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# DATA COLLECTION AND RECORDING INSTRUMENTATION FOR COMMAND, CONTROL, AND COMMUNICATIONS

Instrumentation has been developed to acquire and record performance data for analysis of Navy communications systems. The existing two basic models are modular, multimicroprocessor-based systems using state-of-the-art devices. They were designed to collect, process, and record performance data automatically (i.e., with little or no operator intervention). One is designed as a shipborne system, whereas the other is a more compact version for use in Navy aircraft.

## INTRODUCTION

Both of the data collection and recording systems described in this article use multimicroprocessor concepts that are state-of-the-art technology. The systems are second-generation devices of modular construction that provide a reliable, versatile, and adaptable data collection capability. Their ability to collect, process, and record various types of data is limited only by the imagination and skill of the programmer and by the input/output devices that can comfortably fit on a module.

The shipborne system was the first of these modular microprocessor systems developed at APL. Because of weight and size restrictions, the airborne system was developed later and uses newer technology. This article describes in general terms the basic tasks and functions of these unique systems.

## MODULAR DATA COLLECTION AND RECORDING SYSTEM

The Modular Data Collection and Recording System (Fig. 1) has been developed to instrument various shore and Navy shipboard communications systems. It can collect, process, and record communications performance data automatically by (a) accepting data output by a communications receiver/processor and/or (b) by measuring such communication channel parameters as bit-error rates, time distortion, and signal-plus-noise levels, and then recording the data for off-line analysis.

To minimize the work load on Navy communications personnel, APL developed a methodology (described in the companion article by Preziotti et al. on page 37) that uses a technical test message composed of a unique sequence of 26 bits that, when repeated, generates a repeating sequence of 26 teletype characters, as shown in Fig. 2. Test messages can vary in duration but typically are 3 minutes long and are repeated at intervals as short as 15 minutes.



**Figure 1** — Modular data collection and recording unit and remote data terminal.

By using this unique bit pattern, the acquisition threshold allows the test message to be recognized well below the signal levels necessary for intelligibility of message text on a teleprinter. The system monitors the communications channels for the presence of the technical test message. A first-in/first-out shift register is used to sample the received message and compare it with a pattern stored in read only memory. The received message is cycled through the register so that correlation is examined in each phase, or character, until acquisition is determined. The measurement of bit errors, character errors, time distortion, and signal plus noise is taken during the test message. These measurements are processed by the interface control modules of the modular data collection and recording system.
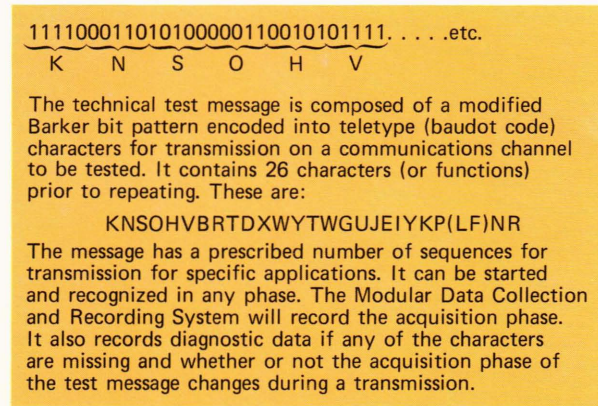
111100011010100000110010101111. . . . .etc.

K   N   S   O   H   V

The technical test message is composed of a modified Barker bit pattern encoded into teletype (baudot code) characters for transmission on a communications channel to be tested. It contains 26 characters (or functions) prior to repeating. These are:

KNSOHVBRTDXWYTWGUJEIYKP(LF)NR

The message has a prescribed number of sequences for transmission for specific applications. It can be started and recognized in any phase. The Modular Data Collection and Recording System will record the acquisition phase. It also records diagnostic data if any of the characters are missing and whether or not the acquisition phase of the test message changes during a transmission.

