by CPMAS-D units.

Creating outage report scenarios is done by the emulator user in an offline mode using the PDP-11 Editor, EDI. Once the emulator software is initiated via the emulator start up controller, EMUSRT, the emulator man/machine task EVDUMM, task OEFS performs the emulated station outage report (termed scenario) input and processing.

As shown in Figure 2-10, the emulator user requests a scenario via entry of an emulator directive, $BGN, at either VT-52 terminal. Emulator subprogram EVDUMM then performs two functions:

a. Verification that the scenario name entered by the emulator user does exist.

b. Notification to the scenario processing portion of subprogram OEFS to commence scenario processing.

Also included in the emulator software is the Data Recording task EDAT. Subprogram EDAT is active for the duration of the emulator usage, and records information relating to fault detection and isolation subprogram execution times, outage loading within the network, and relevant message processing information.

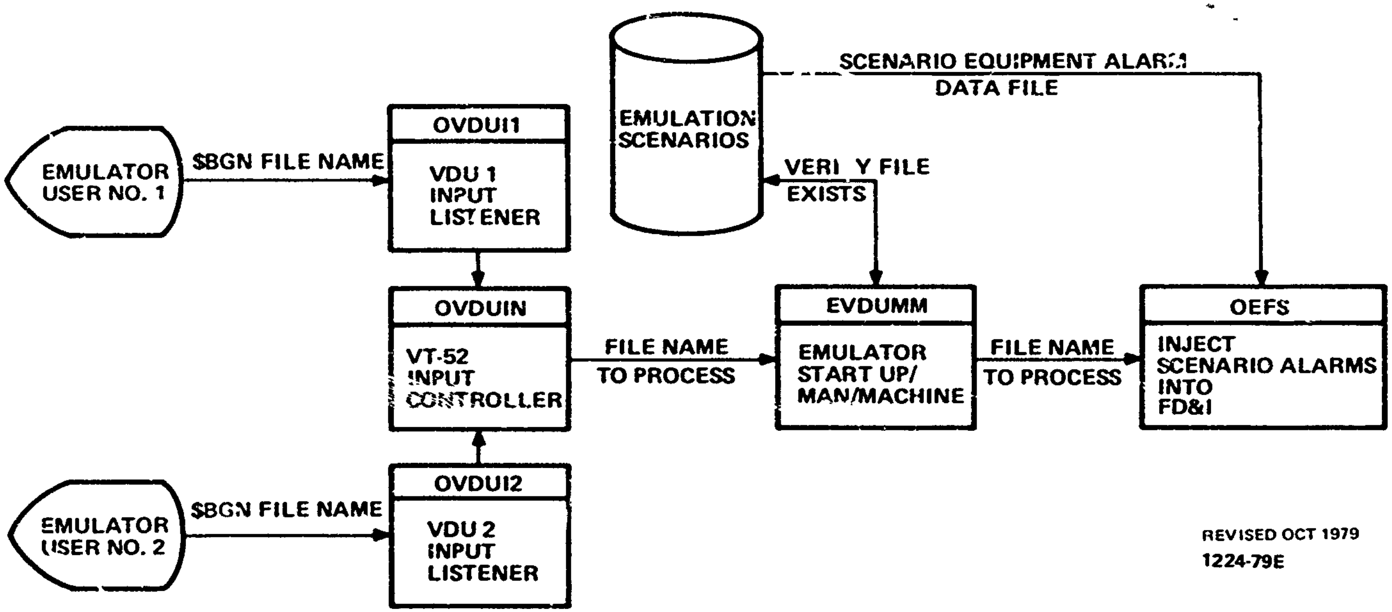

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Figure 2-10. Scenario Processing Flow Diagram

2.2.1.2 CPMAS Emulator Equipment

The CPMAS Emulator operating under internal computer control serves as a digital word pattern source simulating digital and analog (quantized) monitor and performance assessment signals associated with DCS digital transmission multiplex (TDM) and radio (MW-LOS) equipments. It is also a data processor that emulates data communications, processing and display functions of a transmission control system to the extent necessary to affect a CPMAS feasibility demonstration of transmission system performance assessment and fault detection and isolation.

The functions that are performed by the major equipment components of the CPMAS Emulator (Figure 2-11) are specified in the following:

a. Central Processor Unit - The Central Processor Unit (PDP 11/60) is a 16-bit machine with the RSX-11M operating system and is capable of word, byte and bit processing and also stack processing. It provides a Floating Point instruction set as well as a general purpose instruction set that includes register-register, register-memory and memory-memory instructions. It contains 8 programmable general purpose registers and has a vectored interrupt system with 8 priority levels. Its memory-associated capabilities shall include hardware memory management and multiple addressing modes viz., direct addressing of 32K 16-bit words (64 Kbytes), indirect addressing, indexing, byte (8-bit) addressing, sequential addressing and stack addressing.

b. Main Memory Unit - The Main Memory Unit provides for storage of 124K 16-bit words. The memory access and cycle times are 670 nsec and 1130 nsec, respectively.

c. Mass Memory Unit -1 - Mass Memory Unit -1 is a fixed-head disk system, consisting of a single drive, controller, and CPU interface. It is capable of storing 256K 16-bit words. It provides an access time of 10 milliseconds and a word transfer time of five (5) microseconds.

d. Mass Memory Unit -2 - Mass Memory Unit -2 is a dual movable-head cartridge disk system, containing two drives, one controller and one CPU interface. Each disk cartridge is capable of storing at least

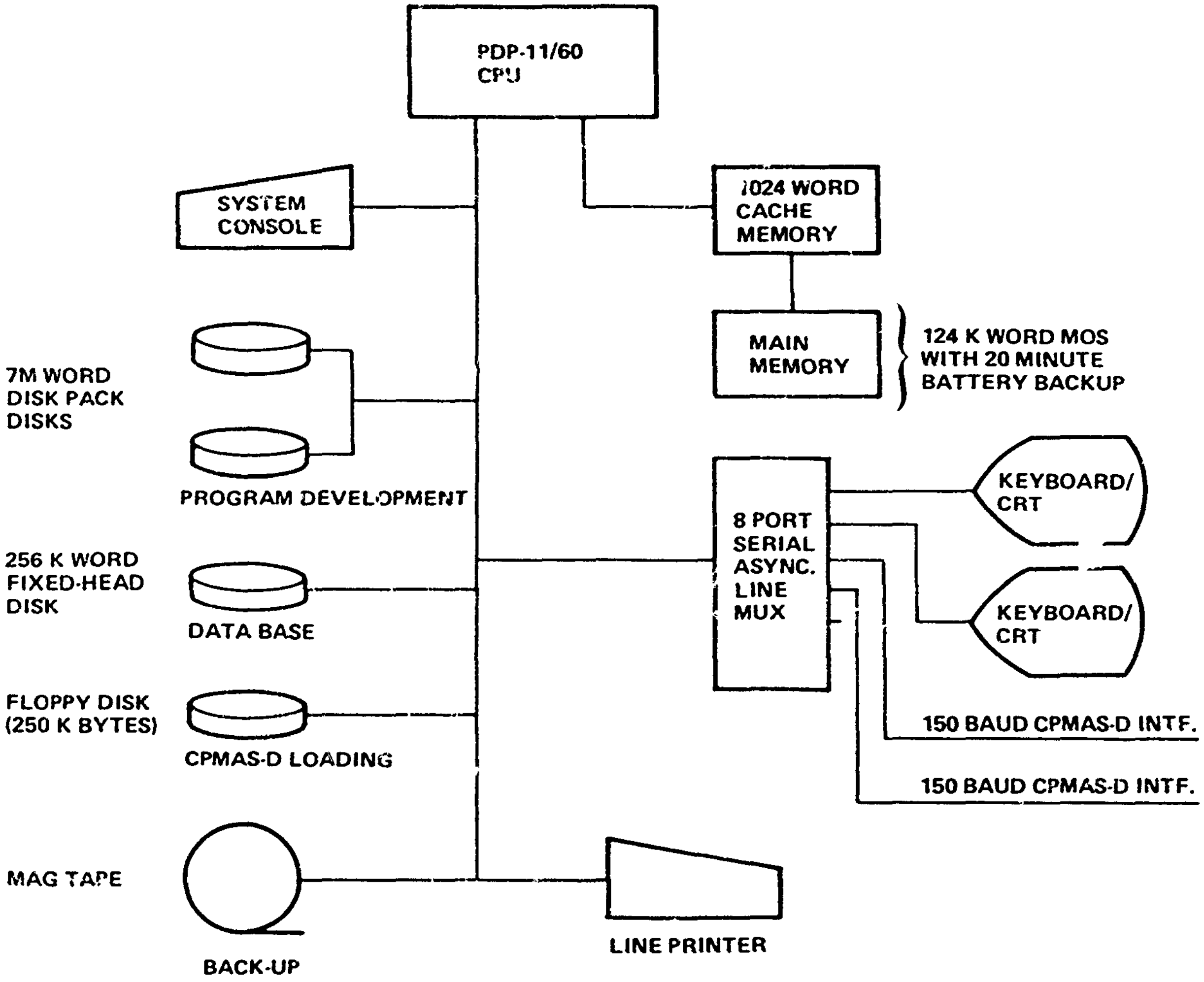

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Figure 2-11. CPMAS Emulator Processor Configuration

14 million bytes. Disk access time is less than 100 milliseconds and the word (16-bit) transfer time is less than 16 microseconds/word.

e. Mass Memory Unit -3 - Mass Memory Unit -3 is a flexible (floppy) media disk system, consisting of a single drive, controller, and CPU interface. The media is capable of storing 256,256 bytes of data in the following industry-standard format:

    Surfaces per disk: 1
    Tracks: 77
    Sectors: 26
    Capacity per sector: 128 bytes
    Recording method: Double Frequency

   This disk has an average data access time of less than 500 milliseconds and a data transfer time of less than 20 microseconds per byte. It is compatible with the mass memory unit of the CPMAS-D, i.e., it is readable by the CPMAS-D.

f. Mass Memory Unit -4 - The fourth Mass Memory Unit is a 9-track magnetic tape system, consisting of a single reel-to-reel tape transport, controller, and CPU interface. The unit uses industry-standard 800 bits per inch (BPI) NRZI recording format. One reel of tape (7½" reel size) is capable of storing 5 million characters.

g. Communications Interface Unit - This unit provides the interface between the external CPMAS-D and the CPMAS Emulator. Operational functions this unit performs include the following:

   1. Monitoring the transmission circuit from the CPMAS-D for Idle or Busy status or Open line condition.

   2. Controlling the status of the transmission circuit to the CPMAS-D.

   3. Processing of message characters to/from the CPMAS-D, e.g., serial/parallel conversion and character parity error detection, as appropriate for supporting the Emulator software.

   4. Transfer and receipt of data and control information to/from the Emulator CPU.

   5. Protocol functions (RS-232 hand shaking) with respect to a low speed (150B) asynchronous modem, when the Emulator is not co-located with a CPMAS-D.

h. Keyboard Display Unit - The Keyboard Display Unit provides for interactive communications with the Emulator processor. The keyboard display unit accepts functional commands and messages from a controller and outputs information to him. The Keyboard Display Unit capability provides for:

   1. Entry of standard ASCII character set during message composition.

   2. Means to facilitate composition, editing and clearing of a message. The unit in conjunction with software resident in the processor provides for a cursor capability.

   3. Visual display of messages (80 characters per line x 24 lines).

i. High-Speed Printer Unit - The High-Speed Printer Unit is an alphanumeric impact printer capable of handling the full 128-character ASCII set. Print speed is 180 characters per second and the printer is capable of printing at least 132-character columns.

j. Keyboard Printer Unit - The Keyboard Printer Unit provides a hard copy interactive terminal capability. Characteristics include operation at up to 30 characters/sec (300 baud), 132 characters per line and a full (128 characters) ASCII keyboard.

2.2.2 CPMAS-D

The CPMAS-D is the measurement acquisition set for the CPMAS for DCS digital transmission systems. Two CPMAS-D feasibility models are part of the CPMAS Emulation/Test System. The CPMAS-D scans transmission equipment monitor points which indicate equipment status and compares the scanned measurements with stored threshold values. All detected state changes or threshold crossings are automatically reported to the CPMAS Emulator.

The CPMAS Emulator can request monitor and threshold data from the CPMAS-D and can change threshold levels stored in the CPMAS-D data base. Loading and changing of the CPMAS-D program and data base take place off-line via a floppy disk with the exception of threshold changes described above.

The CPMAS-D functional flow is shown in Figure 2-12 and consists of four major functions which are outlined below:

a. <u>Initialization Function</u> - Initializes the various tables and buffers as required by the software design and waits for a Start message from the CPMAS Emulator. Upon receipt of the message it causes the CPMAS-D to start normal processing (i.e., Scan and Exception Reporting).

b. <u>Scan and Exception Processing Function</u> - Performs the scanning of monitor points and tags those values that have crossed thresholds or changed status for transmission to the CPMAS Emulator.

c. <u>Transmit Message Function</u> - Formats data and performs the transmission protocol.

d. <u>Receive Message Function</u> - Performs the receive protocol and analyzes the message. The function then processes the request.

The functions that are performed by the hardware major components of the CPMAS-D are presented in Figure 2-13 and specified in the following subparagraphs.

a. <u>Communications Interface Unit</u> - This unit provides the message interface between the CPMAS-D and the CPMAS Emulator. Operating functions include:

    1. Monitoring the transmission circuit from the Emulator for Idle, Busy or Open line status
    2. Controlling the status of the transmission circuit to the Emulator
    3. Processing of message characters to and from the Emulator, e.g., character parity error detection and serial/parallel conversion, as appropriate for support of the CPMAS-D software
    4. Transfer and receipt of data and control information to and from the CPMAS-D CPU
    5. Protocol functions (hand shaking) with respect to a low-speed (150 B) asynchronous modem, when the CPMAS-D is not collocated with the Emulator.

b. <u>ACE Interface Unit</u> - The 16-bit parallel data lines from the ACE unit are terminated by this unit and accessible for scanning (read-in) to the central processor unit (CPU).

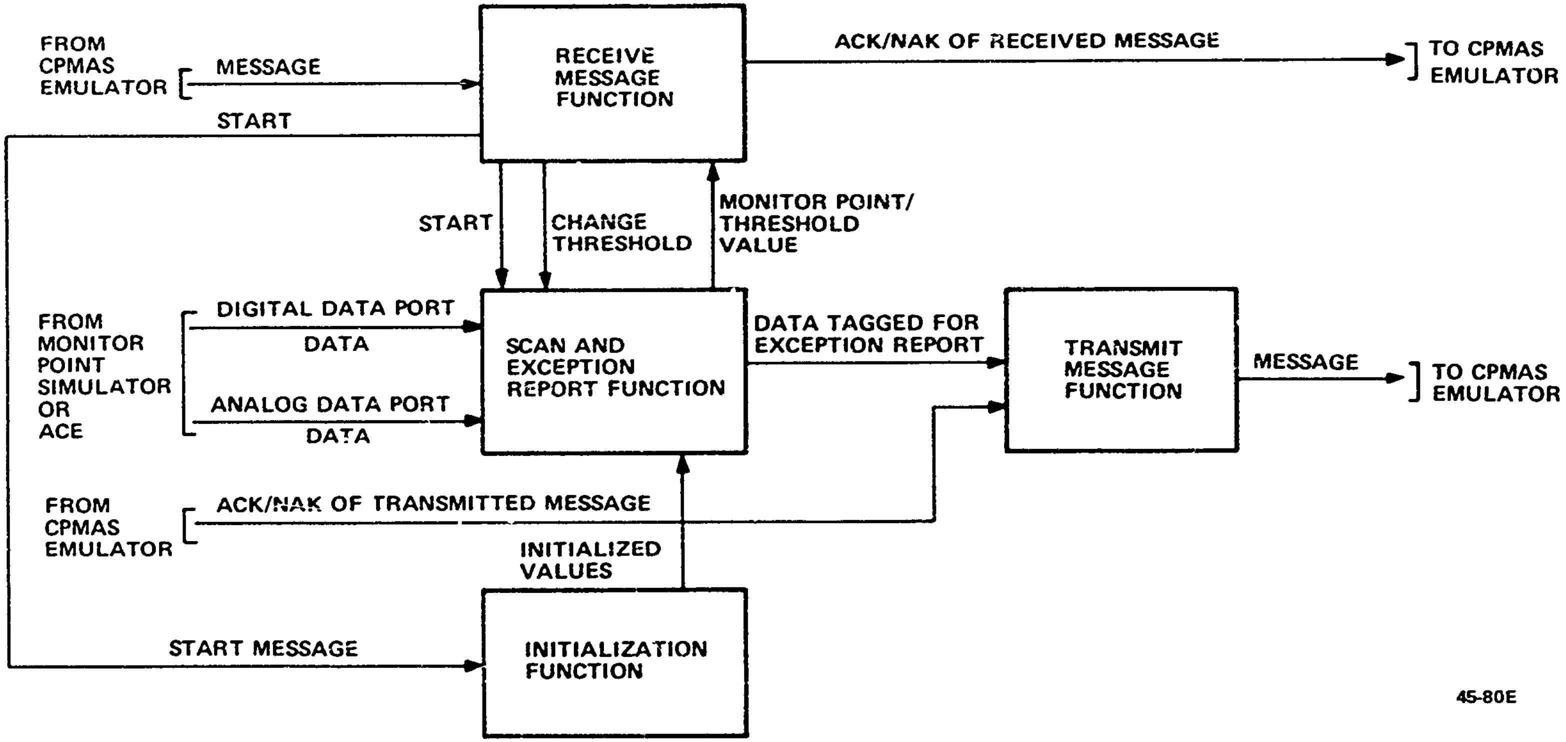

Figure 2-12. CPMAS-D Functional Flow

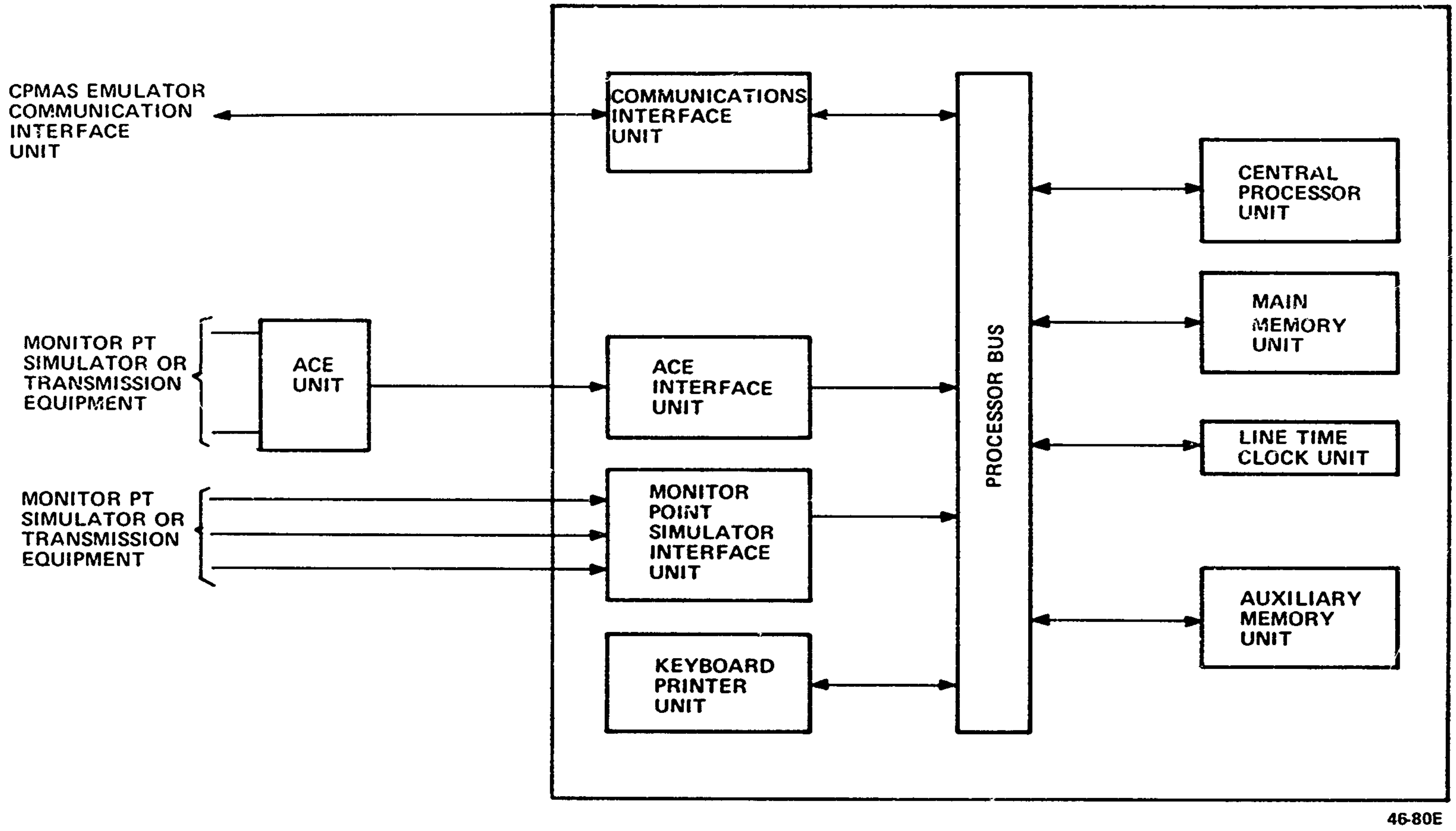

Figure 2-13. CPMAS-D Block Diagram

c. Monitor Point Simulator Interface Unit - This unit provides for binary, pulse, analog type monitor signals, and ACE data signals to be scanned at least once per second. The binary interfaces continually sense the state of their monitor points and permit scanner access during scan cycles. The circuits are non-latching and indicate the present status of the monitor point. The pulse interface circuits provide for 16-bit binary counters to accumulate pulse counts at monitor points. The counter content shall be resettable and available to the scanner unit during scan cycles. The analog interfaces samples a group of analog signal inputs and perform a 12-bit digital conversion. Analog scanning (selection) is program controlled and the results of the analog-to-digital conversion provided to the central processor during scan cycles.

d. Central Processor Unit - The central processor unit (DEC LSI 11/02) (CPU) is a 16-bit word machine capable of word, bit and byte (8 bits) processing and is compatible with the RSX-11S operating system. Its instruction set is downward compatible with that for the CPMAS-Emulator CPU. The CPU is capable of directly addressing 32K words (16-bit) of main memory.

e. Main Memory Unit - The main memory unit provides for storage of at least 32K words (16 bit). Maximum memory access and cycle times are 300 ns and 650 ns, respectively.

f. Line Time Clock Unit - The LTC unit provides for initiating scan cycles and periodic reporting.

g. Auxiliary Memory Unit - The auxiliary memory unit is a flexible (floppy) media disk system consisting of a single drive, controller and CPU interface. The media is capable of storing 256, 256 bytes of data in the following industry standard format.

