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Energy Division

Bonneville Power Administration Communication Alarm Processor (CAP) Final Report

Donald G. MacGregor[†]
Richard T. Goeltz

[†]MacGregor-Bates, Inc.

January 1995

MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
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DEPARTMENT OF ENERGY

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BONNEVILLE POWER ADMINISTRATION COMMUNICATION ALARM PROCESSOR (CAP) FINAL REPORT

Donald G. MacGregor
MacGregor-Bates, Inc.

Rick Goeltz
Oak Ridge National Laboratory

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Prepared for
Bonneville Power Administration

Prepared by
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
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ABSTRACT

Power systems operations and maintenance currently face an ever-increasing need for a high level of computerized support. This paper is the final report of a research and development effort undertaken by the Bonneville Power Administration to develop a computerized decision support system to aid operations and maintenance personnel isolate and diagnose faults on a microwave communication system used for centralized dispatch operations. The system, called **CAP** for Communication Alarm Processor, provides statistical analysis of microwave communication system alarms, as well as an expert system capability for fault isolation and diagnosis. CAP is implemented on a DEC VAX Station 3100 computer, utilizing both knowledge-based programming principles as well as conventional programming techniques

1. INTRODUCTION

The electric power industry relies heavily on computerized support to provide assistance in managing power systems operations and maintenance. This report describes a research and development project undertaken by the Bonneville Power Administration (BPA) to explore the feasibility of utilizing advanced knowledge-based computing principles to provide computerized services in the context of microwave communication system management, a critical component of power systems control and operations.

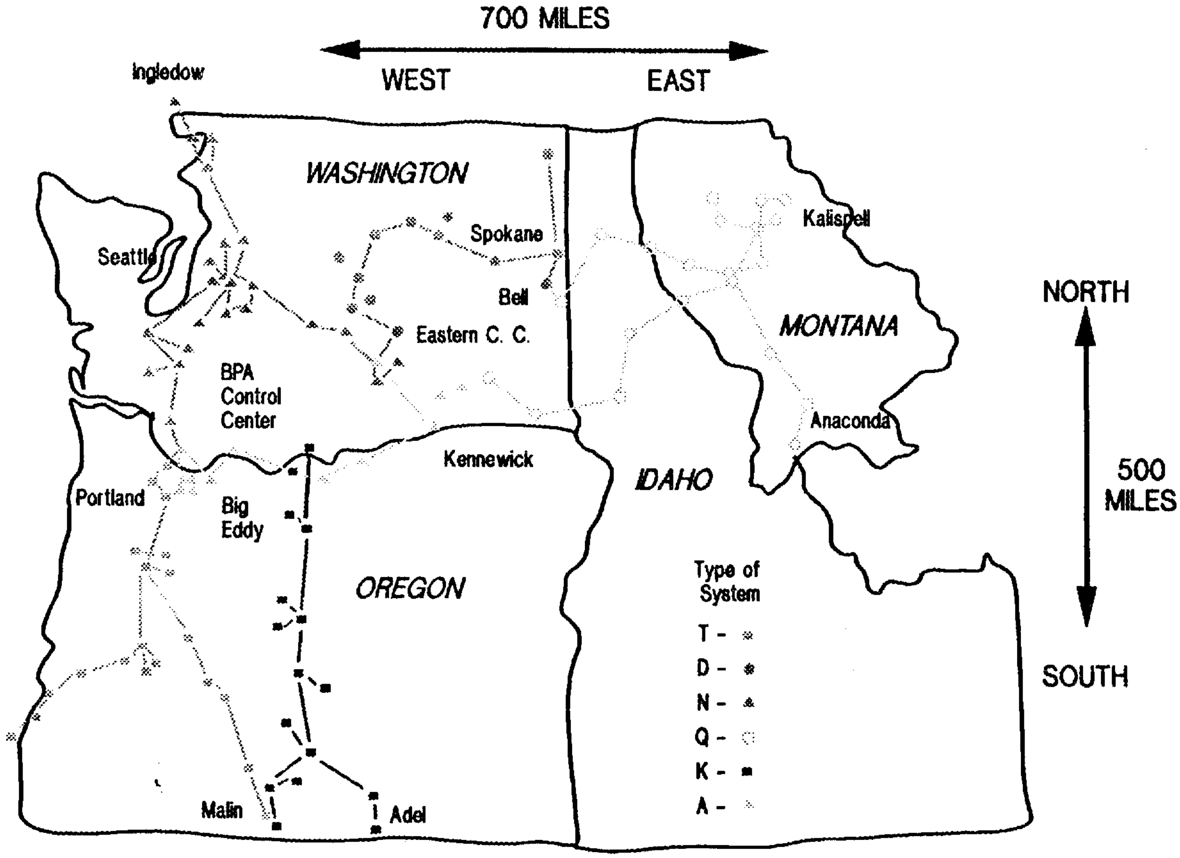
The goal of the project was to provide a research and development prototype that could identify opportunities for the use of artificial intelligence concepts in power systems operations and control. In addition, the prototype was to provide an increment of improvement in existing microwave communication systems maintenance management through the application of statistical techniques to existing performance data in the form of alarms.

The project was titled **CAP** for Communication Alarm Processor. CAP integrates a number of microwave communication system management functions into a single computerized workstation. It provides extensive computerized support for storing and analyzing alarm data relating to communication system performance. CAP also provides automated fault isolation and diagnosis through a knowledge-based reasoning system that utilizes a set of rules similar to those applied by experienced operators in locating and identifying communication system problems. The "expert system" portion of CAP is its most innovative feature from a power systems operation and control standpoint, providing a prototype for how knowledge-based systems could be designed, developed and implemented in other power systems contexts.

This report gives an overview of the CAP system. Technical details of programming and the like are contained in other documentation sources, some of which are provided online at the CAP workstation. Previous Oak Ridge National Laboratory (ORNL) and BPA reports cited in the reference section provide additional background on the stages of CAP's development as well as earlier design considerations and their rationale.

The present report first describes Bonneville Power Administration's power system operations, and the problem domain in which CAP was developed. This is followed by two sections that give an introduction to the basic elements of the microwave communication system, the causes of faults on the system, and the operational task that CAP was designed to support. This is followed by Section 5.0 which overviews the CAP architecture. Sections 6.0, 7.0, and 8.0 give a background on CAP's alarm process, expert system and statistical analysis functions. Section 9.0 offers recommendations for future research and development.

Figure 1.1 BPA microwave communication system.



2. PROBLEM DOMAIN

The Bonneville Power Administration is part of the U.S. Department of Energy and has responsibility for transmitting power from federal power generation facilities in the U.S. Pacific Northwest. Bonneville's Dittmer Control Center is the hub of activities concerned with the safe, reliable, and economic operation of the Federal Columbia River System, which includes Bonneville's high-voltage transmission network. Bonneville's transmission system of over 14,000 circuit miles of transmission lines is interconnected with regional utilities at more than 150 points. The network covers a 350,000 square mile region that encompasses four Pacific Northwestern states: Oregon, Washington, Idaho, and western Montana.

Reliable operation and control of this large, complex power system requires extensive use of automation at substations and control centers. Advances in automation are necessary to keep abreast with increasing power system complexities due to system growth, reduced operating margins, complicated operating and control agreements, environmental constraints, and economic considerations.

To facilitate management of the power transmission system, Bonneville operates a region-wide microwave communications network for protective relaying, load and generator dropping, telemetering of critical quantities, Supervisory Control and Data Acquisition (SCADA) systems operation, and management of Automatic Generation Control (AGC). The microwave network consists of seven major systems with over 140 microwave stations. Figure 1.1 shows the geographic area served by the microwave communication network as well as the seven major systems that comprise the network.

A schematic example of one of the seven systems is shown in Figure 1.2. The system shown in Figure 1.2 is the N-system that runs from the Dittmer Control Center (DITT) remote terminal unit

(RTU) to the Eastern Area Control Center (EACC). A set of backbone repeater stations provide communications along the system, with links to spur stations that are located at end-equipment sites (e.g., substations). Each microwave station in the system is identified by a unique four-letter signature.

2.1 MICROWAVE COMMUNICATION SYSTEM TOPOLOGY

The seven microwave communication systems (MCS) are organized according to the general topology shown in Figure 2.3. Each system orginates at a radio site, usually the Dittmer Control Center though other sites serve as origination points for some systems. Termination (RTU) is at a distant radio site separated by a number of backbone stations. The two end stations and all stations in between, including both backbone and spur stations comprise the *system*. Transmission between stations in the system is bidirectional, running from the originating station to the RTU, and from the RTU back to the originating station. The bidirectional transmission between any two stations is a *hop*. The unidirectional transmission between any two stations is a *path*. Thus, a hop contains two paths, each in opposite directions. In some circumstances, two or more backbone stations are grouped into a unit called a *section* for purposes of monitoring signal quality and isolating malfunctions. Sections include paths on the microwave backbone as well as spurs to substations. This will be discussed in more detail later in this report.