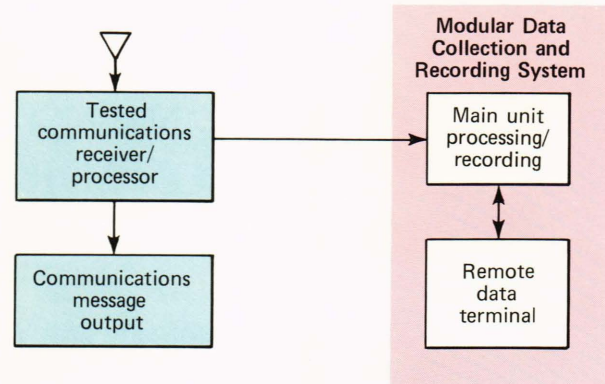Figure 2 — Technical test message.



Figure 3 — Test configuration of the Modular Data Collection and Recording System. It will automatically acquire communications performance data output by a receiver/ processor or by measurement of communication channel parameters such as error rate, time distortion, and signal level and record the data for off-line analysis.

For digital communications (viz, the Verdin system[1] where test messages are not used), system performance measurement data are output on special ports of the Verdin receiver processor. The performance parameters are called communications evaluation performance data. They are processed in the processor interface modules of the Modular Data Collection and Recording System.

## Design and Development Considerations

The design of the Modular Data Collection and Recording System takes advantage of an evolving microprocessor technology and of improved component layout and packaging in order to achieve maximum reliability, measurement flexibility, and compactness. The concept of individual modules to function autonomously was adopted. Each module is personalized to perform the necessary tasks for a particular communications system, with a common mode for dumping its memory to tape and acquiring system intercommunications to provide status and operator interaction.

Design of the equipment involves use of two subsystems. The main unit houses the cartridge tape recorder, cartridge tape modules, central processing modules, and six additional universal module slots for instrumentation. The second unit, or remote data terminal, is used for operator inputs and status display and is also a microprocessor system with its own array of memory, logic, and peripheral support hardware. Figure 3 is a block diagram of the system as it is employed in a typical Navy communications test configuration. A more detailed diagram showing the test configuration used for typical HF, LF, and VLF communications receiving system equipment is shown in Fig. 4.

## Description of Equipment

The main unit of the modular data collection and recording system consists of an aluminum case 17½ inches wide by 18 inches deep by 10¾ inches high,

weighing approximately 55 pounds, and, including the remote data terminal, consuming 185 watts. It operates at 50 to 60 hertz and 95 to 135 volts.

The main unit (Fig. 5) contains the cartridge tape transport that uses standard digital cartridges. The recorder has a 4-track format and records digital data serially in 16K-bit data blocks, one track at a time. There are two cartridge tape modules that are used to control the tape transport and to format serial data from an 8-bit parallel data bus that can be accessed by any of the functional modules in the system. Two central processing modules are used to generate and maintain time of year in Greenwich Mean Time (see the insert on page 45) and to provide coordination to permit only one module to access the cartridge tape module data bus at a time. The central processing modules also distribute time and status to all operational modules and relay intersystem communications between the remote data terminal and system modules. The modules in the Modular Data Collection and Recording System use the Motorola M6800 or M6809 microprocessor chip. Static random access memory is used for data storage, stack, and scratch pad. Part of the random access memory is powered by three alkaline cells that provide battery backup to preserve vital information, i.e., time of power down, Greenwich Mean Time, initialization time, system identification data, operator data entered from the remote data terminal, and the time when each module last used the recorder. A switch to the battery bus is automatic when power fails.