1. Surfaces per disc - 1
2. Tracks - 77
3. Sectors - 26
4. Capacity per Sector - 128 bytes
5. Recording method - Double Frequency

The average data access time is less than 500 ms and The data transfer time is less than 20 µs per byte. This unit is compatible with the floppy disk system of the CPMAS Emulator, i.e., it is capable of reading from the CPMAS Emulator floppy disk.

h. Keyboard Printer Unit - The keyboard printer unit provides a hard copy interactive terminal capability. Characteristics include operation at up to 30 characters per second (300 baud), 132 characters per line printing and a full (128 characters) ASCII keyboard.

2.2.3 Adaptive Channel Estimator

The planned transition of the Defense Communications System (DCS) from an analog FDM/FM system to a digital PCM/TDM system has created the necessity to develop performance monitoring techniques that are applicable to the all-digital world. It is desirable to monitor the transmission system in such a manner that data transmission is not interrupted, while being able to alert the technical controller of a fault prior to the onset of serious system degradation. The adaptive channel estimator (ACE) unit was developed on the CPMAS program to meet the need for a fast and accurate performance monitoring technique applicable to digital transmission systems.

The ACE unit[2] applies adaptive estimation techniques by adaptively estimating parameters that can be related to error rate. The basis of the algorithm is that under low error rate conditions the detected data sequence is an accurate representation of the transmitted data sequence and by using adaptive processing techniques, channel characteristics can be identified. Figure 2-14 presents a functional block diagram of the adaptive channel estimation approach to performance assessment.

The ACE unit accepts signals from the receive portion of a digital radio or from a data demodulator. Three types of signals are required: data detector input signals (i.e., the decision variable which when sampled yields the data detector output

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[2] L. Jankauskas, "Adaptive Estimation of Discrete Nonlinear Channels for Performance Assessment", IEEE Canadian Conference on Communications and Power, Oct. 1976.

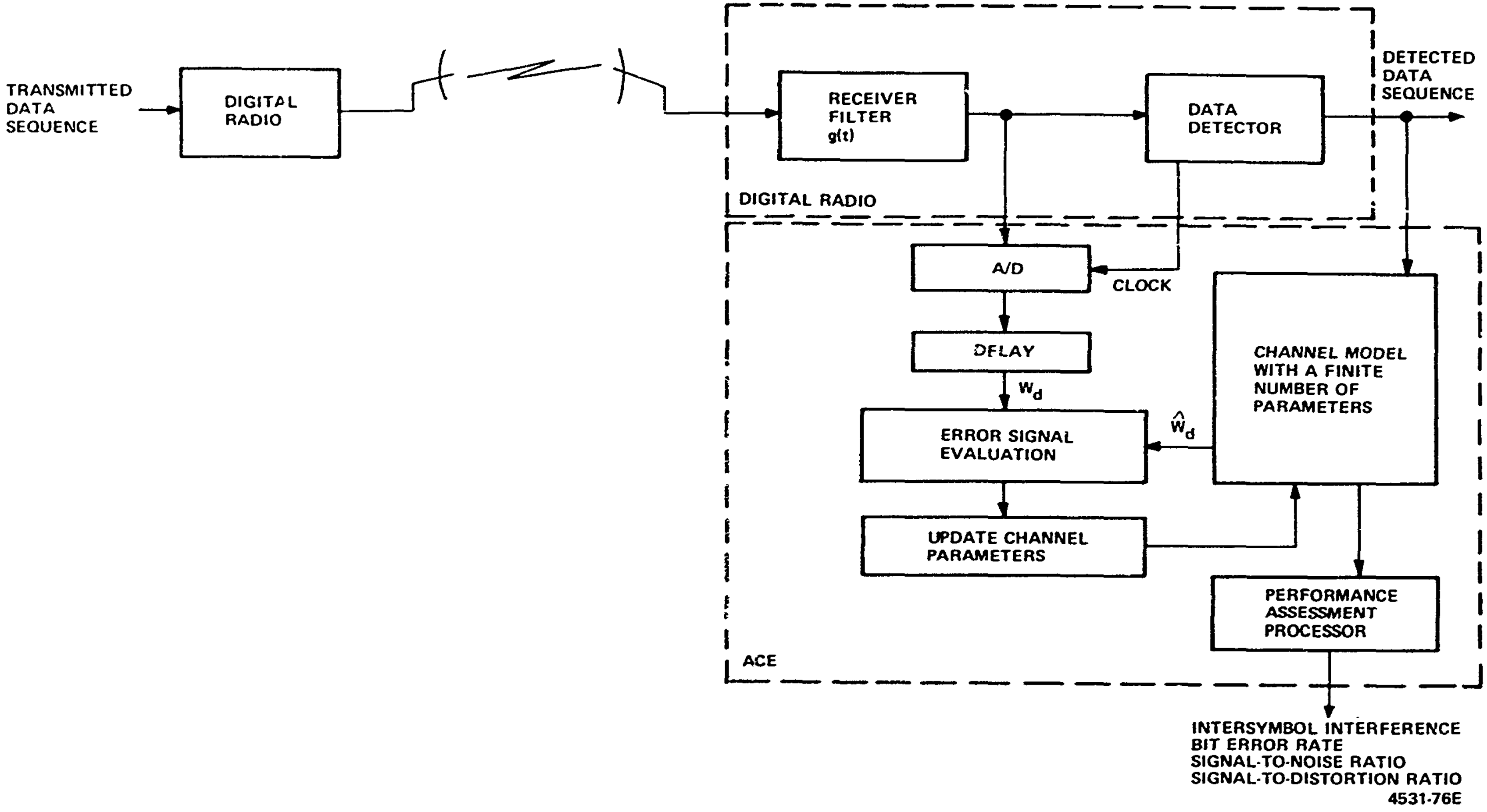


Figure 2-14. ACE Operational Concept

signal), data detector output signals, and sample timing which specifies the instant at which the data detector input signal is sampled.

The nucleus of the technique is a channel model with a finite set of parameters. A quadratic channel model is employed by the ACE unit, where the linear channel model parameters represent the signal and intersymbol interference. Eight contiguous data detector output signals are the inputs to the channel model and are used to form an estimate of the data detector input signal. This estimate is compared with the actual data detector input signal in order to generate an error signal. The error signal is used to update the channel model parameter estimates. A least mean square (LMS) algorithm is used to update the estimates.

After a sufficient number of iterations the parameters in the channel model have converged and the error signal is due primarily to the noise in the data detector input signal. A noise estimate is formed from error signals and, together with the channel model parameters, is used to form estimates of bit error rate (BER), signal-to-noise ratio (SNR), and signal-to-distortion ratio (SDR). The calculation of bit error rate uses a modification of the truncated pulse train approximation that is frequently used to calculate BER for systems degraded by intersymbol interference and additive white Gaussian noise.

The Adaptive Channel Estimator (ACE) implemented on the CPMAS program employed a quadratic discrete channel model from which BER, SNR, and SDR are estimated for one or two digital radio channels. The ACE employs a 16-bit, bit-slice, bipolar microprocessor mounted on 5 P.C. cards with a 48-bit instruction word and a microinstruction execution time of less than 200 nanoseconds. Input data is provided by interface circuitry on three wire-wrap cards which sample the digital radio data detector input signal and detected data stream.

2.3 FAULT DETECTION/ISOLATION

The CPMAS fault detection/isolation algorithm has been uniquely developed for and is an integral part of the CPMAS emulation facility. In this section the fault detection/isolation algorithm will be described.

The inputs to fault detection/isolation are equipment status (either via station emulation or CPMAS-D exception reports) and network connectivity. The global approach used by the algorithm examines in one cycle the entire network status, including all alarm monitor points, and simultaneously locates all faulty equipment.

The CPMAS fault detection and isolation functional flow is shown in Figure 2-15. It consists of five phases. First exception reports or emulated status are received and acknowledged by the algorithm. These reports are used by the algorithm to maintain the current status of all equipments via an Equipment Status Table.

The second step maps the equipment alarms into their effect upon each communication path which is described in terms of its hierarchical transmission structure (supergroups, groups, and channels). For any station each unit of equipment (e.g., radios, second level multiplexers, etc.) is associated with a unique position within this structure. The Equipment Status Table proserves this information thereby enabling the algorithm to map the equipment alarms into a communication path status for each station. The status is represented as either a non-alarmed (in service) or an alarmed (out-of-service) state.

The third step is to delete the sympathetic alarms. The hierarchically described communication path status for each station and the network connectivity are the inputs to this function. The output is a list of stations with real faults. All downstream alarms at the same or lower level from the real fault are classified as sympathetic alarms and deleted. The

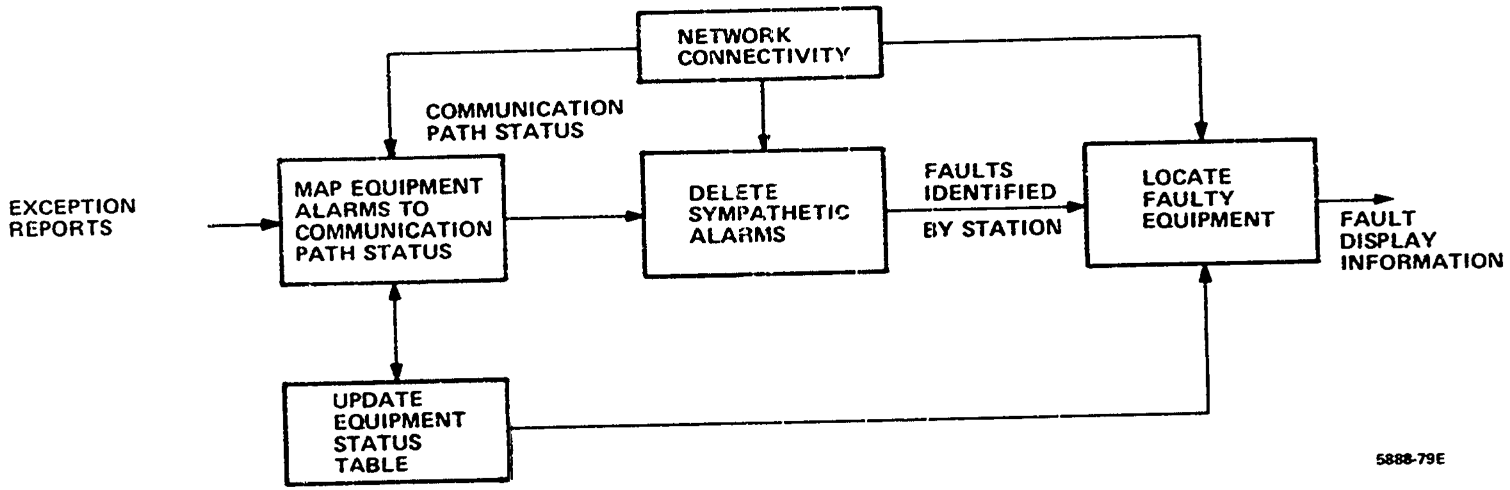


Figure 2-15. CPMAS Fault Detection/Isolation Functional Flow

faults identified by this interim process are described in terms of a station name and a position on the communication path hierarchy. The fourth step determines the equipment corresponding to each real fault. This process consists of scanning the Equipment Status Table for the alarmed equipments at the hierarchical level and station reported as faulted.

The final step is to display the network faults to the Technical Controller. The prime output is a list of all network faults with each identified to the faulty equipment.

The main advantages of this algorithm is its global network approach and fault isolation speed. The global solution is characterized by locating all network faults during each pass of the algorithm. This parallel processing is enabled by our design which describes faults in terms of their communication path status rather than in terms of equipment faults. As the algorithm systematically examines the entire network to delete sympathetics the bookkeeping procedures delineate all independent real faults. The fault isolation time is reduced in two ways. First by using the parallel approach all faults are isolated simultaneously. Moreover, the communication path status reduces the bookkeeping and allows highly repetitive and efficient processing.

The key element of this algorithm is its definition and utilization of communication path status. However, the effectiveness of this concept depends upon network partitioning. As the CPMAS fault detection/isolation algorithm applies to any interconnected network a universally applicable star network partitioning concept was developed to improve processing efficiency. An example of star network division is shown in Figure 2-16. Each star network has only one station with more than two links. Thus, a star network has a central station with any number of legs emanating from it. The number of stations on

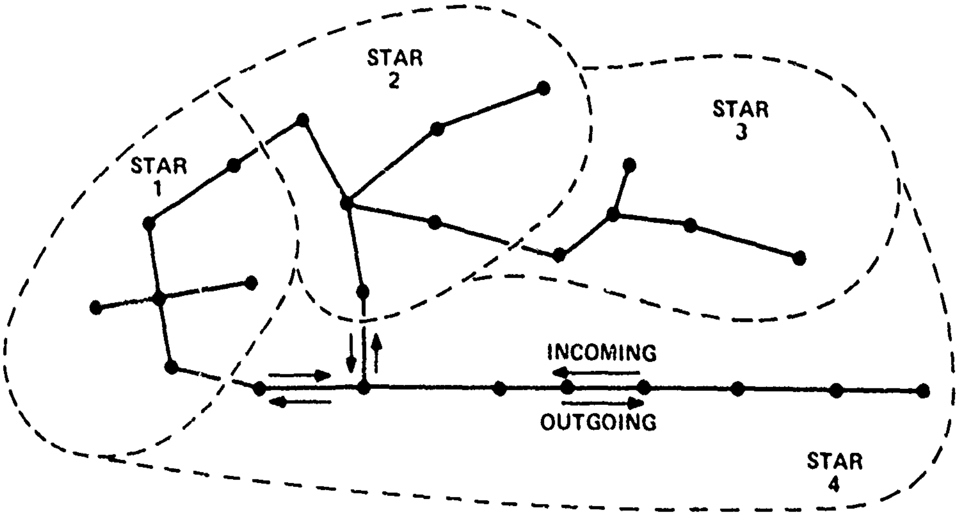


Figure 2-16. Network Partitioning Example

each leg is also arbitrary. The only restriction is that no leg can start and terminate at the same central station. This states that no star network can have a closed loop.

The star network search sequence locates the upstream alarms first. The transmission hierarchy has a specified directionality such that each leg of the star network can be considered as two independent simplex paths, where one path is applicable to data transmission into the central station and the other data away from it. The search sequence exams each of the star network legs starting at the outermost station using those communication path status flags applicable to data transmission into the center of the star. Each station on the leg is examined in order of its position from the central station. The communication path status of each leg is maintained in an internal table indexed by hierarchy. Alarms at each station are compared to the table to determine if it is the most upstream alarm. Alarms so identified are kept in a separate table of real faults. After each incoming leg has been examined the communication status is transferred to the outgoing data transmission portion of the star network legs. This process uses the connectivity of the central station. Then the process is reversed by starting at the innermost station using the communication path status applicable to data transmission away from the center of the star network.

When the communication network is partitioned into more than one interconnected star, then the search sequence is done iteratively. By that we mean approximately N^2 searches are performed each cycle of the algorithm, where N is the number of star network partitions. Stars 1 through N will be searched in sequence. This process is repeated N times. This will allow status information to be passed between star network partitions.

From an algorithm verification viewpoint, the CPMAS fault detection/isolation algorithm is easy to verify since the algorithm follows the network connectivity tables each cycle of the algorithm independently of the number and location of the faults. Previous algorithms relied upon conditional branching which depended upon fault triggers. This results in considerable difficulty in exhaustively testing the algorithm before being placed in the field.

2.4 CPMAS MAN/MACHINE OPERATION

A CPMAS man machine capability is provided so that technical control man/machine operation can be evaluated and detailed status information can be conveniently accessed for subsequent evaluation. CPMAS man/machine operation consists of technical controller commands (Table 2-1), information prompts, and information displays. Figure 2-17 shows the CPMAS command restrictions.

Four types of displays can be generated by the CPMAS Emulator. They are: fault summary displays, equipment detail displays, monitor immediate displays, and threshold displays.

The fault summary display (Figure 2-18) is perhaps the most useful display in an operational environment because it provides the technical controller with a listing of every faulty equipment in his area of responsibility. Information pertaining to each fault is presented so that the operator can assess the severity, location, and status of the fault. The operator can then request an equipment detail display (Figure 2-19) which will list all alarmed monitor points as represented in the CPMAS Emulator data base.

The monitor immediate display (Figure 2-20) permits the operator to examine the present status of all monitor points on an equipment. The CPMAS-D unit will respond to a monitor immediate request by providing the most recent value of all analog and pulse count parameters and the status of all binary monitor points. This display should be useful to maintenance personnel who must repair a faulty equipment.