Figure 1.2 N-System backbone and spur stations configuration.

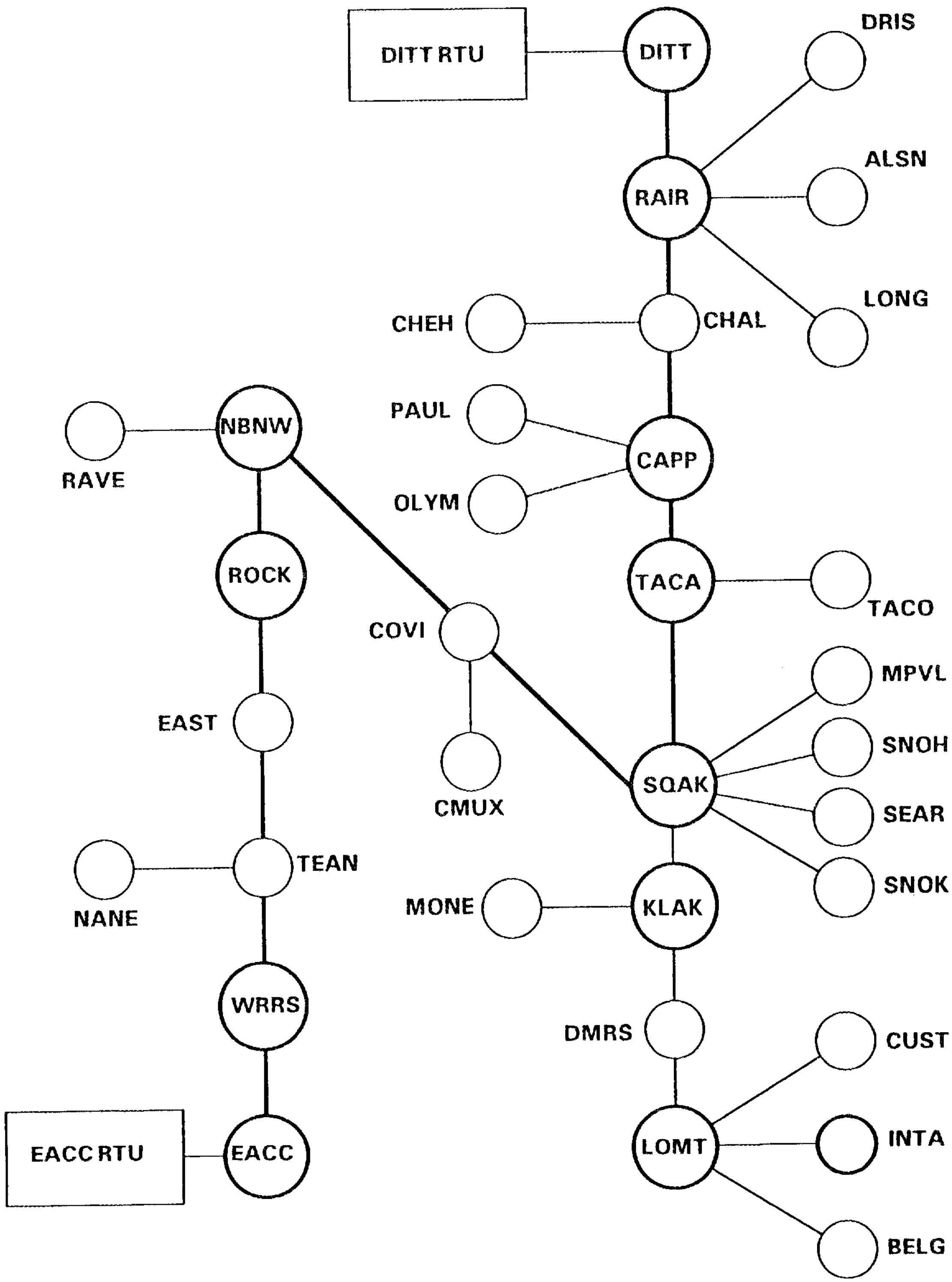
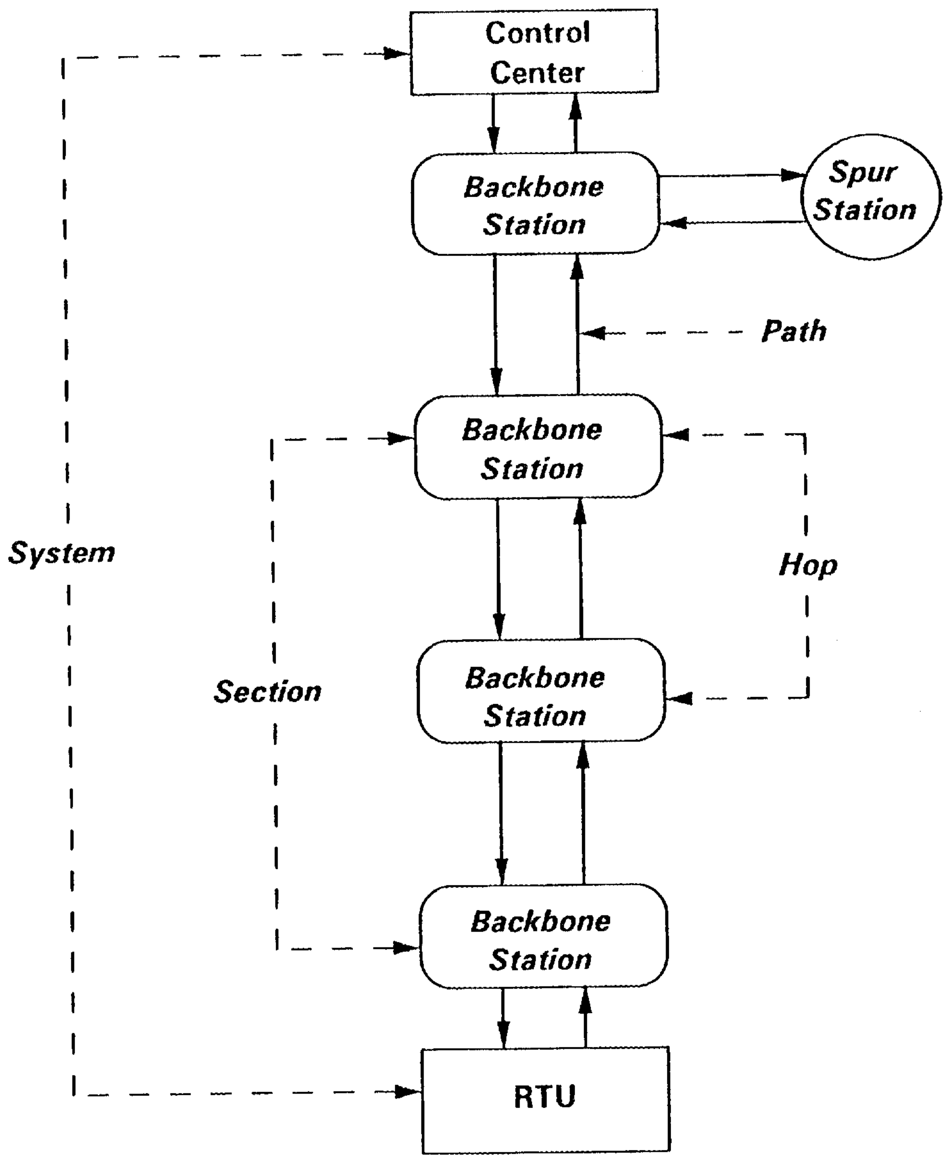


Figure 2.3 Topology schematic for microwave communication network.



3. MICROWAVE COMMUNICATION ALARM SYSTEMS

Centralized control of the power grid demands high reliability in telecommunications. To improve Microwave Control System availability and reduce operating costs, Bonneville developed several automatic monitoring systems that measure microwave communication performance and generate alarms to the Dittmer Control Center. As a general guideline, a reliability factor of 98.986% was established for the microwave communication system (Street & Borys, 1987). This percentage represents the portion of the time that the telecommunications network is available to send and receive power grid control information.

To achieve this high level of reliability, a number of features were incorporated into the network design. First, the seven systems comprising the network are linked together to provide redundant access to each station. Second, each backbone and spur station is comprised of redundant FM (frequency modulated) receivers and transmitters in each direction or path. Should either a receiver or transmitter on a given path fail, the station automatically switches to the non-failed equipment. Figure 3.4 shows a schematic diagram of the equipment configuration at a backbone station.