The threshold display (Figure 2-21) presents the threshold levels for the specified monitor point. This display presents to the operator the threshold levels, as presently stored in the

TABLE 2-1. TECHNICAL CONTROLLER COMMANDS

DISPLAY COMMANDS

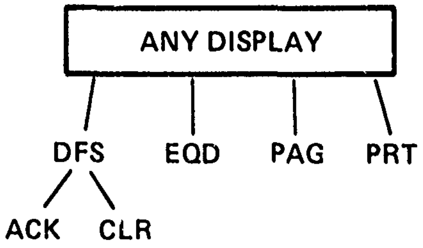
DFS	Display Fault Summary
EQD	Equipment Detail
DTH	Display Threshold
MIM	Monitor Immediate
MSG	Message
PAG	Page
PRT	Print
RCL	Recall
STO	Store

ASSIGN COMMANDS

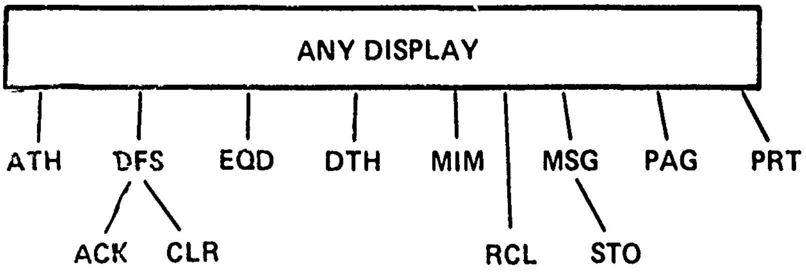
ACK	Acknowledge
CLR	Clear Fault
ATH	Assign Threshold
SRT	Start CPMAS-D

INFORMATION PROMPTS

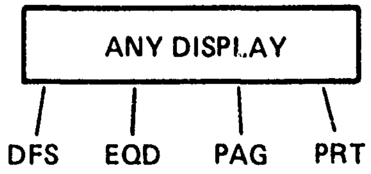
FAULT	System Fault Status Change
MESSAGE	CPMAS-D Message Pending
ILL CMND	Illegal Command
ACK	Acknowledge Valid Command
PENDING	Command Execution in Process



a. NODE A CONTROLLER



b. NODE B CONTROLLER



c. SECTOR CONTROLLER

*NOTE: ACK AND CLR ARE VALID AFTER PAG AND PRT
IF A FAULT SUMMARY DISPLAY IS DISPLAYED

73-80E

Figure 2-17. CPMAS Command Restrictions

```
LINES
 1  } HEADER
 2  }
 3
 4                          FAULT SUMMARY
 5
 6     NO__SEV__ACK__STA__LINK__SG__GP__CH__EQUIP__DIR__I/O__CNT__TIME
 7
 8
 .
 .
 .
 .
 .
 .
23
24       COMMANDS
                                                             74-80E
```

Figure 2-18. Fault Summary Display Format

```
LINES
 1   } HEADER
 2   }
 3
 4                          EQUIPMENT DETAIL
 5
 6     EQUIP TYPE -
 7
 8        ALARMS                                           ALARMS
 9
10
11
12
 .
 .
 .
 .
 .
 .
23
24     COMMANDS                                            75-80E
```

Figure 2-19. Equipment Detail Display Format

```
LINES
  1  }
  2  }  HEADER
  3
  4                         MONITOR IMMEDIATE
  5
  6     STA          EQUIP ID
  7
  8     MONITOR PT         STATUS/VALUE        MONITOR PT        STATUS/VALUE
  9
 10
 11
 12
  .
  .
  .
  .
  .
  .
 23
 24     COMMANDS                                                    76-80E
```

Figure 2-20. Monitor Immediate Display Format

```
LINES
  1  }
  2  }  HEADER
  3
  4                                  THRESHOLD
  5
  6     STA            EQUIP ID         MONITOR PT
  7
  8     RED LOW        AMBER LOW        AMBER HIGH          RED HIGH
  9
 10
  .
  .
  .
  .
  .
 23
 24     COMMANDS
                                                              77-80E
```

Figure 2-21. Threshold Display Format

CPMAS-D data base, that pulse count or analog parameters are compared against to determine an out-of-tolerance condition, i.e., an alarm.

The commands presented in Table 2-1 provide the technical controller with a level of manual intervention in the emulator processing. Nine display commands are provided. Four of these commands allow the technical controller to request a fault summary display (DFS), an equipment detail display (EQD), a threshold display (TDH), or a monitor immediate display (MIM). The fault summary and equipment detail displays will be automatically presented, but since the threshold and monitor immediate displays require information resident at a CPMAS-D unit, an additional command (MSG) is required before these displays are presented. This provides the technical controller the capability to examine CPMAS-D messages at his convenience. The page command (PAG) permits the technical controller to examine all pages of a multipage display. The print command (PRT) provides a hardcopy of the presented display. Store (STO) and recall (RCL) commands allow the technical controller to store a message for display at a later time.

Information prompts are provided to aid the technical controller in using the CPMAS emulation facility. When a faulty equipment is isolated or when the status of a faulty equipment has changed, the CPMAS emulator alerts the technical controller by a FAULT prompt. A fault summary display will present the new information. When a CPMAS-D message is received at the CPMAS emulator, a MESSAGE prompt is presented. A MSG command is required to display the message. Each command input is examined for proper syntax and for consistency with the data base. While this examination is being performed a PENDING prompt is displayed. Valid commands are acknowledged (ACK) and illegal commands are rejected (ILL CMND).

Assign commands permit the technical controller to alter the system. The acknowledge fault (ACK) command provides the technical controller with the capability to keep track of information that he has seen and taken action upon. The clear fault command (CLR) is used to delete corrected faults from the fault summary display. The assign threshold (ATH) command permits the monitor point threshold levels resident in the CPMAS-D units to be remotely changed from the CPMAS Emulator. The start CPMAS-D (SRT) command permits the CPMAS-D units to be remotely started.

2.5 STATION EMULATION

As an aid in testing the fault isolation algorithm, a station emulation capability has been incorporated into the CPMAS emulation facility. Station emulation is accomplished in two manners: first, the CPMAS Emulator has been provided with a station emulation function and, secondly, monitor point simulators and T1-4000 multiplexers are provided.

The station emulation CPMAS Emulator function provides the emulator user with the capability to exercise the CPMAS emulation facility with an expanded network. Fault scenario data can be generated for hypothetical digital transmission system models. These models can contain up to sixteen stations, two nodal areas, and 2048 equipments.

Fault scenarios can be run in which the status of each monitor point in the model network is selected by the emulator user. Tables 5-1 through 5-7 of Section 5 present the points monitored for each equipment type in the model network.

The monitor point simulators provide simulated inputs to the CPMAS-D units. Table 2-2 shows the monitor points provided by each monitor point simulator. The CPMAS-D units scan the monitor point simulator status and report alarm state changes and threshold crossing to the CPMAS Emulator. The T1-4000 multiplexers provide the ACE units their input signals.

TABLE 2-2. MONITOR POINT SIMULATOR DATA

RADIO

- Binary Points (14)

– Receive Data, Timing Loss	(4)
– Transmit Data, Timing Loss	(2)
– Frequency Drift	(2)
– Modulator Output	(2)
– Bite	(2)
– On-Line Xmtr, Rcvr	(2)

- Analog Points (8)

– Receive Signal Level	(2)
– Transmit Power Level	(2)
– Power Supplies	(4)

SECOND LEVEL MUX

- Binary Points (20)

– Supergroup Data, Timing, Frame Loss	(10)
– Group Data, Timing Loss	(6)
– Bite	(2)
– On-Line Unit	(1)
– Standby Status	(1)

- Analog Points (8)

– Power Supplies	(8)

- Pulse Points (4)

– Frame Error, Frame Loss (A & B)	(4)

TABLE 2-2. MONITOR POINT SIMULATOR DATA (Cont.)

FIRST LEVEL MUX

- Binary Points (14)
  - Group Data, Timing, Frame Loss (4)
  - Channel Data, Timing, Frame Loss (9)
  - Bite (1)
- Analog Points (4)
  - Power Supplies (4)
- Pulse Points (2)
  - Frame Error (1)
  - Frame Loss (1)

SUBMUX

- Binary Points (6)
  - Channel Data, Timing, Frame Loss (5)
  - Bite (1)
- Analog Points (3)
  - Power Supplies (3)
- Pulse Points (2)
  - Frame Error (1)
  - Frame Loss (1)

SECTION 3

FAULT DETECTION/ISOLATION TEST AND EVALUATION

The CPMAS fault detection/isolation algorithm has been extensively tested using the station emulation capability previously described (Section 2.5). These tests demonstrated that the algorithm can successfully isolate single and multiple faults and performs independent of alarm arrival order. The fault detection/isolation algorithm successfully isolated the faulty equipment for all tests conducted.

In this section the fault detection/isolation tests will be discussed and an evaluation of the CPMAS fault isolation algorithm presented. This evaluation will examine timing and storage requirements of the algorithm when extended to include a nodal area based upon DCS Europe after the DEB upgrades.

3.1 FAULT ISOLATION TESTS

Testing of the CPMAS fault detection/isolation algorithm (see Section 2.3) was conducted in order to verify the algorithm and to assess performance. Both single (only one faulty equipment in the model network) and multiple (more than one faulty equipment) fault tests were conducted. Tables 3-1 and 3-2 show the tests that were conducted and the characteristics of the equipment alarms, including sympathetic alarms.

For each test conducted, the CPMAS fault detection/isolation algorithm was able to correctly locate the faulty equipment(s).

Furthermore, timing data for the fault detection/isolation algorithm were collected and are summarized in Table 3-3. This table presents the average time for a fault isolation cycle for all the tests conducted. Two cycles of the algorithm are performed before a communications fault is presented to the operator. Since the alarms can arrive at any time in a cycle, on the average one-half of a cycle will pass before the beginning of a cycle with the alarms present.

TABLE 3-1. FAULT ISOLATION TESTS (SINGLE FAULT)

Test	Description*
Single Star	The faulty equipment and all the equipments with sympathetic alarms are all in the same star network
Multiple Star	Some sympathetic alarms are in a different star network than the one that contains the faulty equipment
Multiple Direction Sympathetics	The faulty equipment has sympathetic alarms that propagate in both the transmit and receive directions
Fault First	The alarms from the faulty equipment are presented to the fault detection/isolation algorithm prior to the sympathetic alarms being presented
Sympathetic Alarms First	The sympathetic alarms are presented to the fault detection/isolation algorithm prior to the alarms from the faulty equipment
Sympathetic Transfer	The sympathetic alarms are transferred between channels, groups and supergroups

*Only one faulty equipment in model network.

TABLE 3-2. FAULT ISOLATION TESTS (MULTIPLE FAULTS)

Test	Description
Single Star	The faulty equipments and all the equipments with sympathetic alarms are all in the same star network
Multiple Star	The faulty equipments are in different star networks and the sympathetic alarms from one faulty equipment occur in the star network containing another faulty equipment
Overlapping Sympathetics	The sympathetic alarms of one faulty equipment are masked by the sympathetic alarms of a downstream faulty equipment
Timed Sequenced Faults	The alarms, including sympathetic alarms, from one faulty equipment are presented to the fault detection/isolation algorithm prior to the alarms, including sympathetic alarms, from a second faulty equipment
High Fault Loading	Many (six) faulty equipments and the resultant sympathetic alarms are present in the model network

TABLE 3-3. TIMING DATA

Test	Average Time for a Complete Fault Isolation Cycle (sec)
Single Fault	
Single Star	36.6
Multiple Star	38.9
Multiple Direction Sym.	40.2
Fault First	36.4
Sympathetic Alarms First	33.1
Sympathetic Transfer	42.3
Multiple Faults	
Single Star	38.6
Multiple Star	41.8
Overlapping Sympathetics	40.1
Timed Sequenced Faults	41.7
High Fault Loading	47.1

Thus, two and one-half fault isolation cycles are a typical processing time to isolate a fault once the alarms are present at the emulator. For the faults inserted in the model network, 2 1/2 cycles relates to 1 minute and 23 seconds to 1 minute and 58 seconds.

Thus, a fault isolation time of less than two minutes was demonstrated. Furthermore, since the tests were conducted for up to six faulty equipments in the network, the fault isolation time is relatively insensitive to fault loading. To further demonstrate that fault isolation time is insensitive to fault loading, independent channel and group faults were injected using the station emulation function. The results for a 16-station model network partitioned into three star networks are presented in Figure 3-1. As shown in this figure the fault isolation time is essentially independent of the number of independent faults or their hierarchical level.

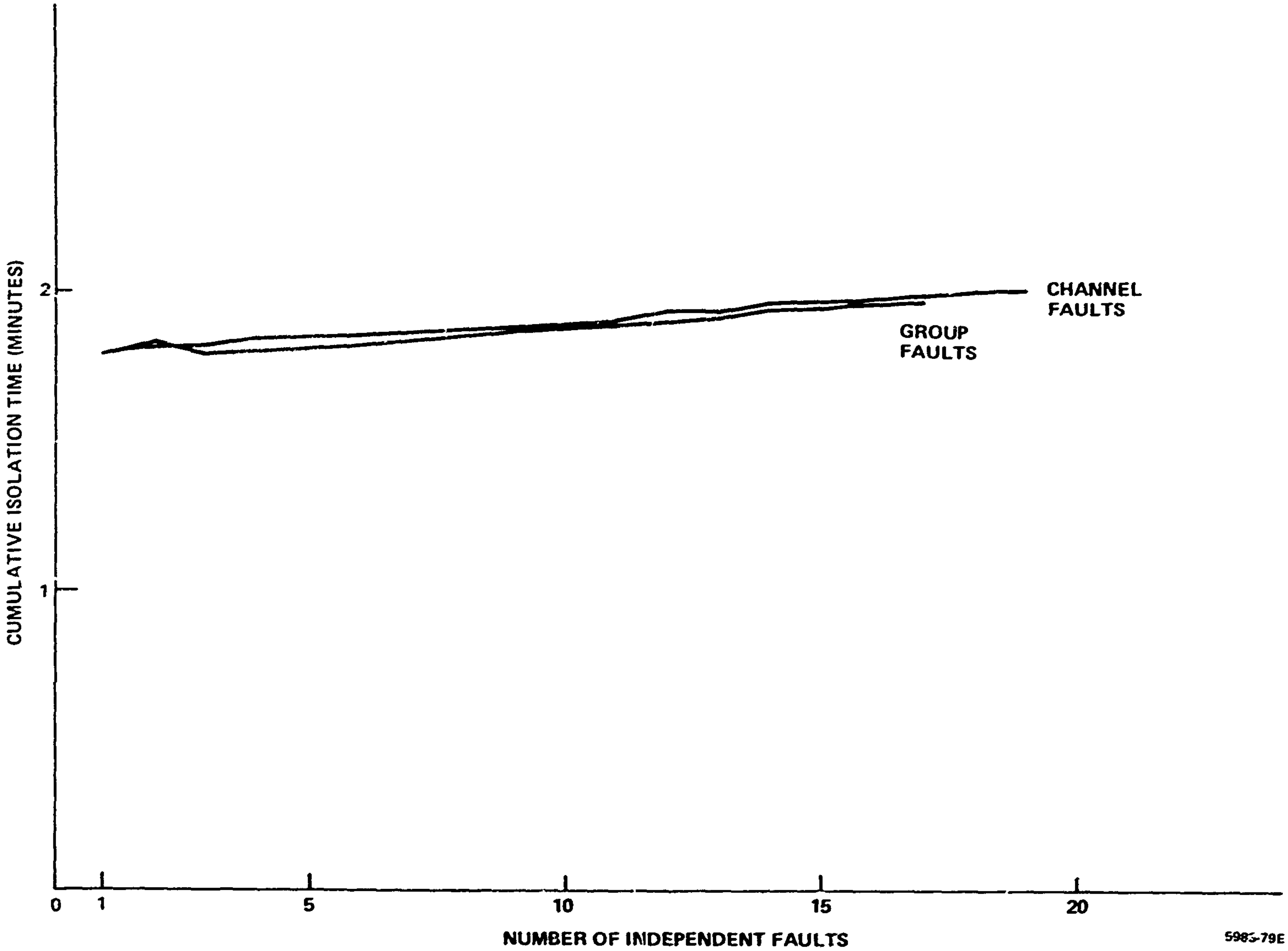


Figure 3-1. Fault Isolation Time (Model Network)

3.2 FAULT ISOLATION EVALUATION

The fault isolation tests described in the preceding section (Section 3.1) demonstrated that the CPMAS fault isolation algorithm has the capability to correctly isolate faulty equipment. In this section the algorithm will be examined with regard to timing and storage requirements when it is applied to a network larger than the 16-station emulated network model (Figure 3-2) that was used for the fault isolation tests. In particular, a European DCS network model based upon the DEB program was developed and forms the basis for the estimated timing and storage requirements of the algorithm.

3.2.1 Storage Considerations

In this section the storage requirements of the CPMAS fault detection/isolation algorithm will be discussed. Two types of storage are required: Data Storage and Program Storage. Data storage is required to store CPMAS data items such as network connectivity tables, equipment alarm status, star network partitioning, interstar reports, etc.; and, thus, the storage required is dependent upon the size and characteristics of the network. Program storage contains the program code (i.e., the CPMAS modules discussed in Section 2.2.1.1), including tables that are embedded in the software. Since the code does not change with the network (as long as the network size is within the software design limits), then the program storage is fixed.

To assess the timing and storage requirements of the CPMAS fault detection/isolation algorithm when the algorithm is employed in an operational environment, a network model based upon the digital European DEB network has been developed. This network model is presented in Figure 3-3, and contains 96 stations.

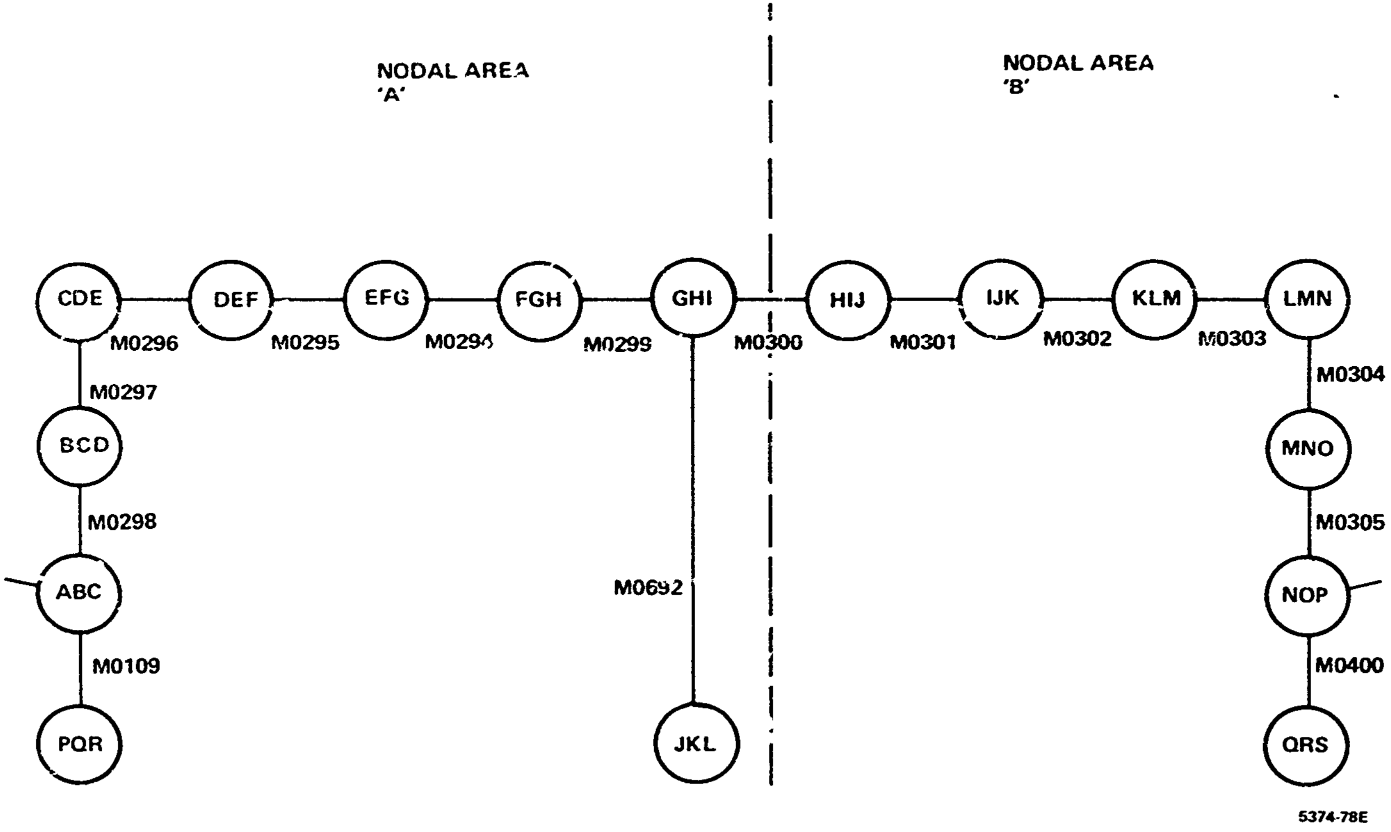


Figure 3-2. Emulated Network Model

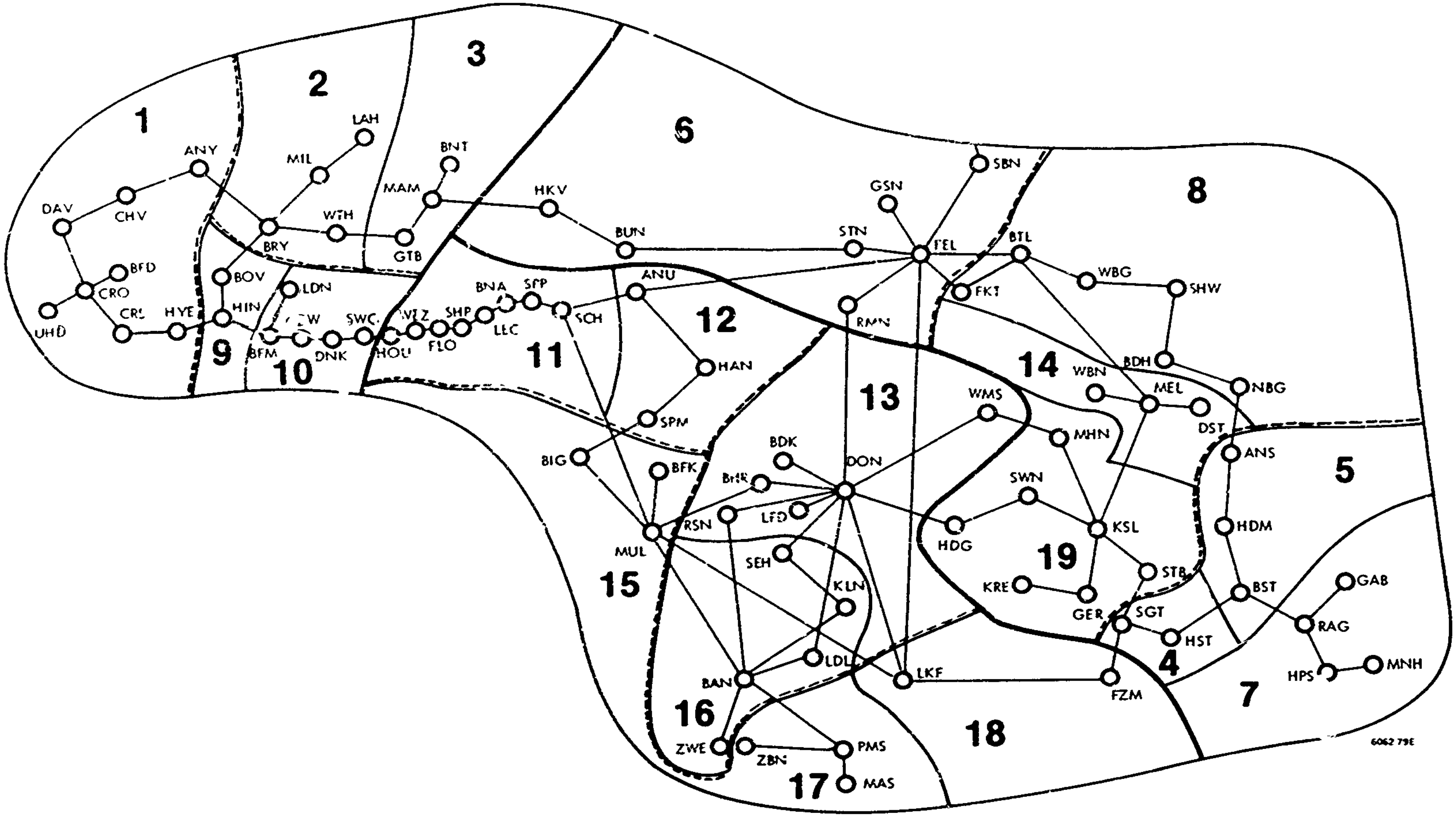


Figure 3-3. DCS Baseline System

The network model of Figure 3-3 is shown partitioned int star networks as required by the fault isolation algorithm (see Section 2.3). The numbers indicated on the network model designate the star networks, the dashed lines designate nodal boundaries, and sector boundaries are the heavy solid lines. It should be noted that the nodal and sector boundaries specified for this model are employed solely for estimating storage requirements and were chosen to reflect as accurately as practical the actual DCS System Control boundaries. The model network consists of nine Nodes in three Sectors.

The data storage requirements for each Node or Sector were determined using the method described in the CPMAS User's Manual. The data storage, S_D, is given by

$$\begin{aligned} S_D = {} & 30,225 + 142*NR + 236*N2 + 592*N1 \\ & + 12*NK + 210*NISR + 8*NS + 12*NSU \\ & + 24* \Sigma\ N\ S/P + 11 * \Sigma\ NPC + 980*NL \\ & + 24*\ NSTA + 420*MAXP + 18*NPG + 20*NST \\ & \qquad\qquad\qquad\qquad \text{(BYTES)} \end{aligned}$$

where

NR ≐ number of radios
N2 ≐ number of second level multiplexers
N1 ≐ number of first level multiplexers
NK ≐ number of key generators
NISR ≐ number of interstar reports
NS ≐ number of sectors
NSU ≐ number of submultiplexers
NS/P ≐ number of stations on a path
NPC ≐ number of paths at the center station
NL ≐ number of links
NSTA ≐ number of stations
MAXP ≐ maximum number of paths at center station.
NPG ≐ number of power generators
NST ≐ number of star networks

The data storage required was evaluated for the nodes and sectors of Figure 3-3 and is presented in Tables 3-4 and 3-5. As shown, the data storage ranges from 71 to 167 kilobytes for the nodal areas and from 160 to 305 kilobytes for the sector areas. Also shown (denoted as MODEL) is the storage required by the 16-station model network used for the fault isolation tests, as well as the program storage of 429 kilobytes which is the actual storage required by the CPMAS Emulator modules. Table 3-6 shows the program storage required by each module. (See Section 2.2.1.1 for a description of the CPMAS Emulator software.)

Table 3-4. Fault Detection/Isolation Storage Requirements (Node)

NODE	DATA STORAGE (BYTES)	PROGRAM STORAGE (BYTES)	NUMBER OF EQUIPMENT
LANGERKOPF	117,000	429,000	523
DONNERSBERG	167,000	429,000	867
SCHOENFELD	85,000	429,000	292
STUTTGART	89,000	429,000	293
KOENIGSTUHL	145,000	429,000	588
FELDSBERG	99,000	429,000	346
CROUGHTON	71,000	429,000	176
MARTLESHAM HEATH	75,000	429,000	212
HILLINGDON	76,000	429,000	222

6018 79E

Table 3-5. Fault Detection/Isolation Storage Requirements (Sector)

SECTOR	DATA STORAGE (BYTES)	PROGRAM STORAGE (BYTES)	NUMBER OF EQUIPMENT
MODEL	93,000	429,000	194
STUTTGART	268,000	429,000	1,227
HILLINGDON	160,000	429,000	610
LANGERKOPF	305,000	429,000	1,682

6019 79E

The PDP 11/60 used for the emulation facility had an addressable main memory of 124 kilowords (248 kilobytes) of which about 32 kilobytes was to support the RSX-11M operating system. Since the CPMAS operational software required storage of 429 kilobytes, the CPMAS program modules were normally stored on disk and only read into main memory when required. Several modules had to be present in main memory continuously in order to handle functions such as interrupt handling (e.g. VT-52 and CPMAS-D Listeners) and other modules were required to be resident simultaneously (e.g. ODBCNT and OSLFI). Therefore, operation of the CPMAS Operational software as presently structured on a 64-kiloword machine is not possible as RSX-11M, ODBCNT, and OSLFI would require more than 64 kilowords of main memory.

With LIST1, LIST2, ORESUM, OVDUI1, OVDUI2, and RSX-11M always present, then these tasks would require approximately 85 kilowords of main memory, thus making operation on a 96-kiloword machine questionable. The CPMAS program has demonstrated that a 124 kiloword main memory machine can provide acceptable operation and adequate response times.

TABLE 3-6. PROGRAM STORAGE

Module Name	Module Function	Storage (bytes)
LIST1	CPMAS-D Listener	5504
LIST2	CPMAS-D Listener	5504
ORESUM	Link Interface	4032
OPRNTR	LA-36 Printer Controller	9664
OVDUI1	VT-52 Input Listener	5184
OVDUI2	VT-52 Input Listener	5184
EVDUMM	Emulator Start-Up/Man Machine	9216
EMUCLO	Emulator Termination	4928
OFALTQ	Man Machine Display Storage	17344
OVDUOT	VT-52 Output Controller	11072
OVDUO1	VT-52 Output	23808
OVDUO2	VT-52 Output	23808
EDAT	Emulator Data	10048
ODBCNT	Equipment Alarm Record Manager	53888
ONODLA	Node A Man Machine	19776
OSECTR	Sector Man Machine	18880
ONODLB	Node B Man Machine	52032
OMSGN1	Message Input and Verification	10240
OMSGN2	Message Input and Verification	10240
OMSGT1	Message Construction and Output	5312
OMSGT2	Message Construction and Output	5312
OELFI	Equipment Level Fault Isolation	12224
OVDUIN	VT-52 Input Controller	10816
EMUSRT	Emulator Start-Up	9792
OSLFI	Station Level Fault Isolation	59392
OEFS	Fault Summarizer	26432

3.2.2 Timing Considerations

The desirability of improving network availability is leading to automated processing of status information and, in particular, automated fault isolation processing. To ensure that fault isolation times have a negligible impact upon availability, the fault isolation time should be small compared to the mean time to restore service. A mean time to restore service of about 30 minutes has been estimated[3] based upon digital transmission equipment with built-in test equipment (BITE). Therefore, fault isolation times of approximately two to five minutes seem acceptable.

The fault isolation tests have demonstrated that a two-minute isolation time is feasible; however, this testing was for the 16-station model network partitioned into three star networks. Approximately N^2 iterations of the algorithm are required to ensure that all the interstar information is processed (where N is the number of star networks). Returning to Figure 3-3, it is noted that there are at most three star networks in a nodal area and so, for a fault isolation algorithm operating on a nodal level, fault isolation times of two minutes are feasible.

Figure 3-4 shows estimates of the fault isolation time as a function of the number of star networks. This figure is based upon test results obtained using the 16-station model network. Implementation of the CPMAS algorithm at the Sector level is also possible. For the European DCS model network five, seven, and seven star networks are present in the three Sectors resulting in fault isolation times of about 3 1/2 and 6 minutes for the model sectors. The fault isolation times presented are based upon the CPMAS Emulator which is a PDP 11/60. A processor

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[3] "DCS Digital Transmission System Performance", Kirk, K. W. and Osterholz, J. L., DCEC Technical Reference 12-76.

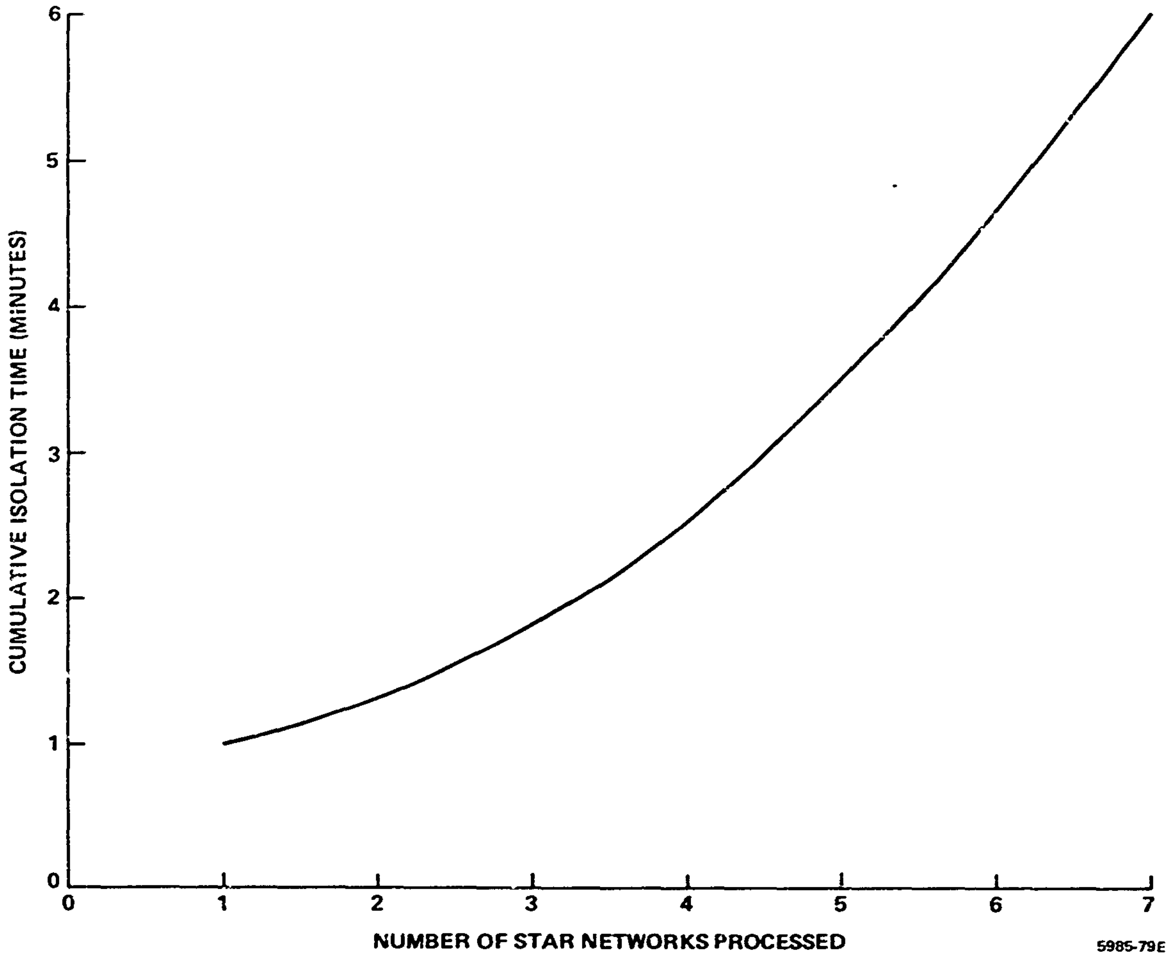

Figure 3-4. Isolation Time for European Network (Estimated)

isolating faults for a Sector would probably be more powerful than the PDP 11/60 and would be capable of residing all the CPMAS programs in main memory, which the PDP 11/60 was not able to do and resulted in disk recalls of program modules.

Furthermore, the CPMAS fault isolation algorithm has not been optimized for operation at the Sector level. In particular, the fault isolation processing should be allocated among station, node, and sector system control levels in order to minimize data transfer and isolation time.

Finally, the approximation of N^2 iterations is based upon a serial connection of N stars. By examining the network connectivity the number of iterations could be reduced with a subsequent reduction in isolation time.

3.3 FAULT ISOLATION EXTENSIONS

The unique fault isolation algorithm developed for the CPMAS Emulation Facility has many advantages, as discussed in Section 2.3. There are, however, areas to which the algorithm can be extended prior to being incorporated in an automated transmission control system. Areas in which the fault detection/isolation may require extensions are: analog/hybrid networks, confidence of results, manual control, and displays. These areas will be discussed below.

3.3.1 Analog/Hybrid Networks

The CPMAS fault detection/isolation algorithm has been developed for the digital DCS; however, the DCS presently is hybrid in that both analog and digital transmission equipment are present. Extending the CPMAS fault isolation to include analog transmission equipment is feasible since the analog transmission network employs a hierarchical multiplexing structure. In fact, the use of the CPMAS fault isolation algorithm for analog/hybrid networks would be conceptually identical to digital fault isolation. That is, the sympathetic deletion routine may not have to be changed at all. The only significant alterations to the algorithm would be in defining new rules which map equipment alarms (or ATEC-derived measurements) into their impact upon path status.

3.3.2 Confidence of Fault Isolation Results

The CPMAS fault isolation algorithm as presently implemented locates the furthest upstream alarm at a hierarchical level. Due to improper threshold settings, bad sensors, service channel failures, etc., no fault isolation algorithm will always locate the fault correctly. Rather than present only the most likely location of the faulty equipment, perhaps several possibilities can be presented along with a confidence measure indicating the relative confidence that is associated with each equipment.

Also, since a fault isolation algorithm is only as good as the monitor point status data provided, under certain circumstances it may be reasonable to automatically verify that the data received are correct and to determine if important data were not received.

3.3.3 Manual Control

As presented, the CPMAS-D unit monitors the status of the transmission equipment and, using exception reports, transmits that status information to nodal control (the CPMAS Emulator), where faults are automatically located. The CPMAS Emulator provides the technical controller with detailed equipment status information (via the equipment detail and monitor immediate displays), which provide the technical controller with the capability to manually intervene in the fault isolation process. For example, the technical controller can recognize fault isolation results that may be incorrect and can request the additional information required to manually isolate the faulty equipment. Since the technical controller may be provided with the capability to remotely switch redundant equipment, manual fault isolation in addition to the CPMAS automatic fault isolation will enhance system control performance.

3.3.4 Displays

The CPMAS Emulator provides the technical controller with four types of displays as discussed in Section 2.4. Additional display types may be desired to aid in the transmission control function. Display of network connectivity information and detailed maintenance information (if the monitor immediate information is not sufficient) will provide the technical controller with information that should be useful in an operational environment.

SECTION 4

ACE TEST AND EVALUATION

An Adapative Channel Estimator (ACE) field test was conducted at the RADC test facilities from November 6, 1978 to January 23, 1979. The purpose of the ACE field test was to gather the data necessary for an evaluation of the ACE development unit as a means of assessing performance of high-speed digital radio transmission systems. Of particular interest during the ACE field test were: measurement accuracy, resolution time, earliness of warning, operating conditions, and range.

The ACE testing was conducted using the partial response modem portion of the T1-4000 multiplexer and a quadraphase shift keyed (QPSK) modem. A wide range of test conditions was assured by inducing degradations on an operational link and by using a line-of-sight (LOS) simulator. The primary purpose of the simulated link was to determine the limitations of the ACE algorithm by simulating propagation media anomalies that are not frequently encountered over operational LOS microwave links. The operational link tests allowed verification of the ACE algorithm in an operational environment.

Tables 4-1 and 4-2 summarize the results of the ACE field tests. These results demonstrate that the ACE unit can be used over a variety of operating conditions and can effectively assess performance of digital communications systems. For the T1-4000 tests, the ACE unit was able to accurately estimate the counted bit error rate (BER). Typical errors of one-half to one order of magnitude were encountered over a range of error rates down to 10^{-9}. The ACE unit was able to form these estimates in about one second. Due to a problem with the timing of the ACE unit when operated with the QPSK modem, the ACE unit experienced typical BER estimation errors of less than 1-1/2 orders of magnitude for the QPSK tests.

TABLE 4-1. ACE TEST RESULT SUMMARY (T1-4000 MULTIPLEXER)

Test	Bit Error Rate (BER)	Signal-to-Distortion Ratio (SDR)	Signal-to-Noise Ratio (SNR)
Signal Level	Typical estimation error was less than one order of magnitude	0.5-dB variation over 30-dB signal level range	SNR decreased with signal level reduction for signal levels below -43 dB
Noise Level	Typical estimation error was one order of magnitude	0.5-dB variation over 13-dB noise level range	SNR decreased monotonically with noise level increase
Media Attentuation	Typical estimation error was one to two orders of magnitude	0.4-dB variation over 12-dB media attenuation range	SNR decreased with media attenuation
Rician Fading	ACE was able to track media fading for rms doppler spreads from 0.062 Hz to 3.98 Hz		
Phase Jitter	Typical estimation error was 1-1/2 orders of magnitude	0.1-dB variation over full range of phase jitter amplitudes	0.3-dB variation over full range of phase jitter amplitudes
Path Loss	Typical estimation error was less than one order of magnitude	0.6-dB variation over 11-dB range of path loss	SNR decreased monotonically with path loss increase
Linear Group Delay	Typical estimation error was about one-half order of magnitude	0.1-dB variation over full range of linear group delays	0.6-dB variation over full range of linear group delays
Parabolic Group Delay	Typical estimation error was less than one order of magnitude	0.2-dB variation over full range of parabolic group delays	0.4-dB variation over full range of parabolic group delays
Local Oscillator Shift	Typical estimation error was less than one order of magnitude	0.3-dB variation over full range of local oscillator shifts	0.3-dB variation over full range of local oscillator shifts

TABLE 4-2. ACE TEST RESULT SUMMARY (QPSK MODEM)

Test	Bit Error Rate (BER)	Signal-to-Distortion Ratio (SDR)	Signal-to-Noise Ratio (SNR)
Signal Level	Typical estimation error was one order of magnitude	3- to 4-dB variation over 11-dB signal level range	SNR decreased with signal level for signal levels below -4 dB
Noise Level	Typical estimation error was one order of magnitude	0.6-dB variation over 4-dB noise level range	SNR decreased monotonically with noise level increase
Media Attentuation	Typical estimation error was two orders of magnitude	5-dB variation over 8-dB media attenuation range	SNR decreased monotonically with media attenuation
Rician Fading	ACE was able to track media fading for rms doppler spreads from 0.062 Hz to 3.98 Hz		
Phase Jitter	Typical estimation error was 1-1/2 orders of magnitude	0.2-dB variation for phase jitter amplitudes from 0.5° to 32°	0.2-dB variation for phase jitter amplitudes from 0.5° to 32°
Path Loss	Typical estimation error was less than one order of magnitude	SDR increased with path loss increase	SNR decreased with path loss increase
Linear Group Delay	Typical estimation error was less than one order of magnitude	1.4-dB variation over full range of linear group delays	SNR decreased with linear delay increases
Parabolic Group Delay	Typical estimation error was three orders of magnitude	SDR increased with an increase in parabolic delay	SNR decreased with parabolic delay increases
Local Oscillator Shift	Typical estimation error was 1-1/2 orders of magnitude	SDR increased slightly (2 dB) with local oscillator offset	SNR decreased by 6 dB with local oscillator offset

The test data were examined and the ACE algorithm evaluated[4], as shown in Table 4-3. The ACE parameter estimates were found to be very sensitive to induced degradations. Several areas that can potentially improve the performance of the ACE unit were delineated and are summarized in Table 4-4. These recommendations address the size of the channel model, the ACE timing, noise reduction, and the use of double precision arithmetic in portions of the ACE processing.