To insure telecommunications availability, BPA developed an automatic monitoring system that measures a number of parameters of system performance and provides an indication of system problems. The *Microwave Monitor System* (MWM) continually monitors seven parameters of the microwave signal:

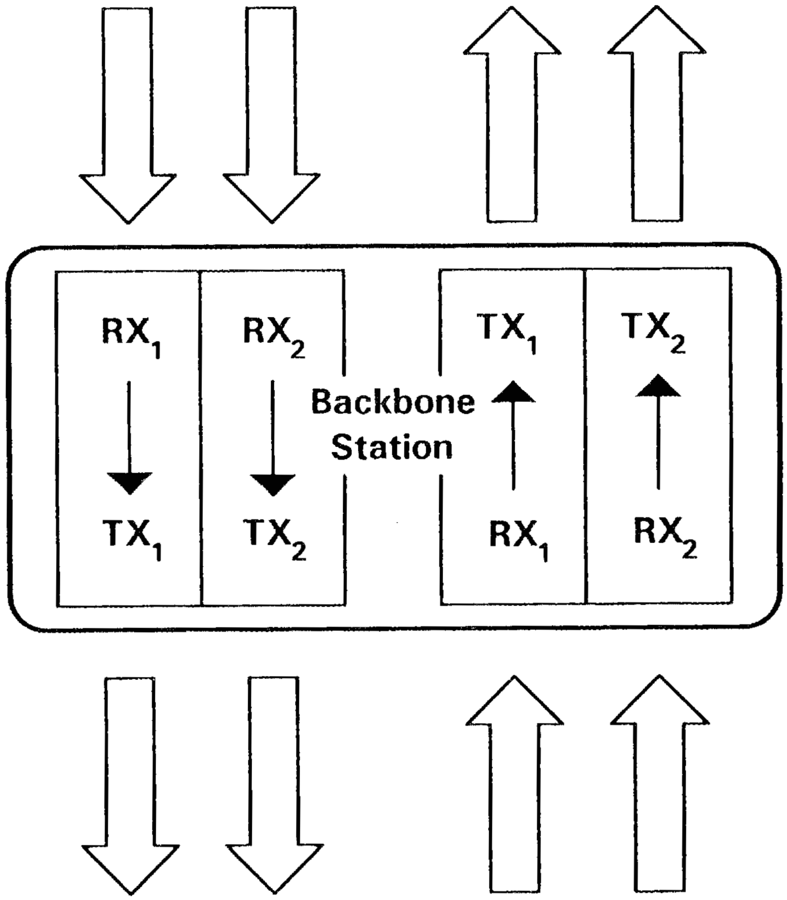
- Noise
- Pilot Level (Carrier Signal Level)
- Phase Shifts
- Turnaround (Crosstalk)

- Baseband Loading (Overmodulation)
- Baseband Frequency Response
- Intermodulation Distortion (Spurious Harmonics)

These parameters are monitored at each end of a system, and the performance data is transmitted back to a Master Terminal Unit over a microwave system other than the one being monitored. Information from the MWM is continuously monitored by operators at the dispatch facility, and is summarized to obtain statistics on network availability to support both operations and maintenance decisions. MWM alarms are generally of three types: *boundary alarms* that indicate a signal parameter has deviated slightly from normal operating conditions, performance alarm that indicate the operating condition margin has decreased by half and *outage alarms* that indicate a degradation in signal quality sufficient to interrupt communications. Table 1 shows each of the MWM alarm types, along with the level of fault isolation provided by the alarm signature.

A second alarm system, BADGER, monitors critical functions at each microwave station. BADGER polls each station on the network to detect the presence of alarms relating to equipment malfunctions, such as receiver and transmitter failures, multiplex failures, electric generator problems, and waveguide depressurization. Alarms are appended with a station signature and sent to the dispatch center where they are monitored by operators. The MWM and BADGER alarm systems provide operators with different types of information: MWM monitors signal quality as it moves from one station to another, while BADGER provides information about equipment problems at specific locations. BADGER alarms are assigned by CAP to one of three categories: Diagnose and Archive (D), Archive Only (A), and Dispose (X). A third set of alarms processed by CAP are generated by end-equipment when control of that equipment is lost. These alarms are primarly used in microwave communication system management to confirm faults reported by the MWM. Two types of end-equipment alarms are currently processed by CAP: telemetering alarms and transfer trip alarms. Telemetering alarms occur whenever information is not received from metering stations at connect-points on the power grid. Transfer trip alarms occur when trip control for power transmission lines cannot be communicated to the opposite ends of a line. Both end-equipment alarm types are provided to CAP through the Real-time Operations and Dispatch System (RODS).

Figure 3.4 Schematic of redundant receivers and transmitters: Bockbone station.



4. OPERATIONAL TASK DESCRIPTION

Monitoring of telecommunications operations is done primarily at the Dittmer Control Center. The primary information inputs for real-time monitoring of telecommunications quality are two displays, one for the MWM and one for the BADGER alarms. In the course of a typical 24-hour period, various alarms are received. Many of these alarms result in alarm messages to operators. The majority of these are BADGER alarms indicating an event at one of the radio sites. From the standpoint of supervisory control, MWM alarms are given greater importance because they indicate problems with signal quality that directly affect the ability of dispatchers to control the power grid. Though BADGER alarms can be indicative of a problem developing at a site that may eventually affect signal quality, MWM alarms are a direct indication of a degraded signal and typically initiate diagnostic activity.

4.1 DIAGNOSTIC SEQUENCE

While the MWM alarms provide direction indication of signal quality, they do not report the precise location where a fault has originated. For two of the alarm types, Noise and Pilot Level, the MWM is able to sectionalize each system, providing an intermediate level of fault isolation. Though reports for these alarms give the section of a system in which the fault occurred, a section typically includes a number of radio sites, any one of which may be the cause of the problem. For the Phase Jitter alarm, the station location is included in the alarm signature, making it relatively each to determine the radio site producing the problem. However, the underlying conditions at the radio site that produced the fault are not available from the MWM. For the other fault types, the alarm gives only a system-wide indication, and does not provide a section or station at which the problem is likely to have occurred.

4.2 CAUSES OF MCS FAULTS

The causes of microwave communication fault are generally attributable to one of four categories: atmospheric conditions, equipment, human caused, and geographical conditions. Figure 4.5 shows a breakdown of these four categories into specific fault causes.

Atmospheric Conditions. Atmospheric conditions influence communication performance by either absorbing energy from the microwave signal (e.g., rain, snow, ice), or by refracting (or bending) the signal with density changes in air layers due to elevation differences between stations. Signal bending can also occur from localized convection current or "heat layers" during the summer season. Signal refraction result in excessive angular deflection of the microwave beam and decoupling at the receiving antenna dish.

Equipment. Equipment problems that effect signal quality can occur at a transmitter, receiver, multiplex, interconnecting cables, antenna, or the power supply.

Human Caused. Human activity at a station can cause disruptions to microwave communications. Scheduled activities may, either intentionally or inadvertently, effect the performance of equipment on the signal path. Unauthorized activity at a site, such as vandalism, can also result in signal degradation.

Geography. Geographical conditions are important in determining the maximum performance that can be expected from a microwave communication hop. For example, long hops are more susceptible to atmospheric disturbances than short hops. Terrain features, such as tall trees or other obstacles, can interfere with signal transmission. One particular hop on the N-system traverses an area of high irrigation activity in the summer time. The resulting convection disturbances set up by differential heating in this region sometimes disrupts the beam angle between the two stations on the hop.

Because each hop is unique in terms of its geographical location, potential for atmospheric disturbances, and type of equipment, diagnosing faults indicated by the MWM and BADGER alarm systems involves:

- use of reasoning based on technical principles, and
- historical knowledge about the unique features of the section, hops and stations that are the focus of the diagnosis.

4.3 MAINTENANCE AND OPERATIONS DECISION SUPPORT REQUIREMENTS

Two categories of decisions require support for the effective operation and maintenance of the microwave communication system.