4.1 DESCRIPTION OF TESTS

The ACE field test consisted of two phases: an installation and check-out phase, and an ACE evaluation phase. The purpose of the installation and check-out phase is to connect the ACE unit to the QPSK modem or the T1-4000 multiplexer and to verify proper operation of the ACE unit. The ACE evaluation phase gathered the performance data necessary to evaluate the performance of the ACE unit. This evaluation was performed over a range of quality measure values and for several operating conditions including simulated and operational links as well as two different data modulation techniques. Figure 4-1 shows the ACE field test program.

During the ACE evaluation tests, four test configurations were employed: T1-4000 multiplexer with the LOS simulator, T1-4000 multiplexer with an operational link, QPSK modem with the LOS simulator, and QPSK modem with an operational link. Figures 4-2 and 4-3 show the ACE test configurations.

The evaluation test program that was conducted during the ACE field tests is presented in Figure 4-4. For this test program a simulated link and an operational link were employed.

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[4] "Adaptive Channel Estimator (ACE) Test Report," March 1979.

TABLE 4-3. ACE EVALUATION SUMMARY

Measurement Accuracy	Typical BER estimation errors were less than one order of magnitude for T1-4000 multiplexer tests and less than 1½ orders of magnitude for QPSK modem tests
Resolution Time	Less than 1 second for all bit error rates
Earliness of Warning	Provided indications of degradations simultaneously with induced degradations
Operating Conditions	Demonstrated ACE operation with T1-4000 multiplexer and QPSK modem over simulated and operational links. Multiple baseband operation was demonstrated.
Range	BER: BERs from 10^{-1} to 10^{-14} were estimated SNR: SNRs from 1 to 24 dB were estimated SDR: SDRs from 12 to 18 dB were estimated

TABLE 4-4. ACE RECOMMENDATIONS

- Reduce T1-4000 multiplexer channel model from 8 linear and 28 quadratic taps to 6 linear and 15 quadratic taps
- Reduce QPSK modem channel model from 8 linear and 28 quadratic taps to 6 linear taps
- Add another delay adjustment to the ACE unit when used with the QPSK modem
- Reduce the ACE noise floor
- Investigate the use of double precision arithmetic processing

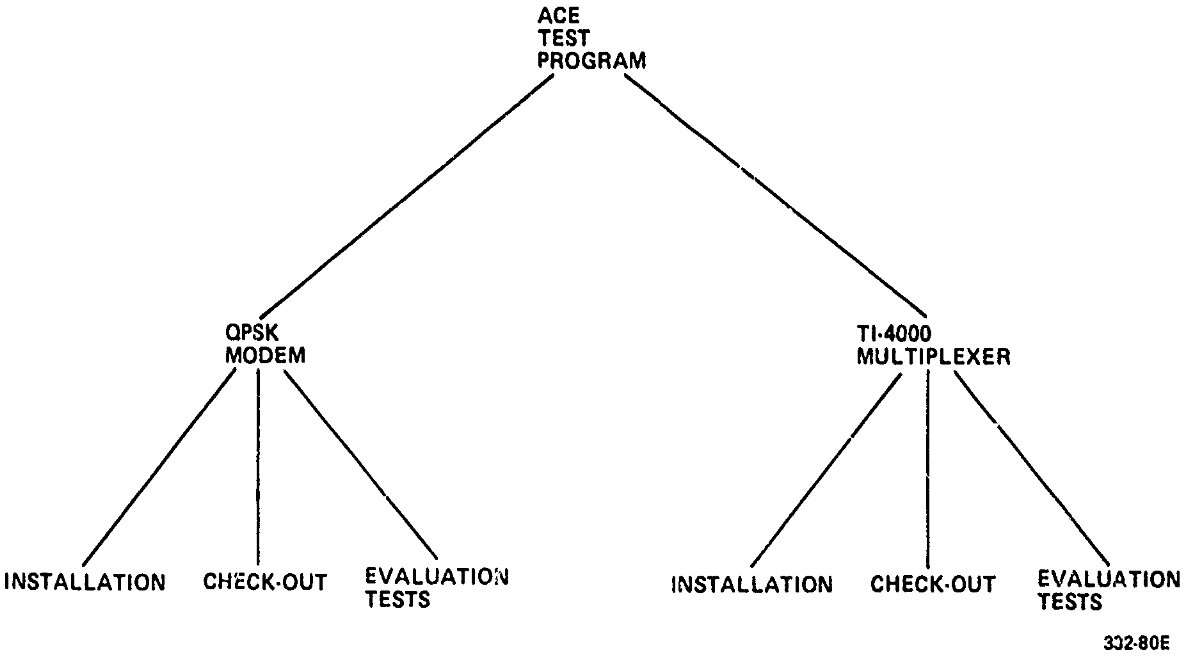
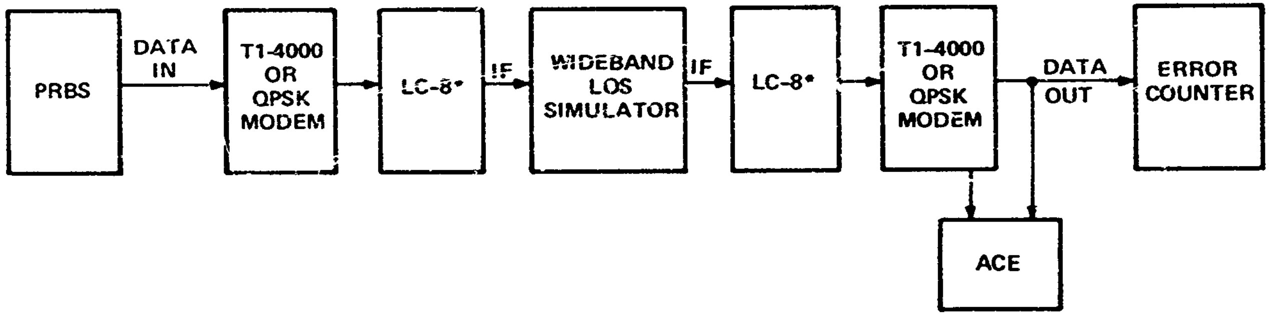


Figure 4-1. ACE Field Test Program



*NOT REQUIRED WITH QPSK MODEM

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Figure 4-2. ACE Test (Simulated Link)

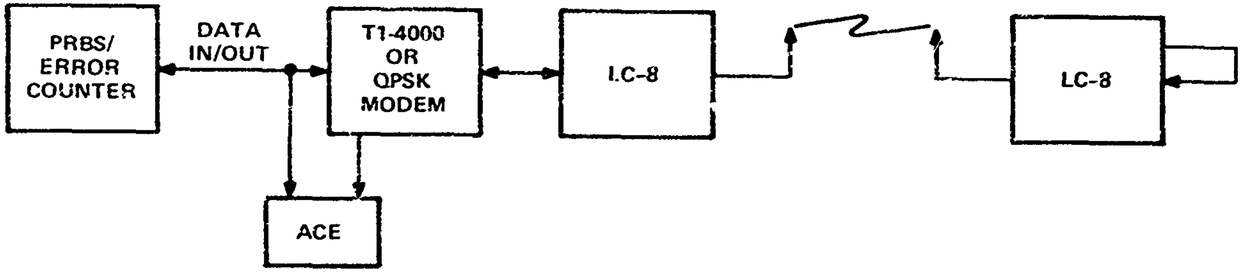

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Figure 4-3. ACE Test (Operational Link)

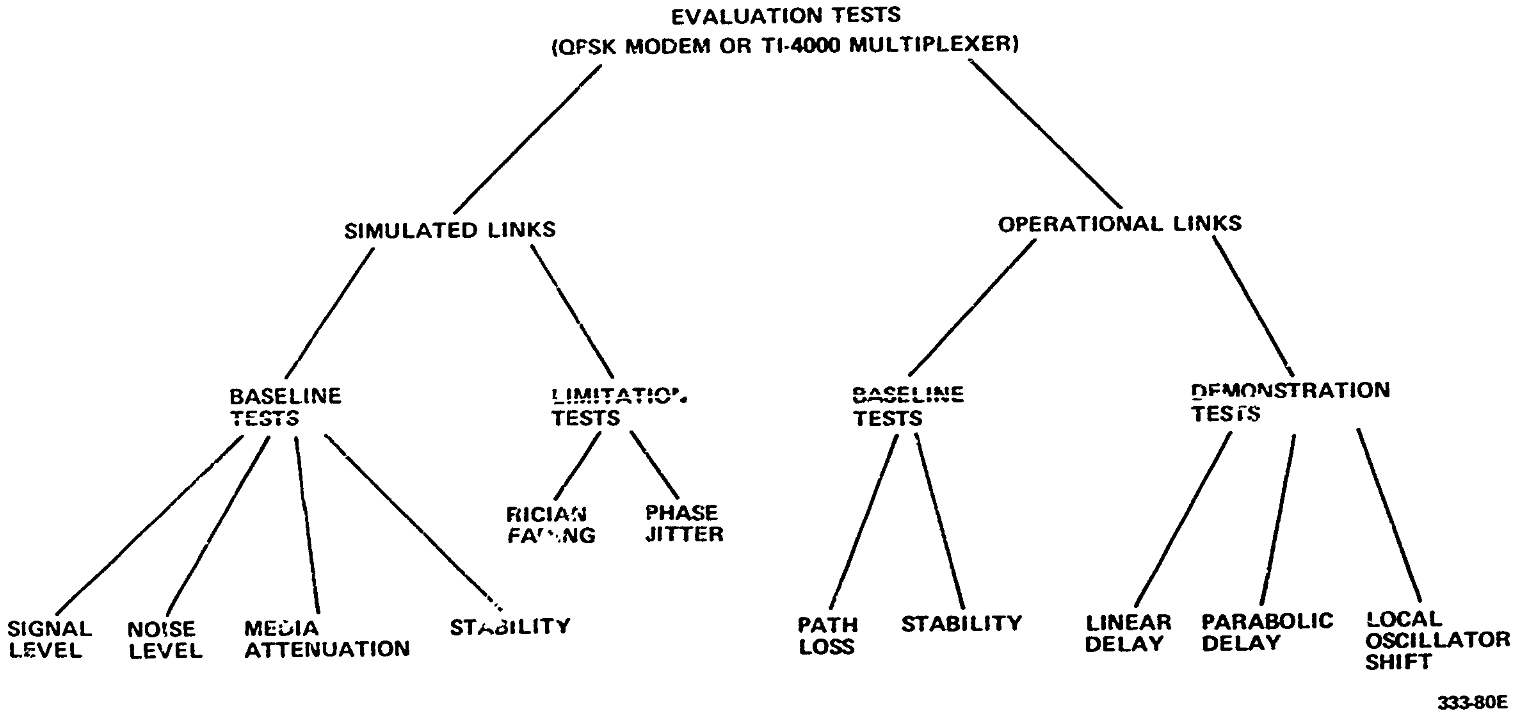

Figure 4-4. ACE Evaluation Test Program

The primary purpose of the simulated link was to determine the limitations of the ACE algorithm by simulating propagation media anomalies that are not frequently encountered over operational LOS microwave links. The operational link tests allowed verification of the ACE algorithm in an operational environment.

The evaluation testing of the ACE unit was divided into three categories: (1) baseline testing, (2) limitation testing, and (3) demonstration testing.

The results of the field test demonstrate that the ACE unit can be used over a variety of operating conditions and can effectively assess performance of digital communications systems. For the T1-4000 tests, the ACE unit was able to accurately estimate the counted bit error rate (BER). Typical errors of one-half to one order of magnitude were encountered over a range of error rates down to 10^{-9}. The ACE unit experienced typical BER estimation errors of less than 1-1/2 orders of magnitude for the QPSK tests.

Figures 4-5 through 4-8 present some typical BER results collected during the ACE field test. As shown in these figures, ACE was able to accurately estimate error rates down to 10^{-9} and tracked the counted error rate through five or six orders of magnitude. Furthermore, it should be noted that the ACE unit forms its BER estimates in about one second, whereas counting errors required up to twenty minutes at the lower error rates.

In conclusion, the field tests demonstrated that the ACE algorithm provides a versatile performance assessment capability without sacrificing performance. It is likely, then, that the ACE should be the best performance assessment algorithm for many practical applications.

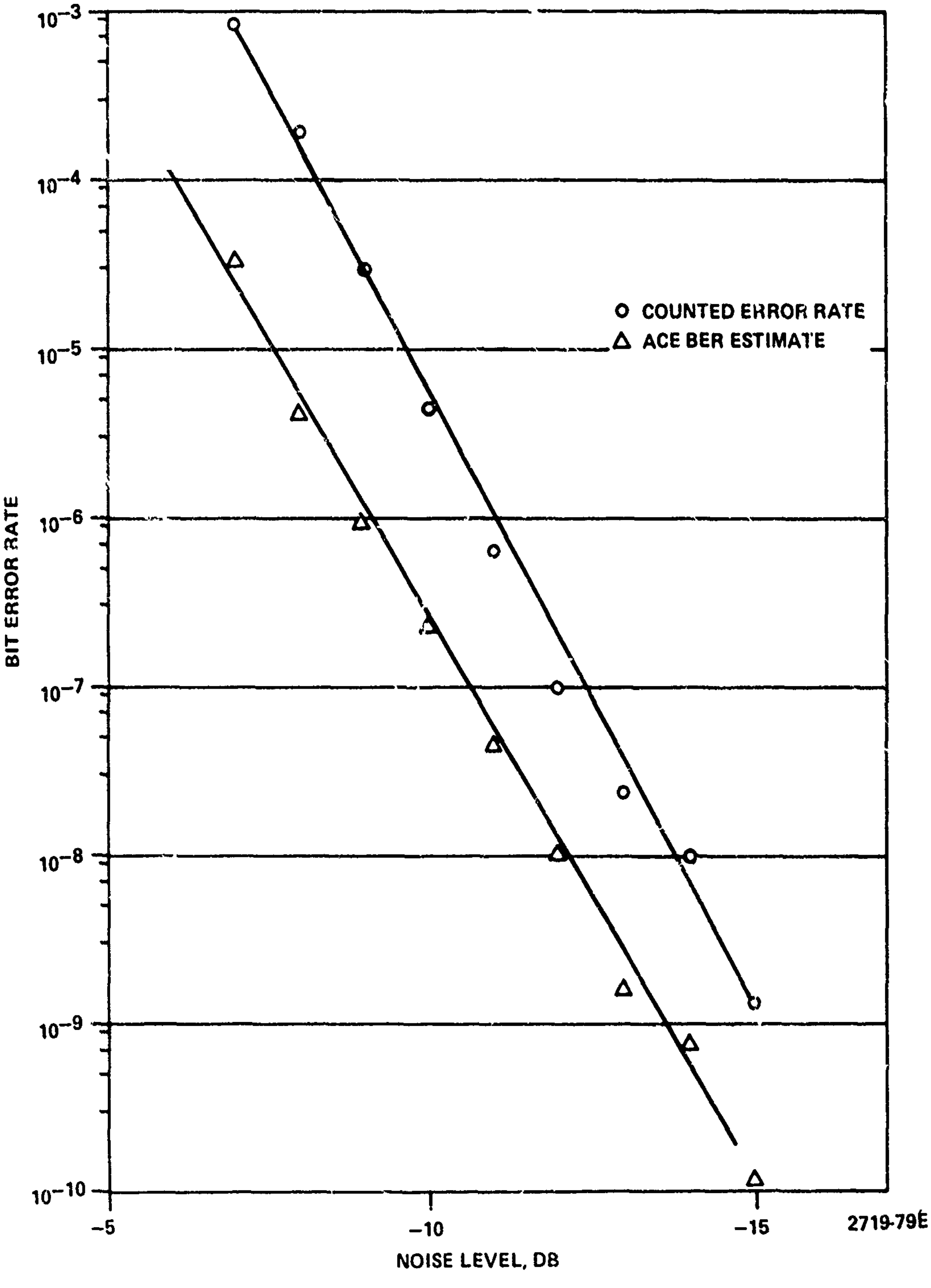

Figure 4-5. T1-4000 Noise Level Test

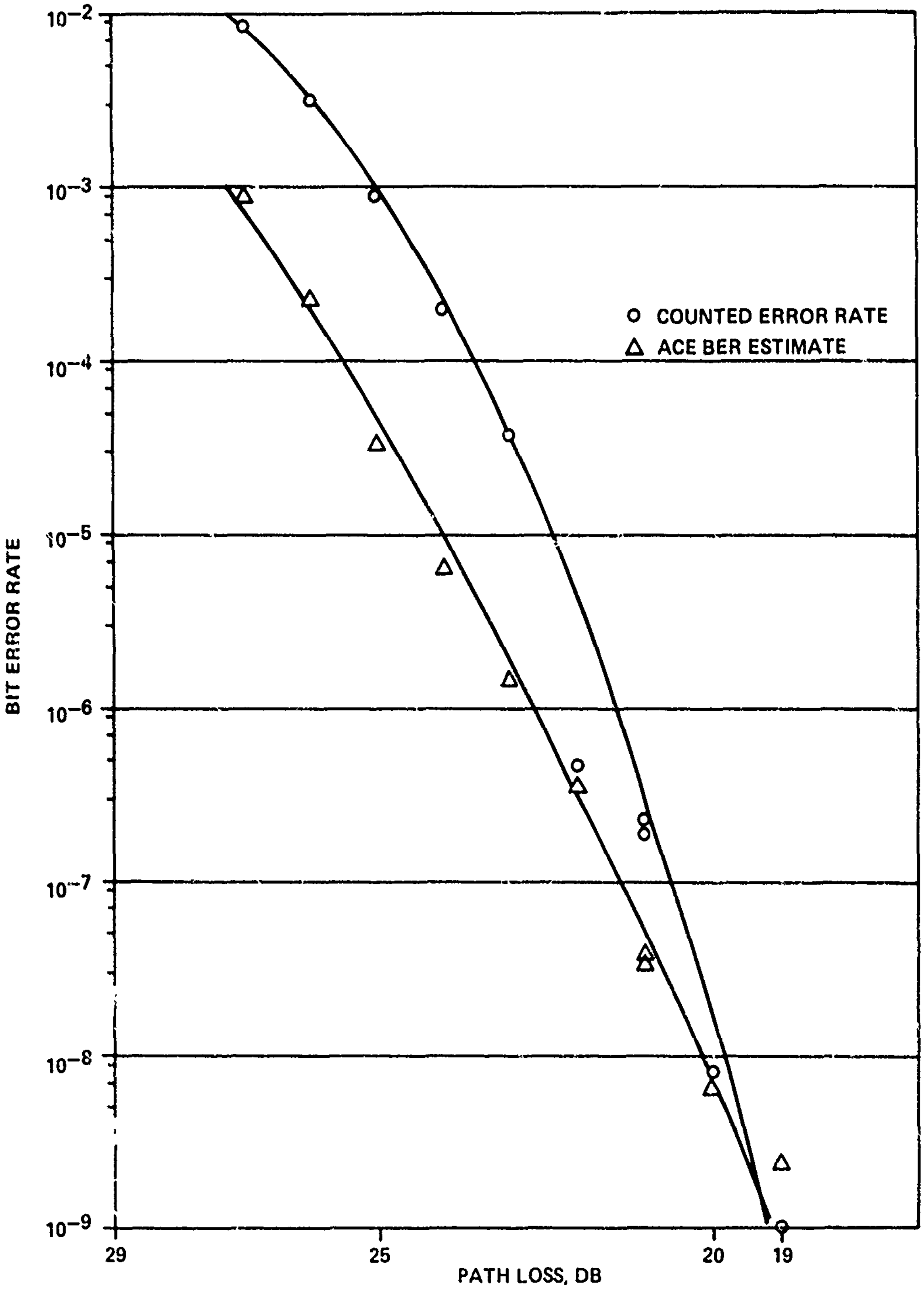

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Figure 4-6. T1-4000 Path Loss Test (RF Loop Back)