The first category is *real-time decisions* in which operations staff are required to perform fault isolation and diagnoses initiated by incoming alarm data. The operators' task is to use both the MWM and BADGER information to:

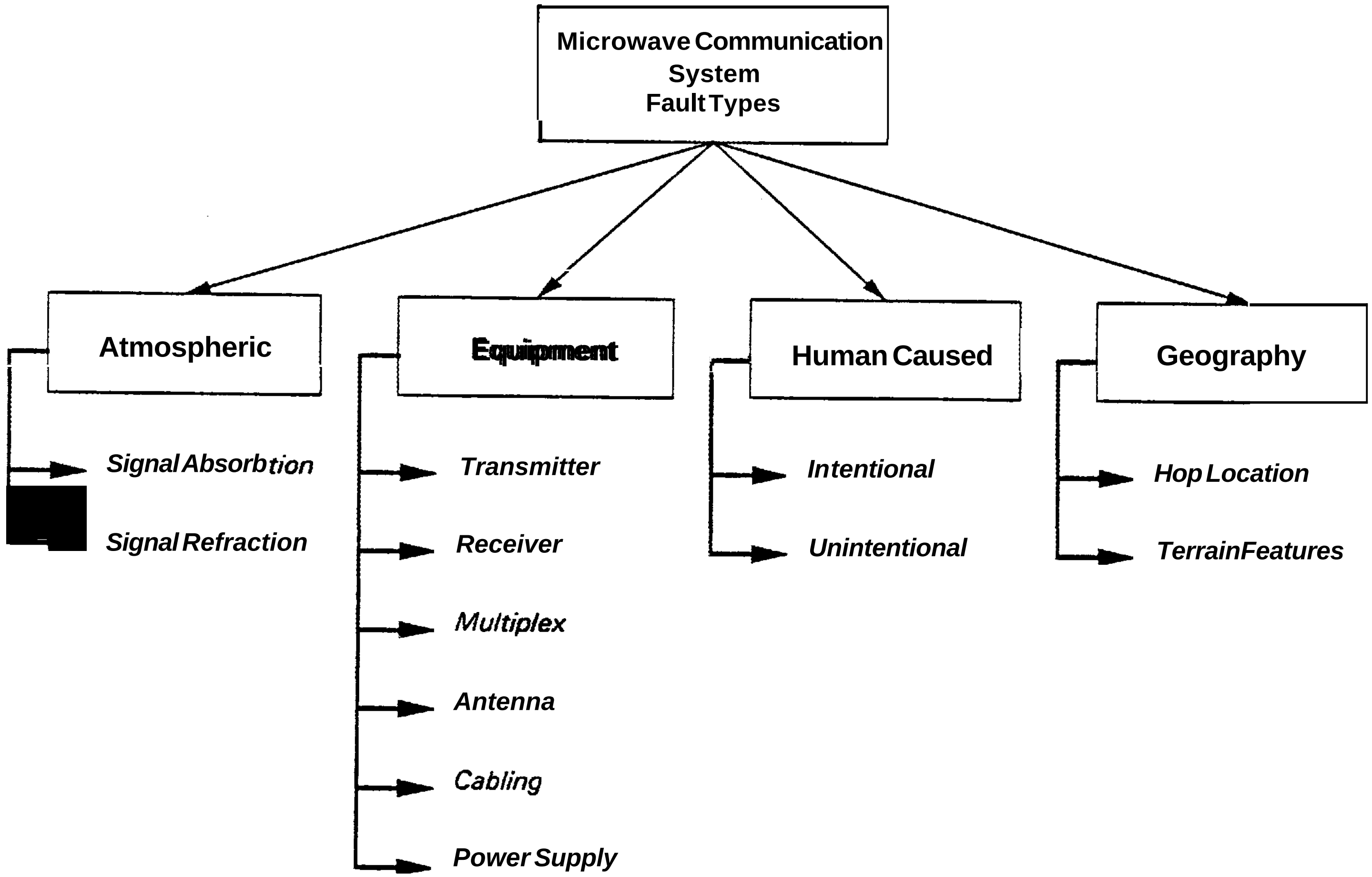
- isolate the location of a fault that has degraded signal quality;
- determine the likely cause of the fault, and
- if necessary, attempt to correct the fault by dispatching maintenance personnel to the site.

The second category of decision support is for maintenance decisions that are performed based on an analysis of aggregate alarm data over a period of months. These decisions include replacement of faulty equipment, upgrading or refurbishing equipment, and geographic reconfiguration of portions of a system. Unlike real-time decisions that are based on single instances of a fault that require a high-level of diagnostic expertise, maintenance decisions are based on a statistical analysis of system performance over a relatively long time period (e.g., one month of alarm data).

Historically, real-time decision support was provided by the MWM and BADGER alarm systems. Support for maintenance decisions was provided by data listings of MWM alarm reports. These were analyzed manually from the MWM printouts with no computerized data archiving of the primary alarm data. No automated fault isolation and diagnosis was available.

To support both the real-time and maintenance decision tasks, an integrated workstation was designed and implemented to provide a decision support suite on a single hardware platform. The integrated system was called CAP.

Figure **4.5** **Microwave** communication **system** fault types.



5. OVERVIEW OF CAP ARCHITECTURE

CAP was designed as a research and development project to demonstrate how alarm processing could be accomplished using a knowledge-based systems approach. At the same time, CAP was to meet an operational and maintenance requirement for improved statistical processing of alarm information. The resulting design was an architecture to provide decision support for microwave communication system operations and maintenance through a workstation that integrated existing alarm sources, statistical analyses, alarm archiving, and fault isolation and diagnoses. Figure 5.6 shows the decision support components integrated by CAP.

5.1 CAP SOFTWARE CONFIGURATION

Figure 5.7 shows a more detailed overview of the CAP architecture. CAP receives inputs from three alarm sources: the Microwave Monitor (MWM), BADGER, and end-equipment alarms from RODS. Each alarm source is input to an Input Data Buffer (IDB) that standardizes the alarm signatures and performs other data preparation such as removing extraneous characters from the incoming data. The output of each IDB goes to a separate data archive. The IDB aggregates intermittent alarms into a single alarm event. The expert system performs fault isolation and diagnoses using a rule-based knowledge system. Output from the expert system is provided to the User Interface, as well as to an expert system archive. The User Interface also makes available data from the IDB's. Support for statistical analysis comes from a set of menu-driven SAS routines that access data from the various archives. Details of the IDB's, CAP Expert System, SAS Maintenance Analysis, and the hardware configuration are discussed below.

5.2 CAP HARDWARE CONFIGURATION

Figure 5.8 shows the CAP Workstation hardware. CAP is installed on a VAX Station 3100, Model 30 computer with 32 Mbytes of board memory. Data archiving is accomplished with a 2.0 Gbyte external hard drive, as well as a DAT drive. A Slat-1 terminal server provides connectivity through the SCSI port for both the MWM and a modem (via MICOM for remote access). BADGER and a printer are connected through the VAX's RS-232 ports. End-equipment alarms are obtained from RODS through an Ethernet connection. A 19-inch color monitor, mouse and keyboard are the principal user-operated elements of the workstation.