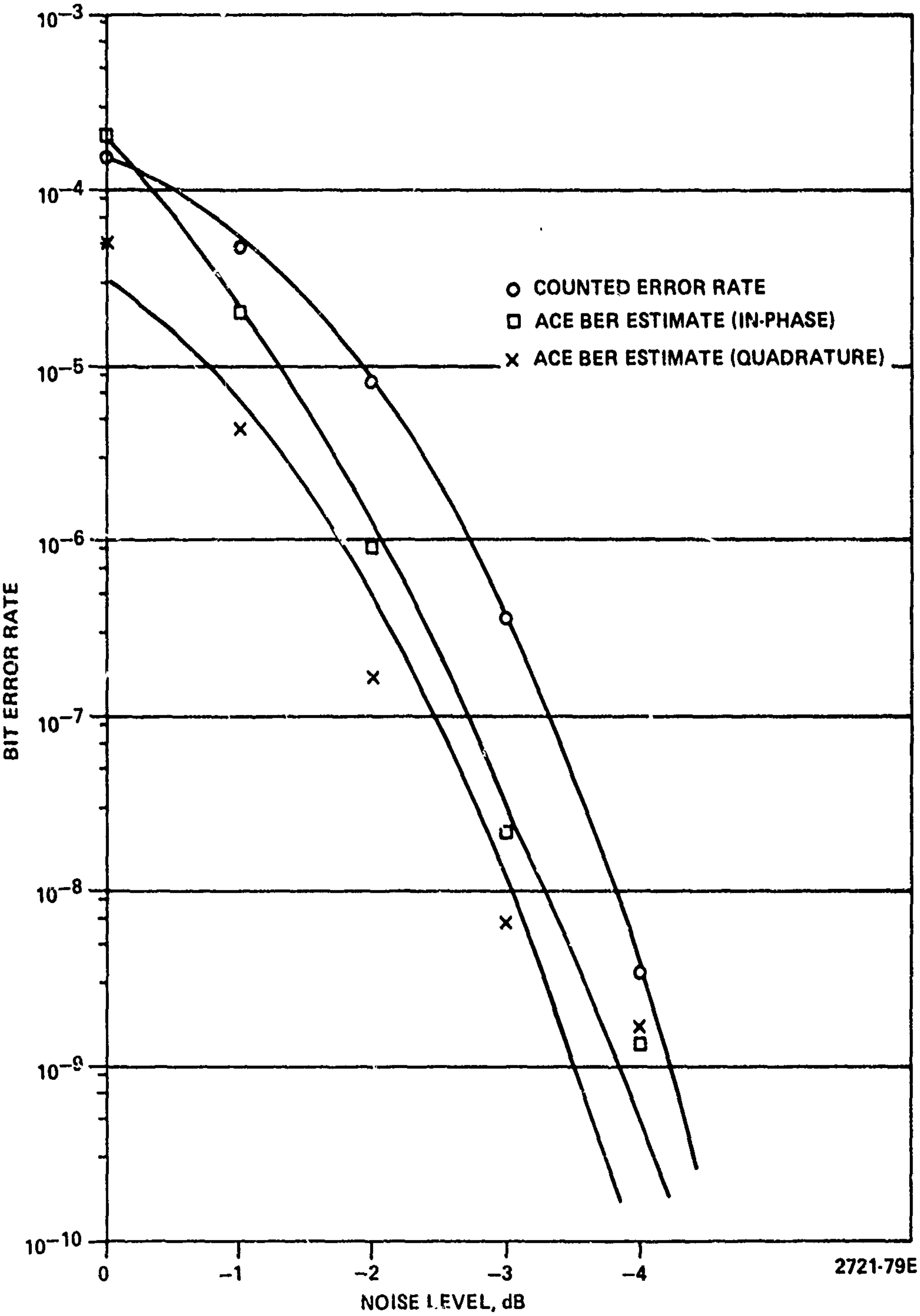

Figure 4-7. QPSK Noise Level Test

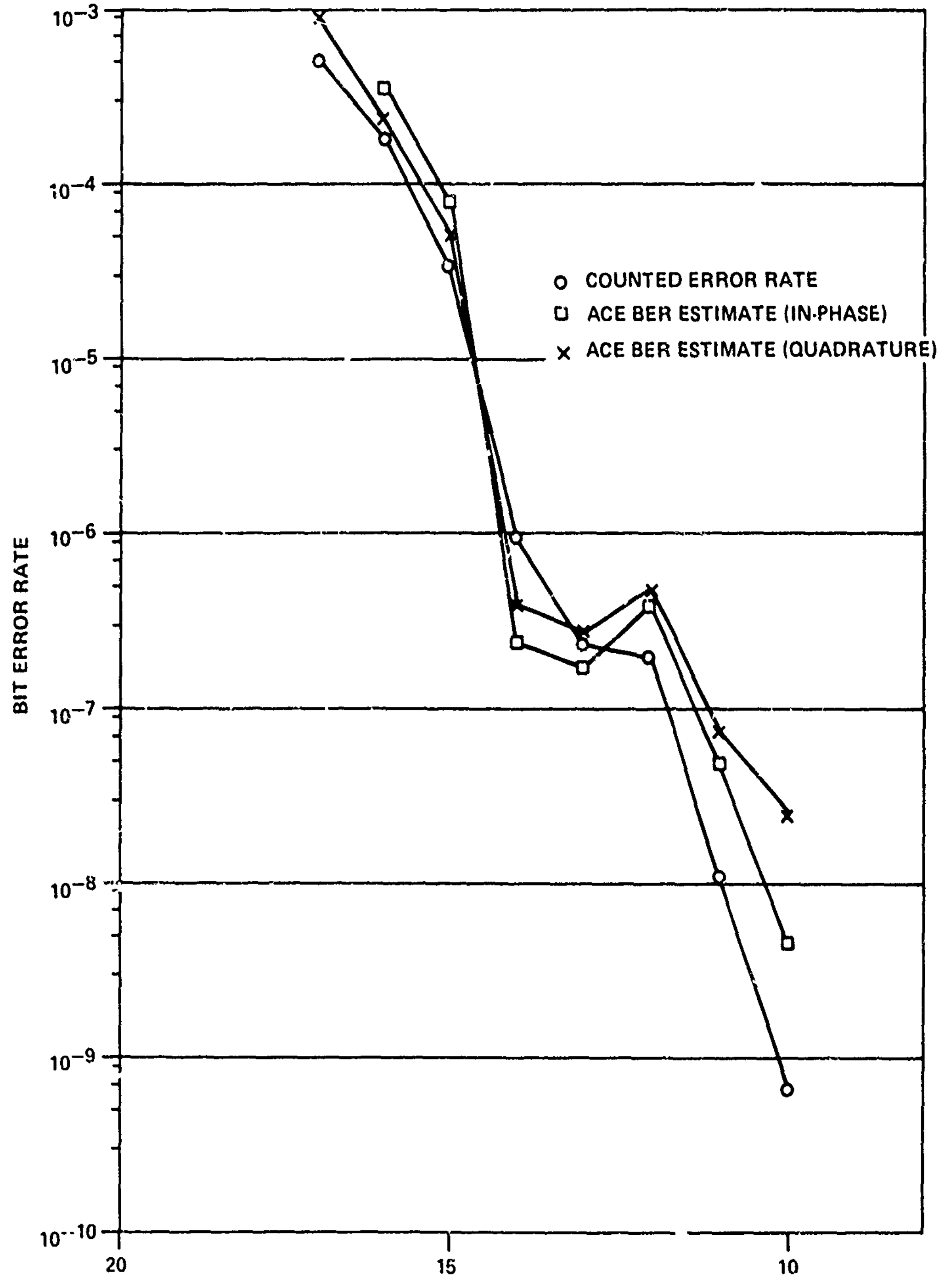

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Figure 4-8. QPSK Path Loss Test

4.2 ACE EVALUATION

The primary purpose of the ACE field test was to gather the data necessary for an evaluation and analysis of the ACE development unit. Of particular interest during the field test were: operating conditions, resolution time, range, earliness of warning, and measurement accuracy. The limitations of the technique are also of interest. It should be noted that several problems did arise during the field test (see Section 5), but this is not unexpected since this field test represents the first time that the ACE unit has operated with on-line digital transmission equipment. Implementation of the recommendations of Table 4-4 would be expected to improve the performance of the ACE unit.

4.2.1 Operating Conditions

The ACE field test demonstrated that the ACE unit can be used over a variety of operating conditions including simulated and operational links as well as two different modulation techniques: baseband partial response and quadraphase shift keying (QPSK). Multiple baseband operation of the ACE unit was demonstrated during the QPSK tests.

4.2.2 Resolution Time

Resolution time of the ACE unit was less than one second (about one-half second); however, with this fast a resolution time, the ACE visual readouts were updated too often for a satisfactory man-machine interface. To improve man-machine performance, the ACE unit resolution time was increased to one second by increasing the number of iterations. This resolution time is the time required to get one ACE estimate of BER, SNR and SDR, and is independent of the error rate being estimated. Therefore, the ACE unit provided very rapid estimates of its performance measures.

4.2.3 Range

The range of parameter estimates that a performance assessment technique provides is an indication of its flexibility in assessing performance. Techniques which bottom out (provide essentially the same performance measure whenever performance is better than a set level) would not be able to indicate changes in system performance until the system has degraded into the useful range of the technique. For example, if a BER estimation technique bottomed out at a 10^{-8} error rate and if, furthermore, a 10^{-7} error rate provided unacceptable performance, then a technical controller would only have the interval from which the system goes from 10^{-8} to 10^{-7} to react or else unacceptable performance may result.

The range of performance measures that the ACE unit estimated was quite large and demonstrated that the ACE unit can be applied over a range of system conditions. ACE BER estimates ranged from about 10^{-1} during QPSK Rician fading tests to 10^{-14} during T1-4000 operation. ACE SNR estimates ranged from about 1 dB to about 29 dB and ACE SDR estimates ranged from about 12 dB to about 18 dB. Therefore, a wide range of ACE parameter estimates was made during the field test.

4.2.4 Earliness of Warning

The early-warning capability of the ACE unit was demonstrated in two manners. First, the range of BER, SDR, and SNR estimates is such as to allow the ACE unit to determine levels of very high system performance and degradations from these levels. Second, it was observed that ACE performance measures detected system degradations simultaneously (within one second) with many actual system degradations. Therefore, ACE parameters will be useful as inputs to an early-warning technical control capability.

4.2.5 Measurement Accuracy

In this section the accuracy of the ACE unit will be evaluated. For this evaluation the counted and estimated BER data will be presented as an estimation difference. The BER difference is defined as

$$\text{BER DIFFERENCE} \triangleq \text{LOG}_{10}\ (\text{ACE BER}) - \text{LOG}_{10}\ (\text{COUNTED BER})$$

Therefore, the value of the BER difference indicates the number of orders of magnitude that the ACE BER differs from the counted BER. For example, a BER difference of 1 indicates that the ACE BER estimate is an order of magnitude higher than the counted BER.

4.2.5.1 T1-4000 Multiplexer Tests

The accuracy of the ACE unit when operated with the T1-4000 multiplexer was evaluated. The results of this evaluation are summarized in Table 4-5, where average and worst case BER differences are presented. From this table it is evident that the ACE BER estimate closely tracked the counted error rate. Average BER differences in the range -1.54 to 0.23 were measured. Furthermore, if error propagation was taken into account, the BER difference would increase by about 0.5 and would generally improve the ACE BER estimates. It should be noted that the estimation accuracy demonstrated was for counted error rates down to 10^{-9} and were resolved within one second.

4.2.5.2 QPSK Modem Tests

The accuracy of the ACE unit when operated with the QPSK modem was evaluated. The results of this evaluation are summarized in Table 4-6, where average and worst case BER differences are presented.

TABLE 4-5. ACE EVALUATION (T1-4000 MULTIPLEXER)

	Average BER Difference (Orders of Magnitude)	Worst Case BER Difference (Orders of Magnitude)
Baseline Tests:		
Signal Level	-0.55	-1.27
Noise Level 1	-0.85	-1.67
Noise Level 2	-1.06	-1.78
Media Attenuation	-1.30	-1.84
Path Loss 1	-0.78	-1.51
Path Loss 2	-0.13	1.67
Limitation Tests:		
Phase Jitter	-1.54	-1.68
Demonstration Tests:		
Linear Delay	0.23	0.74
Parabolic Delay	0.30	1.02
Local Oscillator Shift	-0.46	-1.26

Table 4-6. ACE EVALUATION (QPSK MODEM)

	Average BER Difference (Orders of Magnitude)		Worst Case BER Difference (Orders of Magnitude)	
	In-Phase	Quadrature	In-Phase	Quadrature
Baseline Tests:				
Signal Level	1.15	1.00	3.90	3.19
Noise Level	-0.58	-1.07	-1.23	-1.75
Media Attenuation	1.63	1.43	2.47	1.93
Path Loss 1	0.34	0.38	0.84	1.55
Path Loss 2	0.37	0.16	2.32	2.23
Limitation Tests:				
Phase Jitter	2.07	0.96	2.14	1.07
Demonstration Tests:				
Linear Delay	0.99	0.44	1.30	0.99
Parabolic Delay	3.05	2.76	4.46	4.19
Local Oscillator Shift	1.69	1.43	2.25	2.21

The ACE BER estimates obtained during the QPSK modem tests did not track the counted error rate as well as during the T1-4000 tests. This is evident from Tables 4-5 and 4-6, where the worst case BER difference ranged from -1.75 to 4.46 for the QPSK modem baseline tests, but ranged only from -1.84 to 1.67 for the equivalent T1-4000 multiplexer tests. The primary reason for this is assessed to be the inability of the ACE unit to sample the QPSK modem data detector input signals at the same instant as the modem samples (see ACE Field Test Report, Reference 4).

4.3 PERFORMANCE ASSESSMENT COMPARISON

As a means of comparing the ACE approach against other contemporary performance assessment approaches, the performance monitor rate, PMR, was empirically evaluated from the ACE field test data. PMR has been defined[5] as

$$\mathrm{PMR} = \left. \frac{\left[\dfrac{\widehat{\mathrm{BER}}\ (\mathrm{SNR}_1)}{\widehat{\mathrm{BER}}\ (\mathrm{SNR}_2)} \right]}{\left[\dfrac{\mathrm{BER}\ (\mathrm{SNR}_1)}{\mathrm{BER}\ (\mathrm{SNR}_2)} \right]} \right|_{\mathrm{BER\ (NOMINAL)}}$$

where $\widehat{\mathrm{BER}}\ (\cdot)$ is the bit error rate estimate of the performance assessment approach and BER $(\cdot)$ is the actual error rate. $\mathrm{SNR}_1 < \mathrm{SNR}_2$ and are selected such that the bit error rates are in the range of interest.

PMR, as defined, is a measure of the sensitivity of a performance assessment technique. A PMR of 1 indicates that the estimated BERs change the same number of orders of magnitude as the counted error rate. Therefore, PMRs approaching 1 are desirable.

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[5] Leon, B.J., et al., "Performance Monitors for Digital Communications Systems, Part II," August 1974.

PMRs for several performance assessment techniques have been evaluated and are presented in Table 4-7 along with theoretical and measured PMRs for the ACE unit. As shown in this table, the ACE approach resulted in the highest PMR.

TABLE 4-7. COMPARISON OF ACE WITH OTHER TECHNIQUES

TECHNIQUE	PERFORMANCE MONITOR RATE (PMR)
SAMPLING TIME VARIATION MONITOR	0.16†
JITTER MONITOR	0.08†
SLICER LEVEL VARIATION MONITOR	0.21†
ACE: TI-4000	0.93†, 0.70*
ACE: QPSK MODEM	0.93†, 0.64*

†THEORETICAL
*MEASURED

6029-79E

SECTION 5

CPMAS RECOMMENDATIONS

This CPMAS program has demonstrated the effectiveness of the CPMAS fault isolation algorithm and the ACE performance assessment unit. Additional testing of the fault isolation algorithm, including field and operational environment tests, are recommended (see Section 6) and should be completed before a final recommendation regarding fault isolation for the digital DCS can be rendered. Additional analysis of the ACE unit is also recommended (see Section 6.7).

Implementation of the CPMAS fault isolation algorithm employed the equipment and station alarms of Tables 5-1 through 5-7. These alarms provided the algorithm with the capability to isolate classes of multiple faults, eliminate sympathetic alarms, and isolate a faulty equipment. Further examination of these alarms are recommended based upon the development of the DRAMA equipment. However, consideration should be given to accessing these alarms, if not provided by DRAMA, in order to maximize the capability of the fault isolation algorithm.

A detailed description of the recommended alarms for the transmission equipment is presented in Tables 5-8 through 5-11.

TABLE 5-1. RADIO SET AN/FRC-163 ALARMS

Alarm	Description	Alarm	Description
1	Loss of Decoder Output - A	*33	Bite Alarm - A
2	B	*34	- B
3	Loss of Derandomizer Output - A	35	Demux Frame Error A
4	B	36	Demux Frame Error B
5	Loss of Frame Synchronization - A	*37	Rx Signal Level A Amber
6	B	*38	Rx Signal Level A Red
*7	Loss of MBS Port 1 - A	*39	Rx Signal Level B Amber
*8	1 - B	*40	Rx Signal Level B Red
9	2 - A	*41	Tx Power Level A Amber
10	2 - B	*42	Tx Power Level A Red
11	Loss of SCBS Port 3 - A	*43	Tx Power Level B Amber
12	3 - B	*44	Tx Power Level B Red
*13	Loss of Timing Port 1 - A	*45	P.S. DC Volt #1 A Amber
*14	1 - B	*46	P.S. DC Volt #1 A Red
15	2 - A	*47	P.S. DC Volt #1 B Amber
16	2 - B	*48	P.S. DC Volt #1 B Red
17	3 - A	*49	P.S. DC Volt #2 A Amber
18	3 - B	*50	P.S. DC Volt #2 A Red
*19	On-Line Receiver	*51	P.S. DC Volt #2 B Amber
*20	Frequency Drift Alarm - A	*52	P.S. DC Volt #2 B Red
*21	- B	*53	SDR A Amber
*22	Loss of Modulator Output - A	*54	SDR A Red
*23	- B	*55	SDR B Amber
24	Loss of Multiplexer Output - A	*56	SDR B Red
25	- B	*57	SNR A Amber
*26	Loss of MBS Port 1	*58	SNR A Red
27	2	*59	SNR B Amber
28	Loss of SCBS Port 3	*60	SNR B Red
*29	Loss of Timing Port 1	*61	BER A Amber
30	2	*62	BER A Red
31	3	*63	BER B Amber
*32	On-Line Transmitter	*64	BER B Red

Note: * = Directly or derived from CPMAS-D data.

TABLE 5-2. SECOND LEVEL MUX TD-1193 ALARMS

Alarm	Description	Alarm	Description
* 1	Loss of SGRX Frame - A	*33	Loss of SGTX Data - A
* 2	Loss of SGRX Frame - B	*34	Loss of SGTX Data - B
* 3	Loss of SGRX Data - A	*35	Loss of SGTX Timing - A
* 4	Loss of SGRX Data - B	*36	Loss of SGTX Timing - B
* 5	Loss of SGRX Timing - A	*37	Bite A
* 6	Loss of SGRX Timing - B	*38	B
* 7	Loss of GPTX Data or Timing - A - 1	*39	On-Line Unit
* 8	Loss of GPTX Data or Timing - A - 2	*40	Standby Status
9	Loss of GPTX Data or Timing - A - 3	41	
10	Loss of GPTX Data or Timing - A - 4	*42	SGRX Frame Error Red Alarm A
11	Loss of GPTX Data or Timing - A - 5	43	
12	Loss of GPTX Data or Timing - A - 6	*44	SGRX Frame Error Red Alarm B
13	Loss of GPTX Data or Timing - A - 7	45	
14	Loss of GPTX Data or Timing - A - 8	*46	SGRX Frame Loss Red Alarm A
*15	Loss of GPTX Data or Timing - B - 1	47	
*16	Loss of GPTX Data or Timing - B - 2	*48	SGRX Frame Loss Red Alarm B
17	Loss of GPTX Data or Timing - B - 3	*49	P.S. DC Volt #1 - A Amber
18	Loss of GPTX Data or Timing - B - 4	*50	P.S. DC Volt #1 - A Red
19	Loss of GPTX Data or Timing - B - 5	*51	P.S. DC Volt #1 - B Amber
20	Loss of GPTX Data or Timing - B - 6	*51	P.S. DC Volt #1 - B Red
21	Loss of GPTX Data or Timing - B - 7	*52	P.S. DC Volt #2 - A Amber
22	Loss of GPTX Data or Timing - B - 8	*53	P.S. DC Volt #2 - A Red
*23	Loss of GPTX Timing - A	*54	P.S. DC Volt #2 - B Amber
*24	Loss of GPTX Timing - B	*55	P.S. DC Volt #2 - B Red
25	Loss of GPRX Data or Timing - A/B - 1	*56	P.S. DC Volt #3 - A Amber
*26	Loss of GPRX Data or Timing - A/B - 2	*57	P.S. DC Volt #3 - A Red
27	Loss of GPRX Data or Timing - A/B - 3	*58	P.S. DC Volt #3 - B Amber
28	Loss of GPRX Data or Timing - A/B - 4	*59	P.S. DC Volt #3 - B Red
29	Loss of GPRX Data or Timing - A/B - 5	*60	P.S. DC Volt #4 - A Amber
30	Loss of GPRX Data or Timing - A/B - 6	*61	P.S. DC Volt #4 - A Red
31	Loss of GPRX Data or Timing - A/B - 7	*62	P.S. DC Volt #4 - B Amber
32	Loss of GPRX Data or Timing - A/B - 8	*63	P.D. DC Volt #4 - B Red

Note: * = Directly or derived from CPMAS-D data.

TABLE 5-3. FIRST LEVEL MUX TD-1192 ALARMS

Alarm	Description	Alarm	Description
*1	Loss of GPRX Frame	*23	Loss of CHTX Data or Timing - 7
*2	Loss of GPRX Data	24	Loss of CHTX Data or Timing - 8
3	Loss of GPRX Timing	25	Loss of CHTX Data or Timing - 9
*4	Loss of CHRX Data or Timing - 1	*26	Loss of CHTX Data or Timing - 10
5	Loss of CHRX Data or Timing - 2	27	Loss of CHTX Data or Timing - 11
6	Loss of CHRX Data or Timing - 3	28	Loss of CHTX Data or Timing - 12
*7	Loss of CHRX Data or Timing - 4	*29	Loss of GPTX Data
8	Loss of CHRX Data or Timing - 5	*30	Loss of GPTX Timing
9	Loss of CHRX Data or Timing - 6	*31	Bite
*10	Loss of CHRX Data or Timing - 7	32	
11	Loss of CHRX Data or Timing - 8	*33	GPRX Frame Error Alarm
12	Loss of CHRX Data or Timing - 9	34	
*13	Loss of CHRX Data or Timing - 10	*35	GPRX Frame Loss
14	Loss of CHRX Data or Timing - 11	*36	PS DC Volt #1 Amber
15	Loss of CHRX Data or Timing - 12	*37	PS DC Volt #1 Red
*16	Loss of CHRX Timing	*38	PS DC Volt #2 Amber
*17	Loss of CHTX Data or Timing - 1	*39	PS DC Volt #2 Red
18	Loss of CHTX Data or Timing - 2	*40	PS DC Volt #3 Amber
19	Loss of CHTX Data or Timing - 3	*41	PS DC Volt #3 Red
*20	Loss of CHTX Data or Timing - 4	*42	PS DC Volt #4 Amber
21	Loss of CHTX Data or Timing - 5	*43	PS DC Volt #4 Red
22	Loss of CHTX Data or Timing - 6		

Note: * = Directly or derived from CPMAS-D data.

TABLE 5-4. SUBMULTIPLEXER TDM-1251 ALARMS

Alarm Number	Description
*1	Loss of CHRX Data or Timing
*2	Loss of CHRX Frame
*3	Loss of CHTX Data
*4	Loss of CHTX Timing
*5	Loss of CHTX Reference Timing
*6	Bite
7	
*8	CHRX Frame Error Red
9	
*10	CHRX Frame Loss Red
*11	P.S. DC Volt #1 Amber
*12	P.S. DC Volt #1 Red
*13	P.S. DC Volt #2 Amber
*14	P.S. DC Volt #2 Red
*15	P.S. DC Volt #3 Amber
*16	P.S. DC Volt #3 Red

Note: * = Directly or derived from CPMAS-D data

TABLE 5-5. RF DISTRIBUTION SYSTEM ALARMS

Alarm Number	Significance
1	Air Compressor Alarmed
2	Wave Guide Air Pressure Alarmed
3	VSWR Alarmed
4	Tower Beacon or Sidelight Alarmed

TABLE 5-6. KG-81 TRUNK ENCRYPTION DEVICE ALARMS

Alarm Number	Significance
1	Summary Alarm
2	Power Alarm

TABLE 5-7. POWER GENERATION SYSTEM ALARMS

Alarm Number	Significance
1	Main Fuel Supply Alarmed
2	Day Fuel Supply Alarmed
3	Generator Engine Alarmed
4	Generator Output Voltage Alarmed
5	Any AC Distribution Circuit Alarmed
6	Battery Charger Alarmed
7	Battery Voltage Level Alarmed
8	Any DC Distribution Circuit Alarmed

TABLE 5-8. RECOMMENDED RADIO SET ALARMS

Measurement Provided	Place of Application	Hardware/ Software Required	Measurement Required	Use of Measurement	Interference of Operation
Loss of decoder output	Receiver, decoder output	Transition detector	Detect no transition in data decoder output for both A and B receivers	Isolate decoder faults	None
Loss of derandomizer output	Receiver, derandomizer output	Transition detector	Detect no transition in derandomizer output for both A and B receivers	Isolate derandomizer faults	None
Loss of frame synchronization	Receiver, demultiplexer	Frame loss detector	Monitor each internal TDM for loss of receive frame synchronization both A and B receivers	Isolate radio link faults	None
Loss of MBS port	Receiver, output MBS ports	Transition detector	Detect no transition in MBS output for both MBS ports and the A and B receivers	Isolate radio link faults	None
Loss of SCBS port	Receiver, output SCBS ports	Transition detector	Detect no transition in SCBS output for both A and B receivers	Isolate service channel faults	None
On-line receiver	Receiver	Status indicator	Indicate which receiver is on line	Aid in fault isolation	None
Frequency drift alarm	Transmitter, RF	Frequency indicator	Indicate transmitter frequency has drifted for both A and B transmitters	Isolate transmitter frequency faults	None

TABLE 5-8. RECOMMENDED RADIO SET ALARMS (Cont)

Measurement Provided	Place of Application	Hardware/ Software Required	Measurement Required	Use of Measurement	Interference of Operation
Loss of modulator output	Transmitter, modulator output	Transition detector	Detect loss of modulated signal for both A and B transmitters	Isolate transmitter faults	None
Loss of multiplexer output	Transmitter, TDM output	Transition detector	Detect no transition in multiplexer output for both A and B transmitters	Isolate TDM faults	None
Loss of MBS port	Transmitter, input MBS ports	Transition detector	Detect no transition on input all MBS ports	Fault isolation	None
Loss of SCBS port	Transmitter, input SCBS port	Transition detector	Detect no transition on input SCBS port	Fault isolation	None
Loss of timing port	Transmitter, input timing	Transition detector	Detect no transition on input timing signals, MBS and SCBS ports	Fault isolation	None
Loss of timing port	Receiver, output timing	Transition detector	Detect no transition on output timing signals for both A and B receivers	Isolate radio link faults	None
On-line transmitter	Transmitter	Status indicator	Indicate which transmitter is on-line	Aid in fault isolation	None
BITE	Built-In Test Equipment (BITE)	Status indicator	Indicate that the Built-In Test Equipment has detected a fault	Fault isolation for radio	None

TABLE 5-8. RECOMMENDED RADIO SET ALARMS (Cont)

Measurement Provided	Place of Application	Hardware/ Software Required	Measurement Required	Use of Measurement	Interference of Operation
Demux frame error	Receiver, demultiplexer	Pulse counter	Count the number of frame errors in both the A and B receivers	Isolate TDM faults	None
Rx signal level	Receiver, RF	Power level detector	Indicate the received signal level for receivers A and B	Radio link fault isolation	None
Tx power level	Transmitter, RF	Power level detector	Indicate the transmitted signal level for transmitters A and B	Isolates transmitter faults	None
Power supply DC voltage	Power supplies	Output voltage indicator	Indicate the output voltage for all power supplies	Isolates power supply faults	None
SDR	Receiver	ACE	Adaptive Channel Estimation (ACE) of both the A and B receiver	Isolates radio link faults	None
SNR	Receiver	ACE	Adaptive Channel Estimation (ACE) of both the A and B receiver	Isolates radio link faults	None
BER	Receiver	ACE	Adaptive Channel Estimation (ACE) of both the A and B receiver	Isolates radio link faults	None

TABLE 5-9. RECOMMENDED SECOND-LEVEL MULTIPLEXER ALARMS

Measurement Provided	Place of Application	Hardware/ Software Required	Measurement Required	Use of Measurement	Interference of Operation
Loss of SGRX frame	Demultiplexer	Frame loss detector	Monitor demultiplexer for loss of receive frame syynchronization, both A and B TDM	Isolate multiplexer faults	None
Loss of SGRX data	Demultiplexer	Transition detector	Detect loss of MBS input data for both A and B TDM	Fault isolation	None
Loss of SGRX timing	Demultiplexer	Transition detector	Detect loss of MBS input timing for both A and B TDM	Fault isolation	None
Loss of GPTX data or timing	Multiplexer	Transition detector	Detect loss of digroup input timing or data for all ports and both TDMs, also summary	Fault isolation	None
Loss of GPRX data or timing	Demultiplexer	Transition detector	Detect loss of digroup output timing or data for all ports	Fault isolation	None
Loss of SGTX data	Multiplexer	Transition detector	Detect loss of MBS output data for both A and B TDM	Isolate multiplexer faults	None
Loss of SGTX timing	Multiplexer	Transition detector	Detect loss of MBS output timing for both A and B TDM	Isolate multiplexer faults	None

TABLE 5-9. RECOMMENDED SECOND-LEVEL MULTIPLEXER ALARMS (Cont)

Measurement Provided	Place of Application	Hardware/ Software Required	Measurement Required	Use of Measurement	Interference of Operation
BITE	Built-In Test Equipment (BITE)	Status indicator	Indicate that the Built-In Test Equipment has detected a fault	Fault isolation for TDM	None
On-Line unit	TDM	Status indicator	Indicate which multiplexer is on-line	Fault isolation	None
Standby status	TDM	Status indicator	Indicate status of off-line multiplexer	Fault isolation	None
SGRX frame error	Demultiplexer	Pulse counter	Count the number of frame errors in both the A and B TDM	Isolate demultiplexer faults	None
SGRX frame loss	Demultiplexer	Frame loss detector	Monitor TDM for loss of receive frame synchronization both A and B TDM	Fault isolation	None
Power supply DC voltage	TDM, power supplies	Output voltage indicator	Indicate the output voltage for all power supplies	Isolates power supply faults	None

TABLE 5-10. RECOMMENDED FIRST-LEVEL MULTIPLEXER ALARMS

Measurement Provided	Place of Application	Hardware/ Software Required	Measurement Required	Use of Measurement	Interference of Operation
Loss of GPRX frame	Demultiplexer	Frame loss detector, pulse counter	Monitor demultiplexer for loss of receive frame synchronization	Isolate multiplexer faults	None
Loss of GPRX data	Demultiplexer	Transition detector	Detect loss of digroup input data	Fault isolation	None
Loss of GPRX timing	Demultiplexer	Transition detector	Detect loss of digroup input timing	Fault isolation	None
Loss of CHRX data or timing	Demultiplexer	Transition detector	Detect loss of channel timing or data at each output port timing summary	Fault isolation	None
Loss of CHTX data or timing	Multiplexer	Transition detector	Detect loss of channel timing or data at each input port. Timing and data summary	Fault isolation	None
BITE	Built-In Test Equipment (BITE)	Status indicator	Indicate that the Built-In Test Equipment has detected a fault	TDM fault isolation	None
GPRX frame error	Demultiplexer	Pulse counter	Counts the number of frame errors in TDM	Multiplexer fault isolation	None
P.S. DC volts	Power supplies	Output voltage indicator	Indicates the output voltage of all power supplies	Power supply fault isolation	None

TABLE 5-11. RECOMMENDED SUBMULTIPLEXER ALARMS

Measurement Provided	Place of Application	Hardware/ Software Required	Measurement Required	Use of Measurement	Interference of Operation
Loss of CHRX or timing	Demultiplexer	Transition detector	Detects loss of channel input data or timing	Fault isolation	None
Loss of CHRX frame	Demultiplexer	Frame loss detector, pulse counter	Monitors demultiplexer for loss of receive frame synchronization	Isolate multiplexer faults	None
Loss of CHTX data	Multiplexer	Transition detector	Detects loss of channel output data	Fault isolation	None
Loss of CHTX timing	Multiplexer	Transition detector	Detects loss of channel output	Fault isolation	None
CHRX frame error	Demultiplexer	Pulse counter	Counts the number of frame errors in TDM	Multiplexer fault isolation	None
P.S. DC volt	Power supplies	Output voltage indicator	Indicates the output voltage of all power supplies	Power supply fault isolation	None

SECTION 6

FUTURE RESEARCH AND DEVELOPMENT

During this study, areas that warrant further research and development were identified. These research and development areas would aid in arriving at an optimum CPMAS for the DCS digital transmission system. In particular, the objectives of the CPMAS future R&D are to: (1) evaluate performance of the CPMAS fault detection/isolation algorithm under various network configurations and fault loads, (2) evaluate Sector level fault isolation, (3) verify CPMAS performance in an operational environment, (4) evaluate interface approaches between CPMAS and ATEC, (5) evaluate CPMAS assumptions against the presently planned DCS, and (6) evaluate concepts of operation of the ACE unit.

To accomplish these objectives, seven areas are recommended for future R&D: (1) CPMAS emulation facility tests, (2) Sector level fault isolation, (3) CONUS link tests, (4) operational environment tests, (5) CPMAS and ATEC interface (6), CPMAS baseli reexamination, and (7) ACE investigation.

6.1 CPMAS EMULATION FACILITY TESTS

The fault isolation tests conducted on this program evaluated performance of the fault isolation algorithm for one model network. Additional testing of the fault isolation algorithm using the CPMAS emulation facility will allow performance to be related to network parameters; for example, the fault isolation time could be empirically related to the number of network links, first-level multiplexers, stations, star networks, etc. This will aid in comparing the CPMAS fault detection/isolation algorithm with other contemporary algorithms.

Stressing the algorithm in a simulated environment will identify weaknesses in the algorithm that may be more difficult to resolve in a field test. The algorithm stresses can be provided in two manners: (1) extreme network configurations will stress the network connectivity-related portions of the algorithm; and (2) potential weaknesses in the algorithm could be located through analysis and stressed via simulation.

This future R&D area will consist of the following tasks:

a. Empirically evaluate the fault isolation time by creating networks that can grow in integral units of parameters which influence fault isolation time. This evaluation should follow an in-depth analysis to determine what network parameters influence fault isolation time and to identify those modules in the algorithm that are influenced.

b. Empirically evaluate the fault isolation time by creating network extremes, such as sparse or highly interconnected networks. Causes of any failures in the algorithm should be identified and corrected. Significant discrepancies should be predicted; fault isolation time (using the empirical data from task (a), preceding) and the observed isolation time should be investigated.

c. Analysis of the algorithm should be conducted to locate potential weaknesses. These weaknesses should then be stressed via simulation by creating the proper networks and fault scenarios. Any failure of the algorithm should be investigated.

6.2 SECTOR LEVEL FAULT ISOLATION

A unique fault isolation algorithm has been developed on this program and incorporated in the CPMAS emulation facility. The algorithm consists of three main functions: alarm mapping, sympathetic deletion, and equipment isolation. With the hierarchical structure of DCS System Control, it is desirable to complete the fault detection/isolation process for both the Sector and Nodal transmission control levels. In particular, the three main fault isolation functions must be allocated between the Sector and Node.

As an example, Figure 6-1 shows one possible allocation in which all three fault isolation functions are performed at the Nodal level, and Sector only provides a communications path to transmit internode reports containing the status of the internode communications paths. This approach maximizes the processing load at the Node and results in minimal communications between Node and Sector. However, with this approach the Nodal processors are not synchronized and care must be taken to ensure that adequate time is allowed to permit all the status information to be transferred between Nodes before isolating the fault. Of course, another approach would be to perform all three fault isolation functions at the Sector level. This will eliminate the synchronization problem since all the processing will be performed in one processor, but the information flow between Sector and Node will be significant because the exception reports from each equipment in the Sector must be sent to the Sector level.

An alternate approach to allocate the fault isolation functions is presented in Figure 6-2. The alarm mapping and equipment isolation functions are performed at the Nodal level, while the sympathetic deletion is performed at the Sector. This approach is attractive since communications between Node and Sector can be reduced by sending the communications path status as exception type reports, and the synchronization problem is eliminated since the sympathetic deletion function, which is the only time-critical function, is performed in one processor. Also, the sympathetic deletion algorithm can be retained at the Nodes to provide a back-up capability.

This future R&D area will consist of the following tasks:

a. Evaluate alternatives for allocating the CPMAS fault isolation functions between the Node and Sector. This evaluation should consider fault isolation time, communications load between the Node and Sector, synchronization requirements of the processors, and processing requirements.

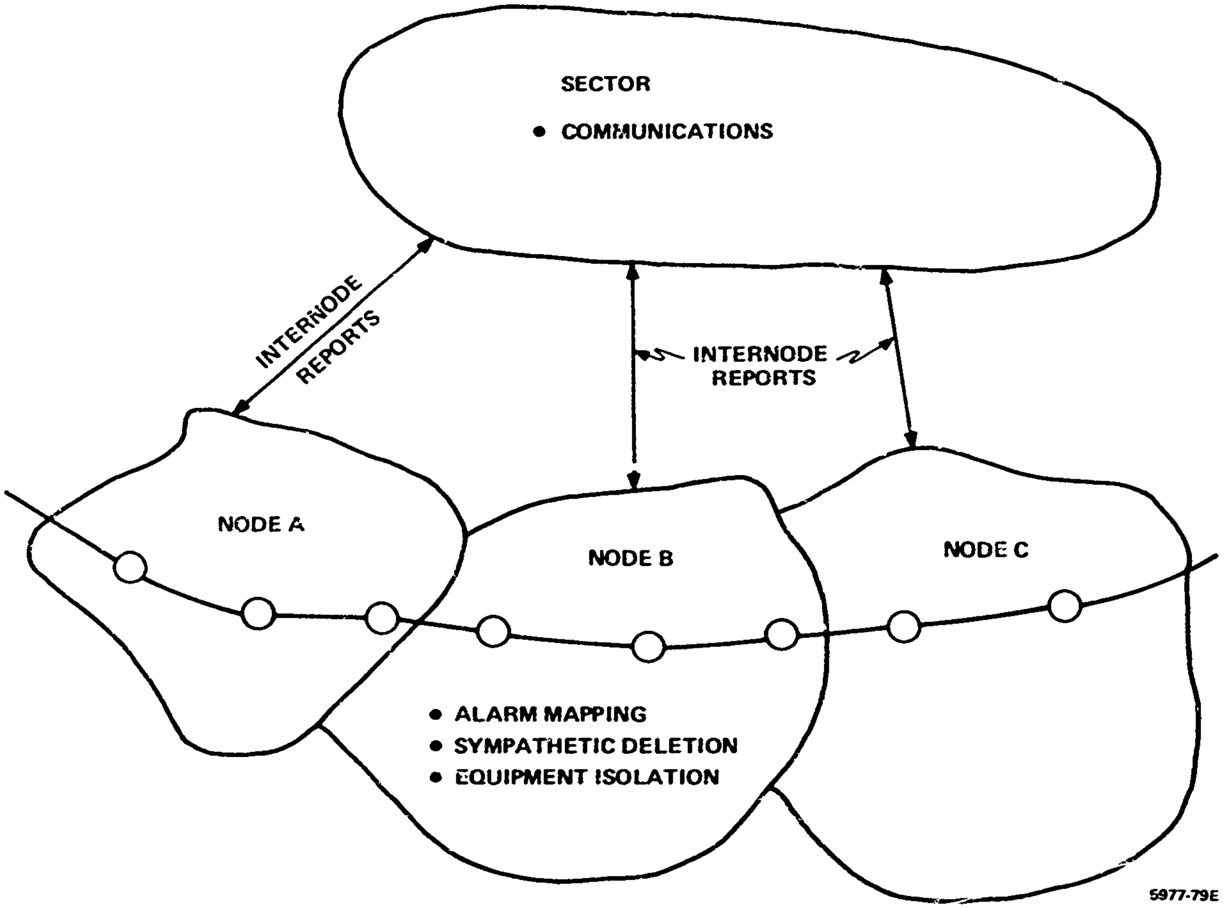

Figure 6-1. Fault Isolation Functional Allocation (Example 1)