Figure 5.6 CAP integrated workstation model

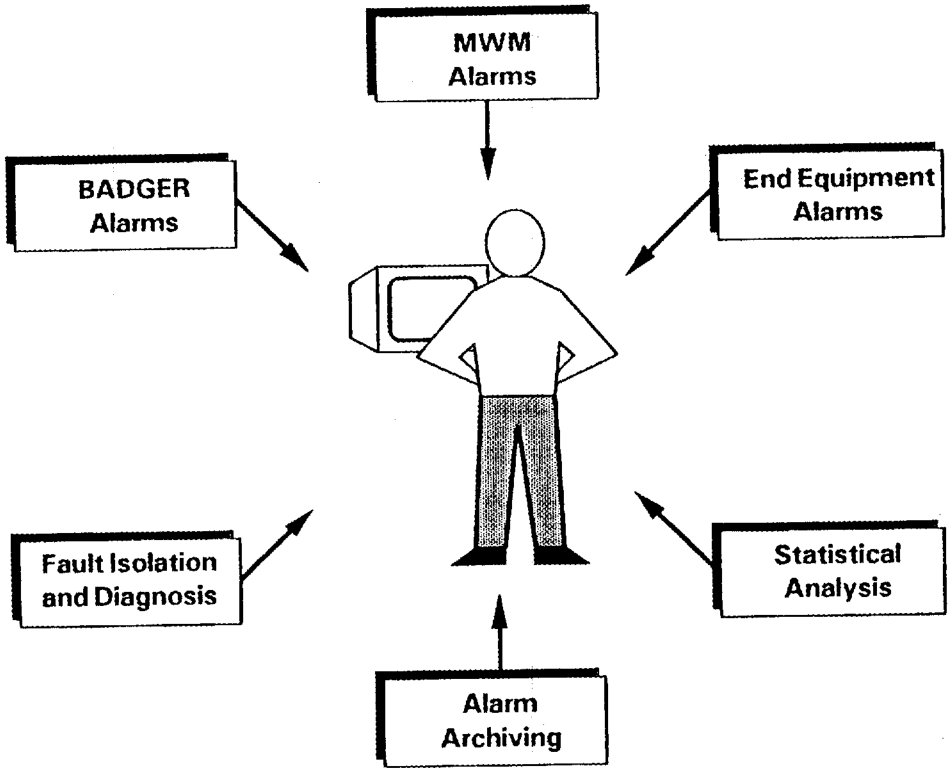


Figure 5.7 CAP architecture

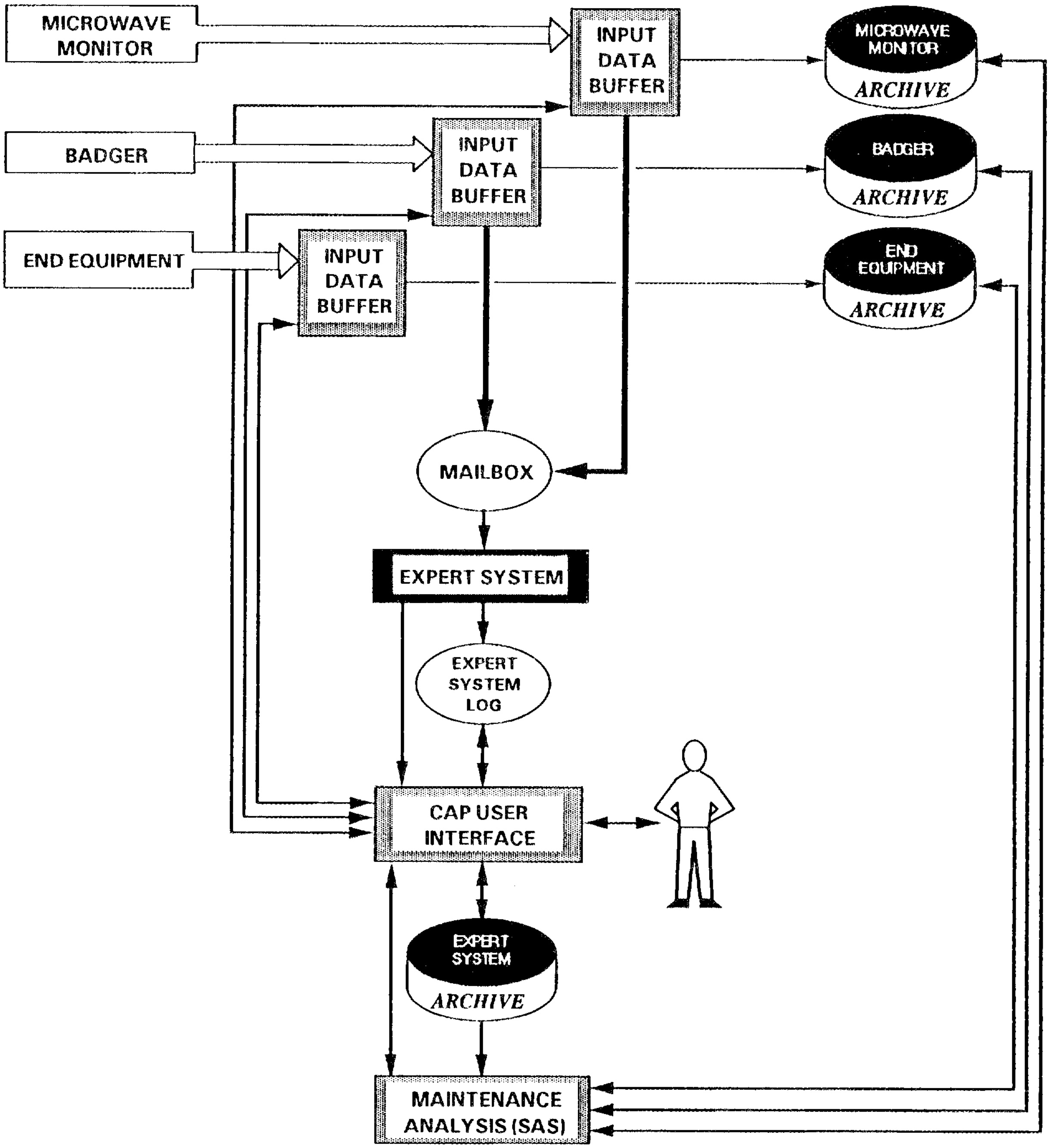
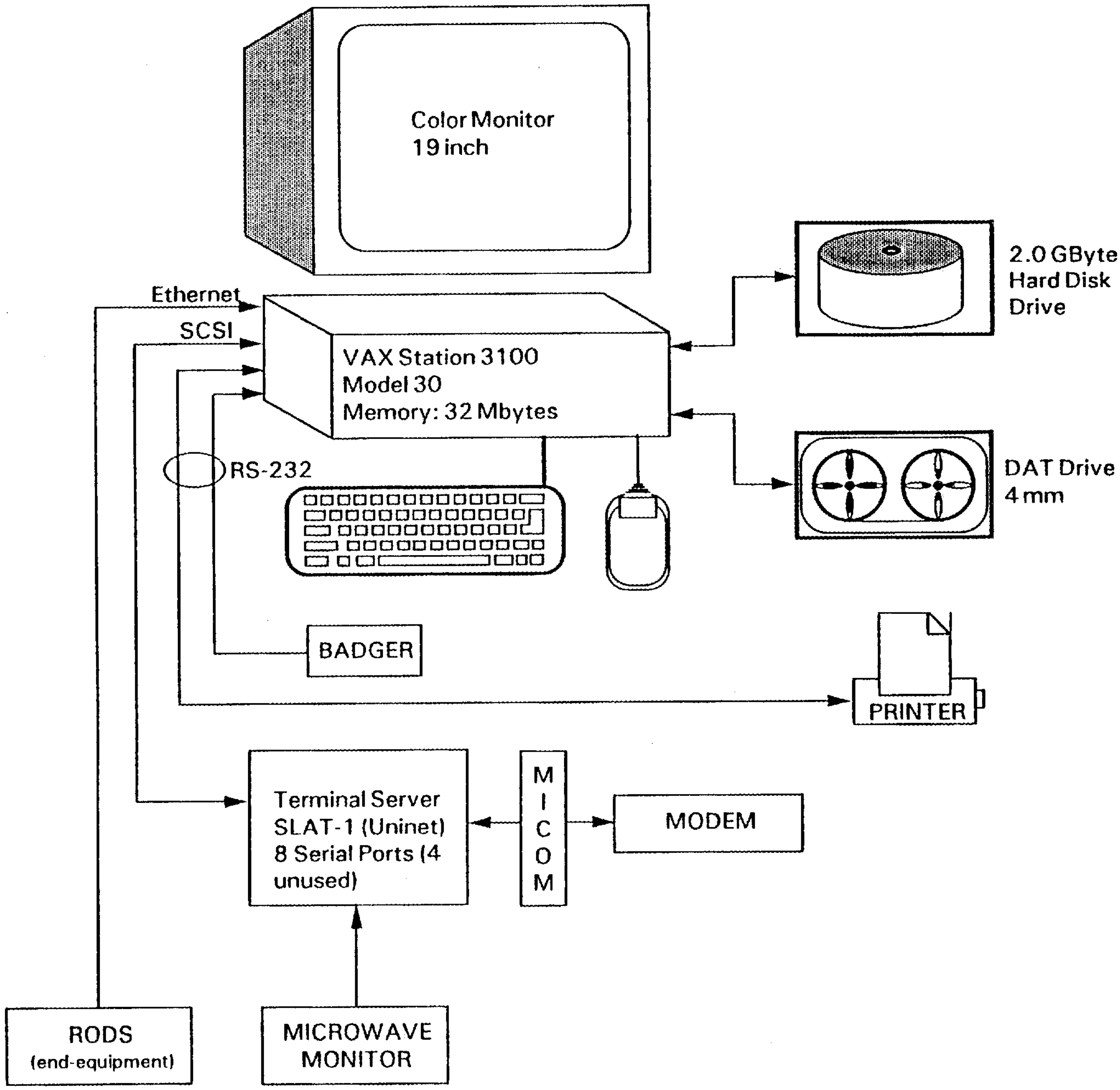


Figure 5.8 CAP hardware configuration



6. ALARM PREPROCESSING

Alarms from each of the three alarm sources are received by CAP through either an Ethernet connection to RODS in the case of end equipment alarms, or through an RS-232 port in the case of MWM and BADGER. Alarms are generally received as a message containing fields for a date/time stamp, origin, type of alarm as well as a record terminator (e.g., carriage return) and other delimiters (e.g., commas, spaces). However, the message content is not equivalent for the three alarm systems, and the organization of the alarm records is not standardized. The IDB's receive alarm information and convert their respective alarm records into a standardized format.

7. CAP EXPERT SYSTEM

The goal of the CAP expert system (ES) was to provide fault isolation and diagnosis for each of the seven fault types discussed in Section 3.0. The principal sources of data for the expert system are:

- MWM alarms;
- BADGER alarms;
- Topological descriptions for each system;
- Hop-specific noise history data;
- Hop-specific geographical data;
- Season of the year;
- Expert assessments of uncertainty.

7.1 KNOWLEDGE ENGINEERING AND REPRESENTATION

The knowledge engineering phase of the expert system development consisted of a number of interviews with domain experts having a detailed knowledge of how the microwave communication system is configured, the causes of faults on the system, and the relationship between alarm patterns and fault causes. Initial interviews focused on defining a model of the diagnostic process that the expert system would follow. Two general approaches were considered, both based on the methods used by the domain experts. The first approach was based on the observation of the domain experts that problems with the system evolve over time, and that the evolution of faults can be observed and tracked by noting patterns of alarms that occur before the signal actually becomes degraded. This is the *fault evolution* model, and it implies a diagnostic architecture for the expert system in which expert knowledge of evolutionary patterns are used to assign incoming alarms to a set of open diagnostic frames. A diagnostic conclusion would be output to the user as soon as sufficient information was available. Subsequent alarms would further discriminate between diagnoses by maximizing the variance in their respective weights.