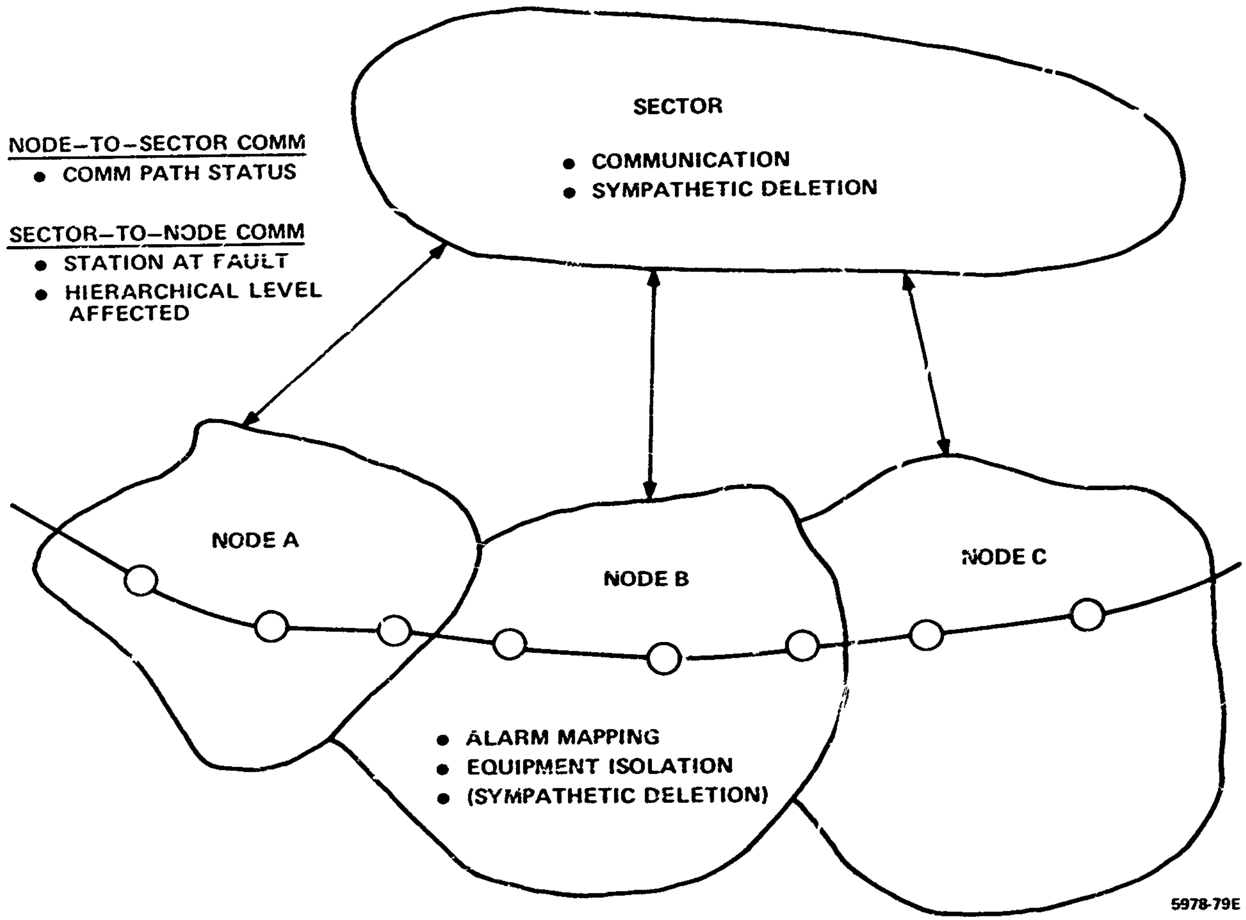

Figure 6-2. Fault Isolation Functional Allocation (Example 2)

b. Design, code, and test the recommended alternative.

c. Integrate the approach into the CPMAS emulation facility. Perform integration tests to ensure proper operation.

6.3 CONUS LINK TESTS

Testing of the CPMAS fault isolation algorithm has been limited to simulated networks and equipments. Testing of the algorithm in a transitional field test environment will reduce the technical risk and the cost of an operational test. It will also permit the evaluation of CPMAS interface circuits required to extract the monitor point signals from the transmission equipment.

The CPMAS fault isolation algorithm can be tested at the RADC test facility in a manner similar to the ACE field test of this program. Figure 6-3 shows a possible equipment configuration for these tests. This configuration consists of two stations (more stations can be equipped with CPMAS and transmission equipment if a larger test network is required) equipped with three levels of multiplexing with one of the stations being remotely monitored by a CPMAS-D.

This future R&D area will consist of the following tasks:

a. Locate the required monitor points on the transmission equipment. Design, build, test, and install sensors.

b. Generate test plans/procedures for the field test.

c. Conduct the field test.

d. Analyze test data and generate field test report.

6.4 OPERATIONAL ENVIRONMENT TESTS

Testing of the CPMAS system in an operational environment would provide a basis for accepting CPMAS for transmission control of the digital DCS. This basis would consist of: (1) an evaluation of the CPMAS fault isolation algorithm under actual operating conditions; (2) an evaluation of the CPMAS

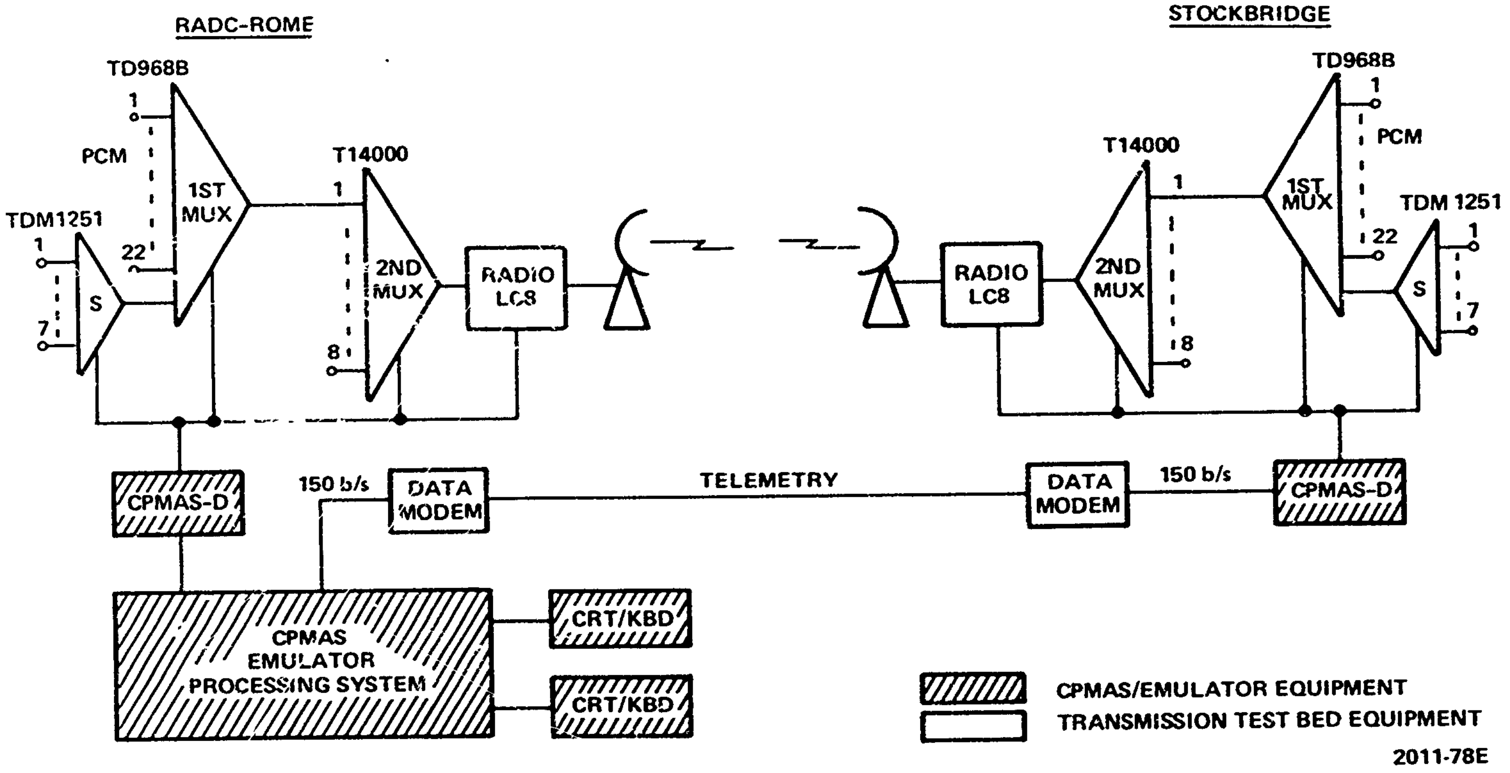

Figure 6-3. CONUS Link Test Configuration

man/machine operation; and (3) an evaluation of the CPMAS system, including the ACE, CPMAS-D, and CPMAS Emulator, in the DEB network.

A possible location for performing the CPMAS operational environment tests would be the DEB Stage II sites indicated on Figure 6-4. These sites are planned for testing the ATEC system and so would be likely CPMAS test sites. Parallel testing of ATEC and CPMAS may provide additional benefits; however, ATEC is not required to evaluate CPMAS. Table 6-1 shows the quantities of transmission equipment, ATEC equipment, and CPMAS equipment that are required at each of the DEB sites.

This future R&D area would consist of the following tasks:

a. Select and survey the stations at which the tests will be performed.

b. Build and test additional CPMAS-D and ACE units. Locate monitor points and design, build, test, and install sensors.

c. Define network configuration tables and displays for the selected stations. Generate test plans/procedures.

d. Conduct the operational environment tests.

e. Analyze test data and generate test report.

6.5 CPMAS AND ATEC INTERFACE

Operational deployment of the CPMAS system as the performance monitoring and assessment system for DCS digital transmission facilities would require that CPMAS and ATEC interface in two primary areas. First, the tables that drive the CPMAS fault isolation algorithm must be generated from the ATEC data base. In particular, network connectivity and equipment status information are required. Secondly, the CPMAS-D unit must communicate with the Node via the ATEC communications channel and using the ATEC protocol. The CPMAS-D unit must be compatible with this ATEC protocol.

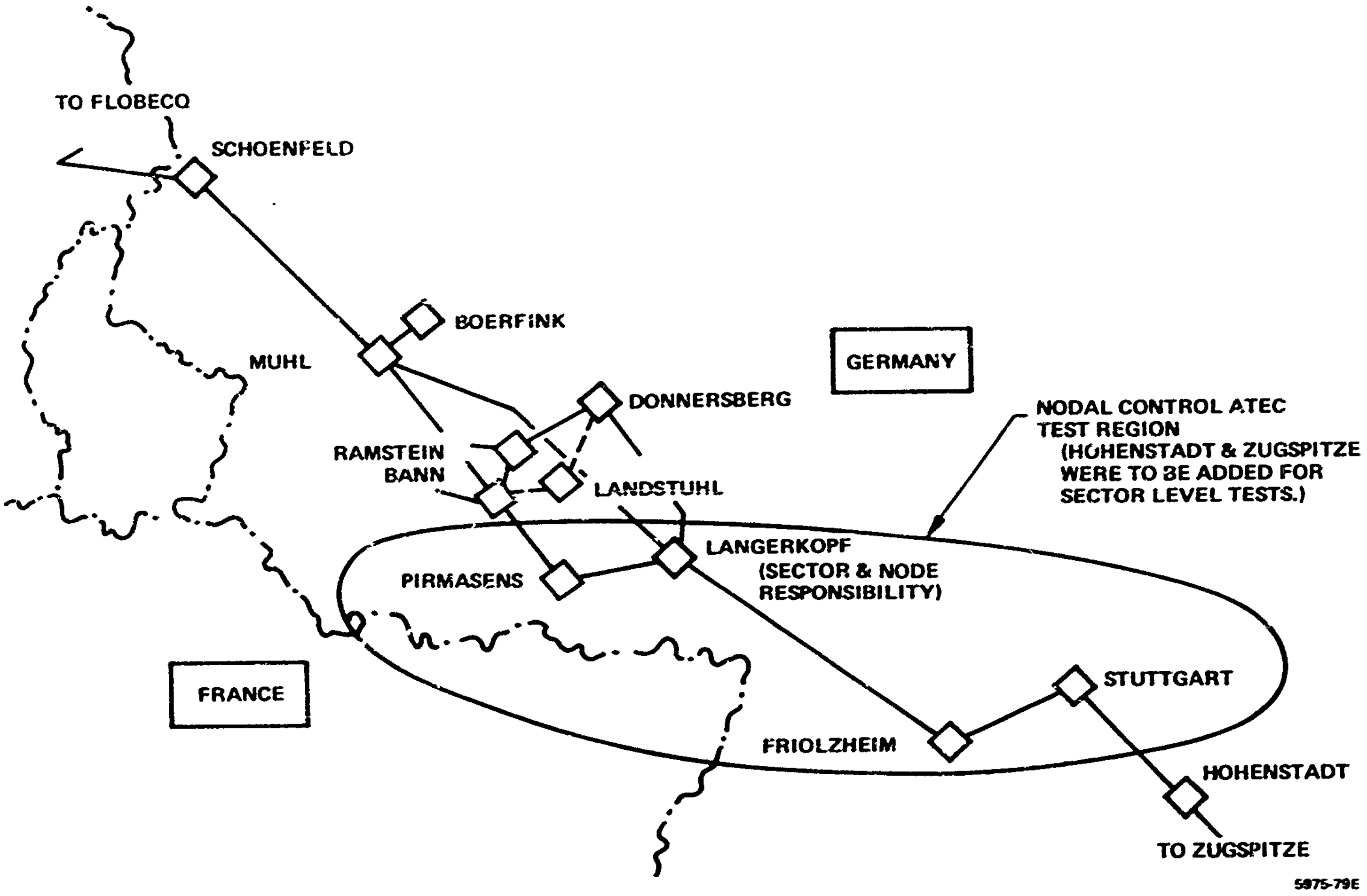

Figure 6-4. DEB Stage II

TABLE 6-1. DEB II EQUIPMENT QUANTITIES

		STUTTGART	HOHENSTADT	FRIOLZHEIM	LANGERKOPF	DONNERSBERG	PIRMASENS	RAMSTEIN	BANN	MUHL	SCHOENFELD	BOERFINK	LANDSTUHL	TOTAL
DRAMA	AN/FRC-163	2	1	2	4	3	2	2	4	3	1		2	26
	TD 1193	4	2		8	6	4	4	7	6	2		3	46
	AN/FCC-98	11	9		26	28	15	23	23	14	10	0	10	160
	KG-81	4	2		8	6	4	4	7	6	2		3	46
	CY-104	3			4	3		1	2	3	2	8	1	27
ATEC	CIS	1		1	1		1							4
	ARS	1		1	1		2							5
	CTS	1		1	1		1							4
	PCS	1		1	1		1							4
	BTS	-		-	1		1							2
	IMS	7		-	8		5							20
	OTS	1		-	1		1							3
	DMS	-		-	-		5							5
	NODE EQPT.	-		-	1		-							1
CPMAS	CPMAS-D	2		1	4		2							8
	ACE	1		1	1		1							4
	PDP 11/60	-		-	1		-							1

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ABBREVIATIONS

ACE	ADAPTIVE CHANNEL ESTIMATOR
ARS	ALARM REPORTING SET
BTS	BASEBAND TEST SET
CIS	COMMUNICATIONS INTERFACE SET
CTS	CONTROLLER TERMINAL SET
DMS	DC MONITORING SET
IMS	IN-SERVICE MONITORING SET
OTS	OUT-OF-SERVICE TEST SET
PCS	PARAMETER CONVERTER SET

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This future R&D area would consist of the following tasks:

a. Evaluate ATEC data base structure versus CPMAS tables and fault isolation requirements.

b. Generate a software-requirements specification for the data base to fault isolation algorithm interface.

c. Modify and test the CPMAS protocol and data formats in accordance with ATEC.

6.6 CPMAS BASELINE REEXAMINATION

Since the initiation of the CPMAS program, ATEC and DRAMA have evolved and the DEB upgrades have begun to be deployed. The CPMAS model network, which is the baseline network for this program, should be reexamined in the light of these developments. Additionally, with the increasing emphasis on the Sector level system control functions, a Sector model network should be developed. As the DRAMA procurement progresses, the monitor points that will be provided by the digital DCS transmission equipment become defined. The operation and capabilities of the CPMAS fault isolation algorithm should be examined when only those monitor points are available.

This future R&D area would consist of the following tasks:

a. Establish updated DCS Node and Sector model networks based upon the most recent ATEC, DRAMA, and DEB information.

b. Evaluate the CPMAS fault isolation algorithm based upon the DRAMA-provided monitor points.

c. Determine cost impact of adding CPMAS recommended monitor points.

6.7 ACE INVESTIGATION

The ACE unit has been shown to be a useful performance assessment technique. However, an operational concept for the ACE unit has not been formulated, and a detailed comparison with alternate approaches has not been conducted. Therefore, further investigation of the ACE unit is recommended, concentrating on concepts for deploying the ACE and its advantages and disadvantages relative to other approaches.

A concept of operation for ACE would include determining the number of radios that each ACE would assess, specifying ACE resolution time, and examining the merits of placing the ACE S/H and A/D into the digital radio.

This future R&D area would consist of the following tasks:

a. Develop an ACE concept of operation.

b. Conduct a detailed comparison between ACE and other performance assessment techniques.

LIST OF ACRONYMS

ACE - Adaptive Channel Estimator
ACK - Acknowledge
ACOC - Area Control Operations Center
ARS - Alarm Reporting Set
ASCII - American Standard Code for Information Interchange
AUTODIN - Automatic Digital Network
AUTOSEVOCOM - Automatic Secure Voice Communications
AUTOVON - Automatic Voice Network

BER - Bit Error Rate
BITE - Built-In Test Equipment
BPI - Bits per Inch
BTS - Baseband Test Set

CH - Channel
CIS - Communications Interface Set
CNT - Recurrence Count
CONUS - Continental United States
CPMAS - Communications Performance Monitoring and Assessment
CPMAS-D - CPMAS - Digital
CPU - Central Processor Unit
CTS - Controller Terminal Set

DC - Direct Current
DCAOC - Defense Communications Agency Operations Center
DCS - Defense Communications System
DEB - Digital European Backbone
DIR - Direction
DMS - DC Monitoring Set
DRAMA - Digital Radio and Multiplexer Acquisition

EQUIP - Equipment

FCO - Facility Control Office
FDM - Frequency Division Multiplexing
FKV - Frankfurt - Koenigstuhl - Vaihingen

LIST OF ACRONYMS (Cont)

GP - Digital Group
GTE - General Telephone and Electronics Corporation

ICO - Intermediate Control Office
ID - Identification
IMS - In-Service Monitoring Set

LMS - Least Mean Square
LOS - Line of Sight
LTC - Line Time Clock

MAS - Measurement Acquisition Subsystem
MBS - Mission Bit Stream
MILDEP - Military Department
MW-LOS - Microwave Line of Sight

NAK - Not Acknowledged
NATO - North Atlantic Treaty Organization
NCS - Nodal Control Subsystem
NO - Number
NRZI - Non-Return to Zero Inverse

OTS - Out-of-Service Test Set

PC - Printed Circuit
PCM - Pulse Code Modulation
PCS - Parameter Converter Set
PROM - Programmable Read-Only Memory
PT - Point

QPSK - Quadra-Phase Shift Keyed

RADC - Rome Air Development Center
RCOC - Region Control Operations Center
R&D - Research and Development
RF - Radio Frequency

LIST OF ACRONYMS (Cont)

SCS - Sector Control Subsystem
SDR - Signal-to-Distortion Ratio
SEV - Severity
SG - Supergroup
SNR - Signal-to-Noise Ratio
STA - Station

TDM - Time Division Multiplexing

U.S. - United States

VDU - Video Display Unit

MISSION
of
Rome Air Development Center

RADC plans and executes research, development, test and selected acquisition programs in support of Command, Control Communications and Intelligence (C^3I) activities. Technical and engineering support within areas of technical competence is provided to ESD Program Offices (POs) and other ESD elements. The principal technical mission areas are communications, electromagnetic guidance and control, surveillance of ground and aerospace objects, intelligence data collection and handling, information system technology, ionospheric propagation, solid state sciences, microwave physics and electronic reliability, maintainability and compatibility.