A second candidate approach was based on a model in which fault isolation and diagnosis is done only when actual signal degradation has occurred. Since the MWM gave continuous monitoring of signal quality, diagnostic activity would not be initiated until a MWM alarm arrived. This is the *triggering* model and implies a diagnostic architecture in which a triggering event defines a diagnostic frame, with other alarm inputs and data used to provide diagnostic refinement.

From interviews with the domain experts, it was apparent that both models were used in actual operations. However, the triggering model was the stronger candidate because the conditions under which diagnostic activity would be initiated were clearer and better defined.

7.2 LOGIC TREE REPRESENTATION OF FAULTS

Subsequent interviews during the knowledge engineering phase focused on the development of a set of logic trees to represent the relationship between alarms, hop-specific data, uncertainty assessments, and fault diagnoses. The logic tree approach was used because it provided the most natural language for representing faults from the experts' perspective and was a useful communication tool during expert system programming. Figure 7.9 shows a completed logic tree for one particular fault type: Noise Outage on the backbone due to various weather-related problems. In this example, a combination of MWM alarms, BADGER alarms, hop information (e.g., noise history, length, passive reflector), and season of the year are used to discriminate between four candidate diagnoses.

7.3 UNCERTAINTY REPRESENTATION

Weighting for the diagnoses are in terms of confidence factors that are propogated through the logic network. These were assessed subjectively by domain experts for each piece of evidence. Combination of confidence factors was done according to the following rule:

$$CF(A,B) = CF(A) + CF(B) - [CF(A) * CF(B)/100];$$

where CF(A,B) is the combination of confidence factors CF(A) and CF(B) to yield a total confidence factor (Buchanan & Shortliffe, 1984). This combination rule has worked moderately well in testing but does not provide optimal combination. A key difficulty encountered with this approach is its lack of intuitive appeal to the domain experts. Though uncertainty is often expressed in verbal terms by experts, numerical representation of uncertainty is unfamiliar, though theoretically more precise. In general, the domain experts were uncomfortable with use of certainty factors as weights for diagnoses because they lacked a convenient and intuitive interpretation.

7.4 EXPERT SYSTEM DIAGNOSTIC PROCESS

The CAP expert system is a knowledge-based system for fault isolation and diagnosis. The expert system uses a set of rules of the "if-then" type to infer possible causes for the occurrence of alarm activity.

The expert system is built on two models, shown in Figure 7.10. The first model is a set of general diagnostic principles that apply independently of the specific location of a possible fault. These principles are encoded in the expert system as a rule network that is used to reason based on specific alarms at specific locations.

The second model is a topological description of each of seven microwave communication systems. The topological model is contained in a separate set of files that can be accessed and updated without reconfiguring the rule network. The general diagnostic reasoning model and the topological model are combined to perform fault diagnosis and isolation.

An example is shown in Figure 7.11. This is a portion of the complete logic tree in Figure 7.9 relating to the diagnosis of noise outage on the backbone caused by weather. Figure 7.11 shows the general reasoning model for diagnosing weather-related power fading. Multiple rules and data-types are required for this diagnosis. However, the basic diagnostic process is highlighted in the following rules.

IF there is evidence of *sta1_rx_sta2*
AND there is evidence of *sta2_rx_sta1*
THEN *rx_muting* is confirmed.

This rule specifies that receiver muting (*rx_muting*) is confirmed if there is evidence of BADGER receiver alarms (*rx*) from stations in both directions on a hop.

IF there is no evidence of *sta1_ndif_sta2*
AND there is no evidence of *sta2_ndif_sta1*
THEN *no_two_way_ndif* is confirmed.

This rule specifies that no two-way noise differential (*no_two_way_ndif*) is confirmed if there is no evidence of BADGER noise differential alarms (*ndif*) from stations in both direction on a hop.

The results of these two rules are combined with other evidence in the rule below to confirm the hypothesis that the problem is due to weather-related power fading.

IF there is evidence of *rx_muting*
AND there is evidence of *no_two_way_ndif*
AND there is evidence of *hop_characteristics_2*
AND there is evidence of *noise_on_section*
THEN *power_fade_problem* is confirmed.

The objects *hop_characteristics_2* and *noise_on_section* pertain to other sources of evidence relating to diagnosing noise problems attributable to weather.

Using the example shown above, if the initiating trigger was a MWM noise outage alarm on the N-system, the alarm signature would identify the alarming section. This section and its associated hops, paths, and stations would become the focus of diagnostic activity, through a mapping done by the Messenger (see Section 7.5). The objects *sta1*, *sta2*, *rx*, and *ndif* are instantiated as location-specific alarms. The rule network is fired once for each topological element, and the appropriate diagnoses are confirmed.

The sequence is initiated when microwave signal degradation is sufficient to produce a triggering event in the form of a MWM alarm. A diagnostic frame is opened according to the level of focus. For noise alarms, the diagnostic focus is a noise section, which will contain at least one hop, two paths, and two stations (see Section 2.0). BADGER alarms relevant to the diagnostic focus are retrieved from the Mailbox. The rule network is then fired and the diagnoses reported to the user through the Messenger. The diagnoses are then archived with a date/time stamp. The diagnoses are referred to the user for confirmation and feedback as to which diagnosis is the true cause of the problem.

7.5 EXPERT SYSTEM MESSENGER

The expert system is supported by a set of services provided by the Messenger. The Messenger is collection of routines that perform control, utility, and reporting functions. Figure 7.12 shows the general functions performed by the messenger.

7.6 REPORTING OF DIAGNOSES

The output from the expert system is provided in a window. Figure 7.13 is an example of a typical output for a noise outage problem. Here, four diagnoses are reported, along with their respective confidence factors indicating their relative weight given the available evidence. In this example, the noise outage problem occurred at a noise section containing two hops: King Lake (KLAK) - Devils Mountain (DMRS) and Devils Mountain (DMRS) - Lookout Mountain (LOMT) [see Figure 1.2]. According to the expert system, the most likely cause of the noise outage alarm was a weather path fade on the KLAK-DRMS hop (confidence factor = 82). This diagnosis is supported by receiver muting and two-way noise differential alarms (from BADGER), a MWM noise performance alarm on one of the paths for the hop, the summer season, and a prior history of noise on the hop.

7.7 CAP EXPERT SYSTEM PROGRAMMING

The CAP expert system rule-base is programmed in Nexpert Object, from Neuron Data Corporation. The subroutines contained in Messenger, as well as other subroutines used to support archiving are programmed in C. The expert system knowledge-base contains a total of 232 rules, and 133 objects.

Figure 7.9 Logic tree **for weather-related noise outage diagnosis.**

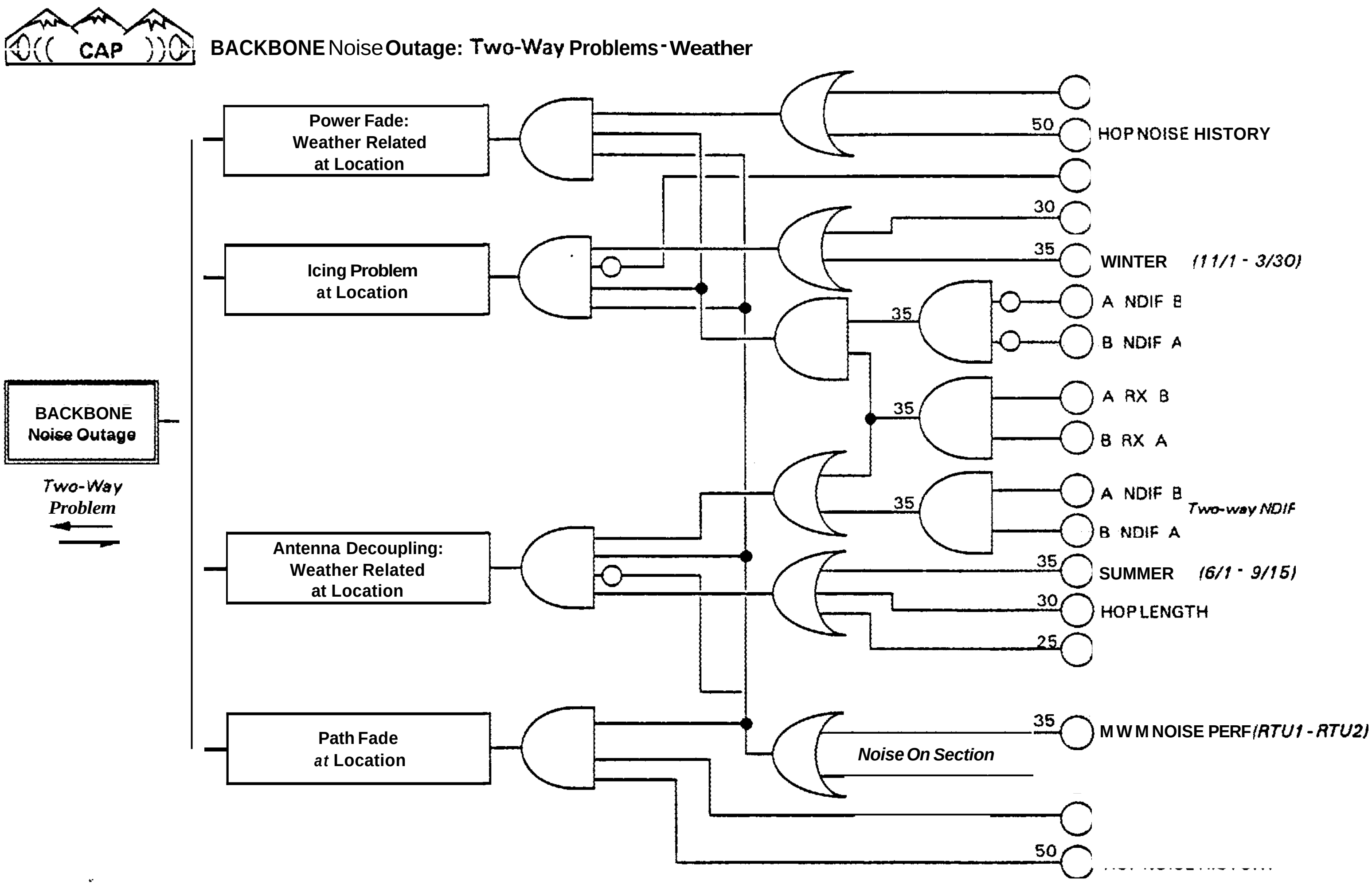


Figure 7.10 CAP models.

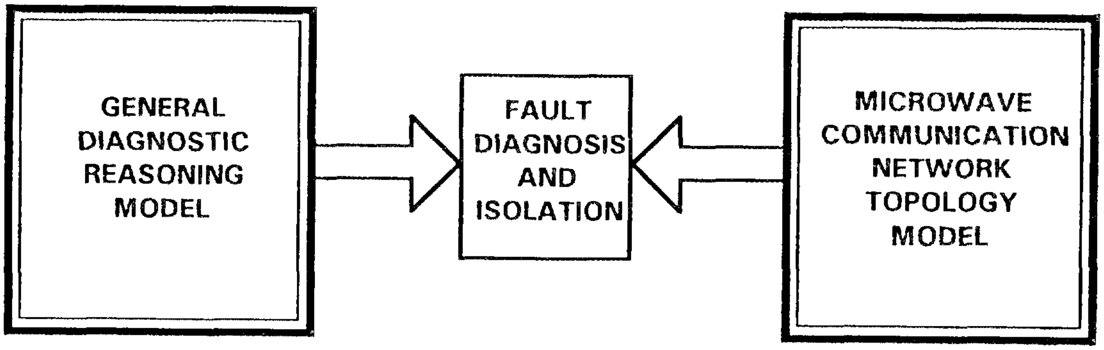


Figure 7.11 Logic tree for weather-related noise outage due to power fade.

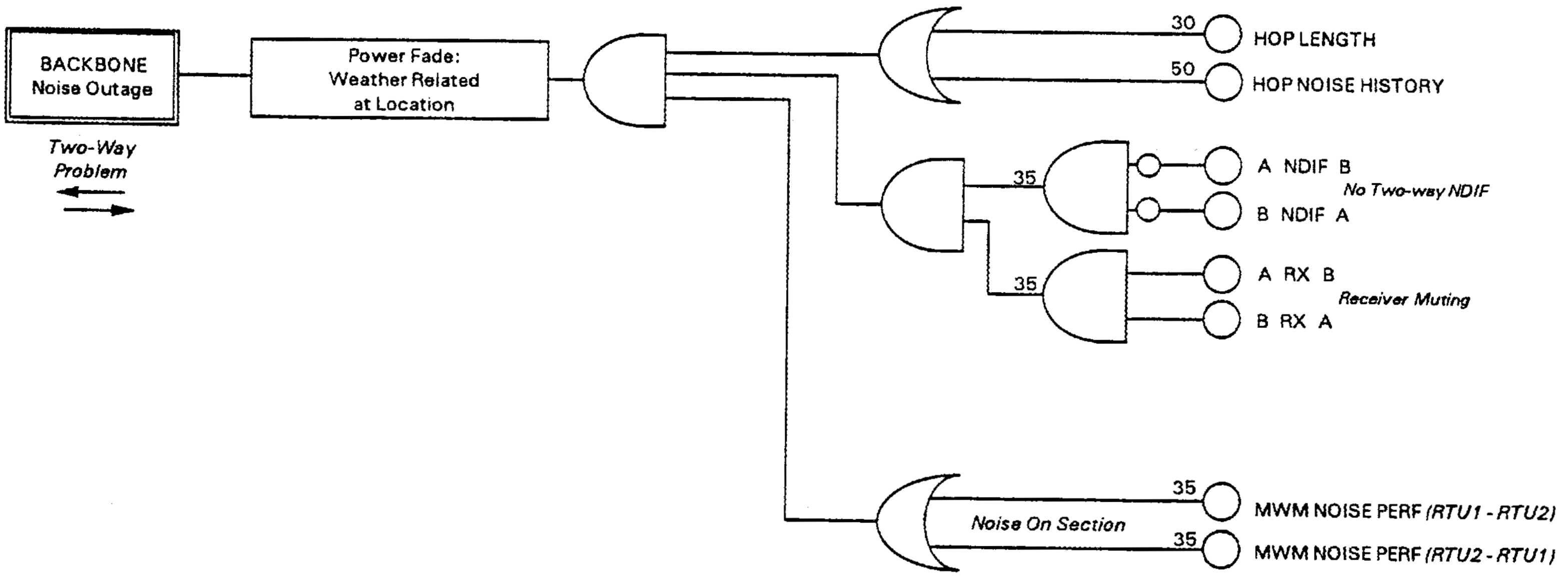


Figure 7.12 Expert system messenger.

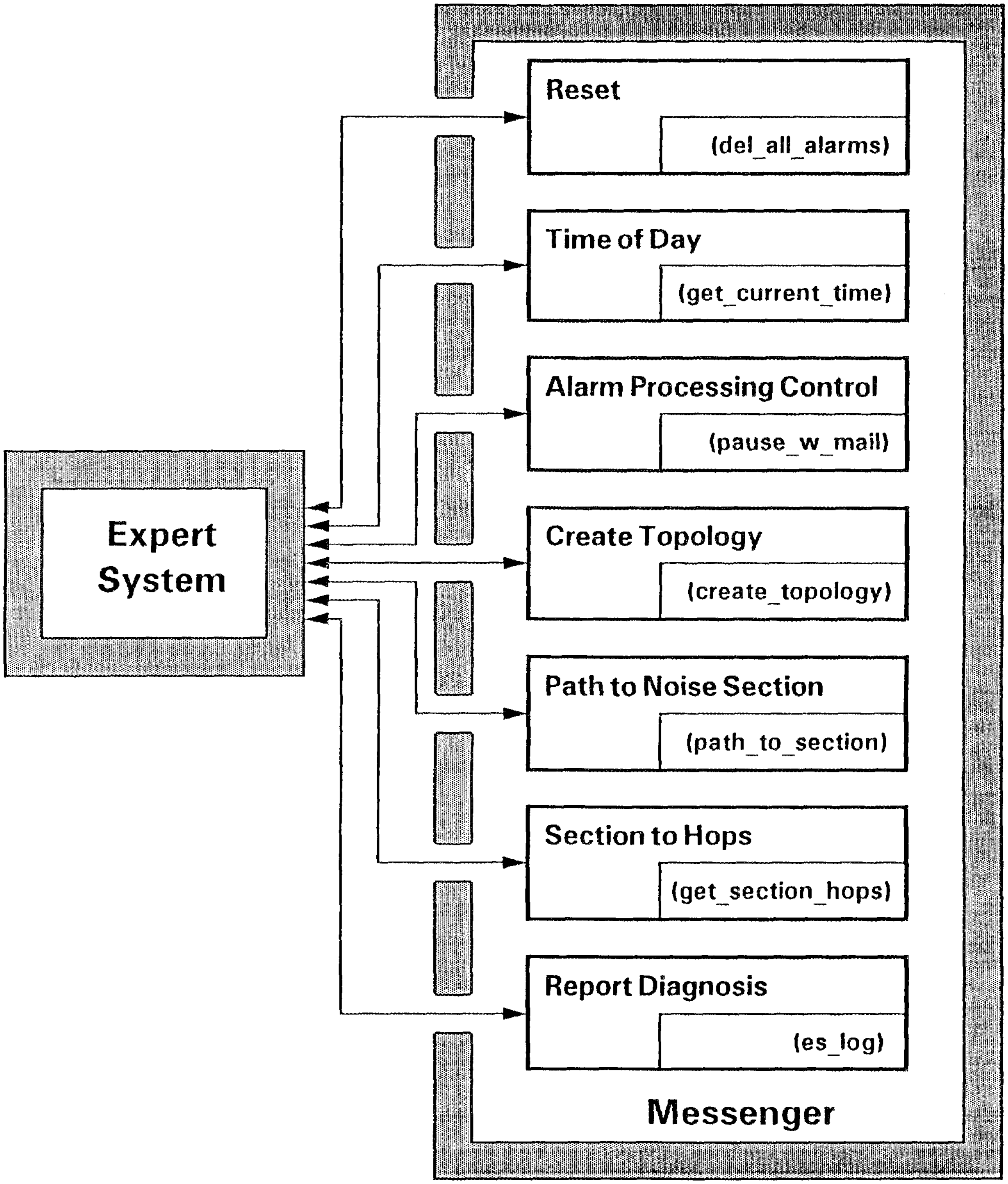


Figure 7.13 Example of CAP diagnostic output for noise outage fault.

Menu **Expert System** KB

```
16:47:05  Feb 2  Noise outage   KLAK-LOMT
      82 Weather path fade on KLAK-DMRS
            In general, it is the SUMMER season
            History of noise on this hop is considered
            Receiver muting (two-way RX)
            Two-way NDIF
            Noise performance on the KLAK-DMRS path

      63 Wave guide or antenna shift on KLAK-DMRS
            Receiver muting (two-way RX)
            Two-way NDIF
            Noise performance on KLAK-DMRS path

      54 Weather path fade on DMRS-LOMT
            In general, it is the SUMMER season
            History of noise on this hop is considered
            Noise performance on the DMRS-LOMT path

      53 Wave guide or antenna shift on DMRS-LOMT
            Noise performance on the DMRS-LOMT path
            Absence of noise history on this hop is considered
```

8. CAP STATISTICAL ANALYSIS

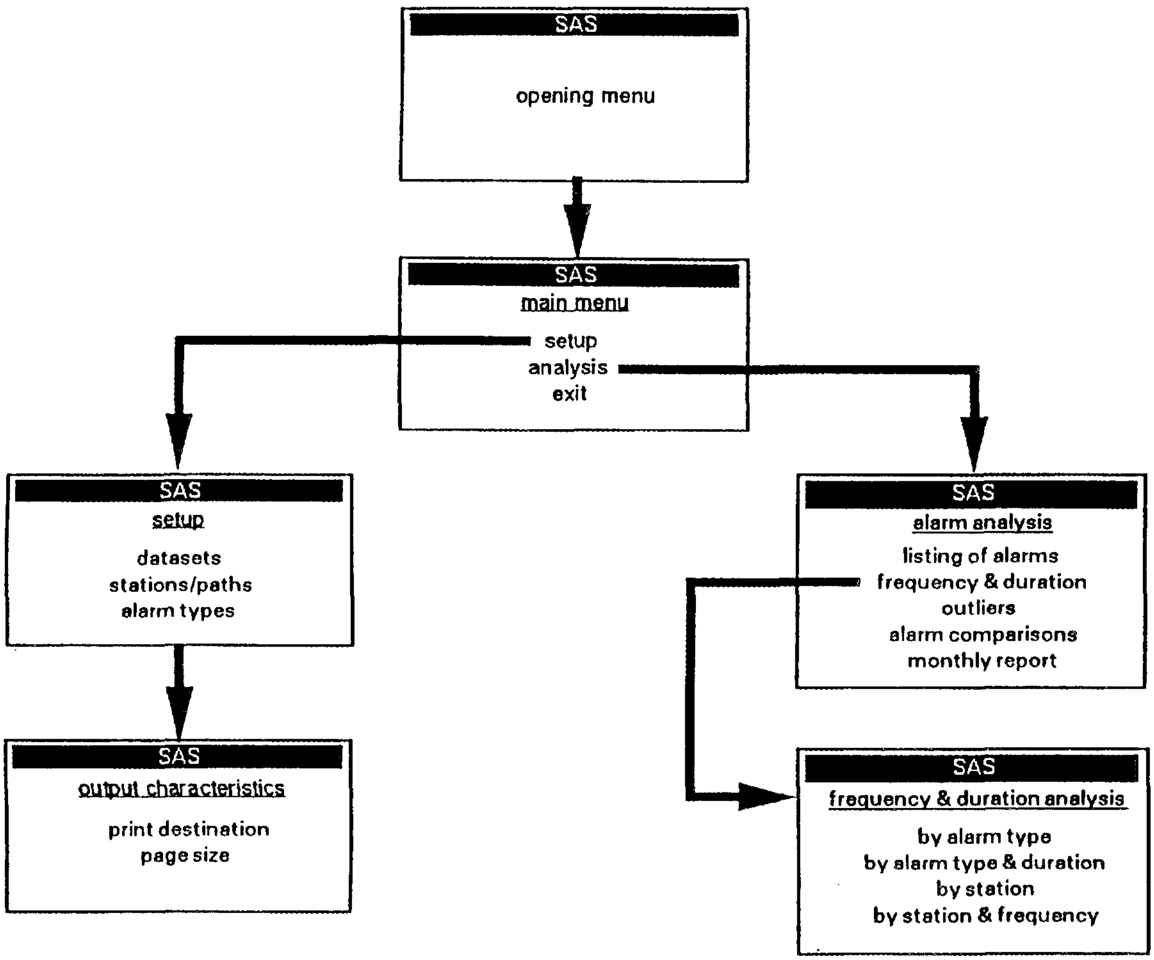
A important aspect of microwave communication system management is the statistical analysis of performance and alarm data. Statistical analysis can be used to support a number of mission requirements, including:

- Optimization of maintenance schedules,
- Conversion from scheduled to "as-needed" maintenance,
- Identification of long-term trends in system performance,
- Prediction of equipment failures, and
- Support for RCM (reliability-center maintenance).

CAP provides support for statistical analysis through a menu-driven interface that provides user access to a set of statistical routines that can be applied to data contained in the BADGER alarm archives. The statistical routines are part of a larger statistical package called Statistical Analysis System supplied by the SAS Institute (SAS, 1990). A set of menus guides the user through a series of decisions that identify the types of data to be analyzed and the statistical procedures to be applied to the data. A key advantage of using the SAS statistical package is that additional analyses can be incorporated into CAP in the future with minimal effort by simply expanding (or changing) the menu-driven front end. Alarms are archived continuously and organized into monthly files.

Figure 8.14 shows the structure of the menus used to identify datasets, specify output characteristics, and select statistical analyses.

Figure 8.14 Structure of BADGER menu system.



9. RECOMMENDATIONS FOR FUTURE RESEARCH AND DEVELOPMENT

As of this writing, CAP has the capability to provide alarm preprocessing, alarm archiving, and fault isolation and diagnoses using data provided by the Microwave Monitor, the BADGER alarm system, and end-equipment alarms. During the development of CAP, emphasis was placed on processing a number of different alarm types. Considerable effort was involved in standardizing alarms and alarm signature (alarm preprocessing).

Several opportunities are available to extend CAP to provide greater depth in alarm processing. One option is to bring into CAP more of the alarm data generated by the Microwave Monitor. At present, only performance and outage alarms are available from the MWM. The raw information on which these alarms are based is not available to CAP. Were such data available, greater diagnostic specificity could be obtained from the expert system. Statistical analyses of that data could also prove valuable in maintenance decisions.

Additional end-equipment alarms can also be brought into CAP through RODS. These alarms can also be used to confirm the outage conditions reported by the expert system (and the MWM).

At a more fundamental level, CAP's expert system capabilities could be extended through the use of a different reasoning model than the one currently employed. The fault evolution model discussed in Section 7.1 is a possible approach that could be used to provide supporting diagnoses or to provide candidate diagnoses in advance of a triggering event.

Though CAP currently has the ability to receive confirmation from operators as to the actual cause of faults reported by the expert system, additional refinement needs to be undertaken to give CAP the capability to learn its diagnostic process based on actual experience. Alternative diagnostic strategies, such as neural nets, could also be explored.

CAP provides a demonstration of the power of computerized decision support to assist power systems management. The expert system portion of CAP can be a useful context for familiarizing Bonneville Power Administration personnel with the principles of knowledge-based systems.

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