Six module slots have been provided in the Modular Data Collection and Recording System, with a universal backplane bus system that is compatible with any type of operational or test module to be used. Each slot is uniquely wired to the central processing modules to permit them to detect which slots are in use and the type of operational or test module in each slot.
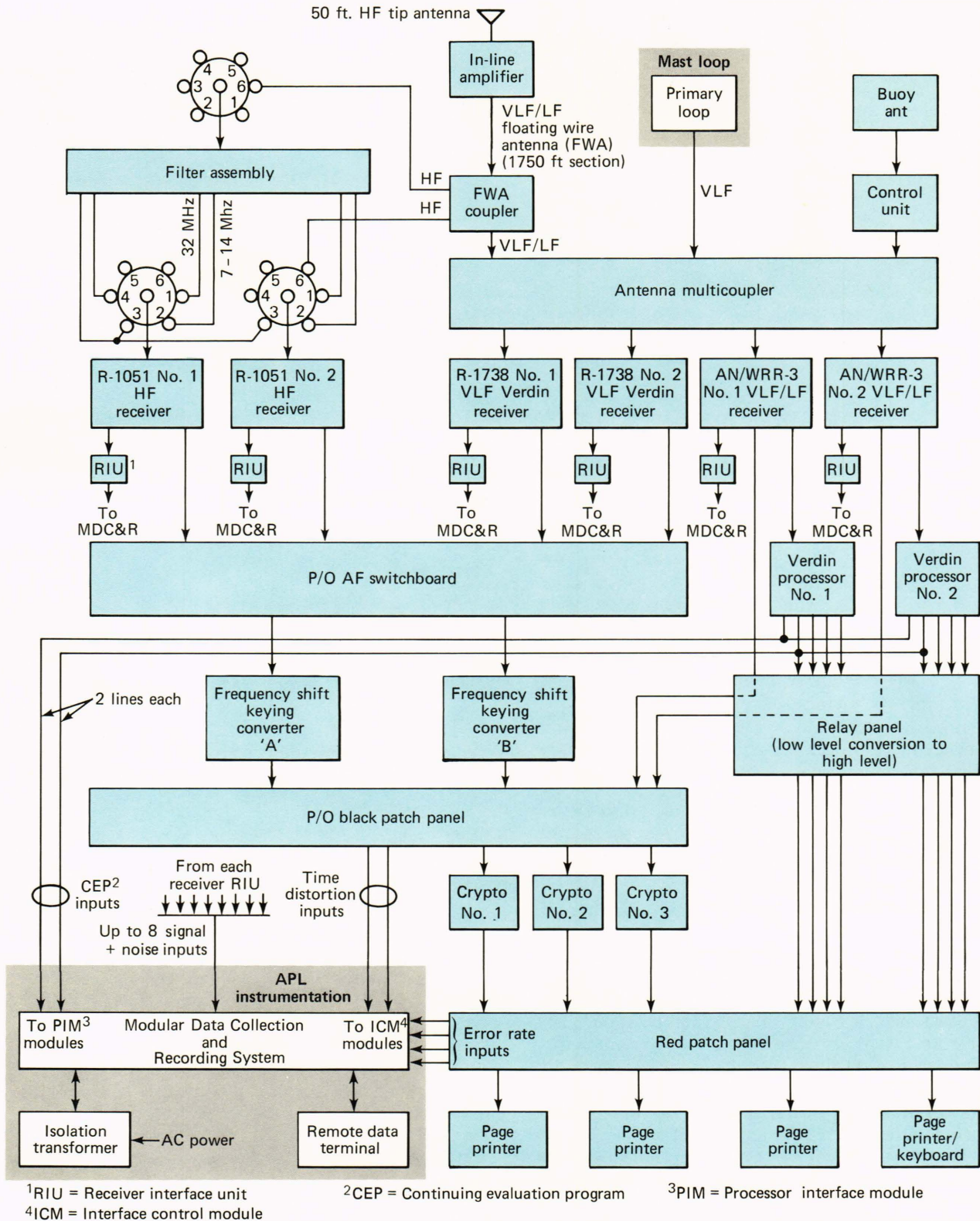
**Figure 4** — Typical HF, LF, and VLF communications receive system equipment and the test configuration used to instrument Navy communications systems. Modular Data Collection and Recording System elements are highlighted.

[1]RIU = Receiver interface unit     [2]CEP = Continuing evaluation program     [3]PIM = Processor interface module
[4]ICM = Interface control module

Two types of operational module have been developed for use in the universal module slots of the Modular Data Collection and Recording System. The

processor interface module monitors and processes the performance data output by the Verdin communications processor, and the interface control module
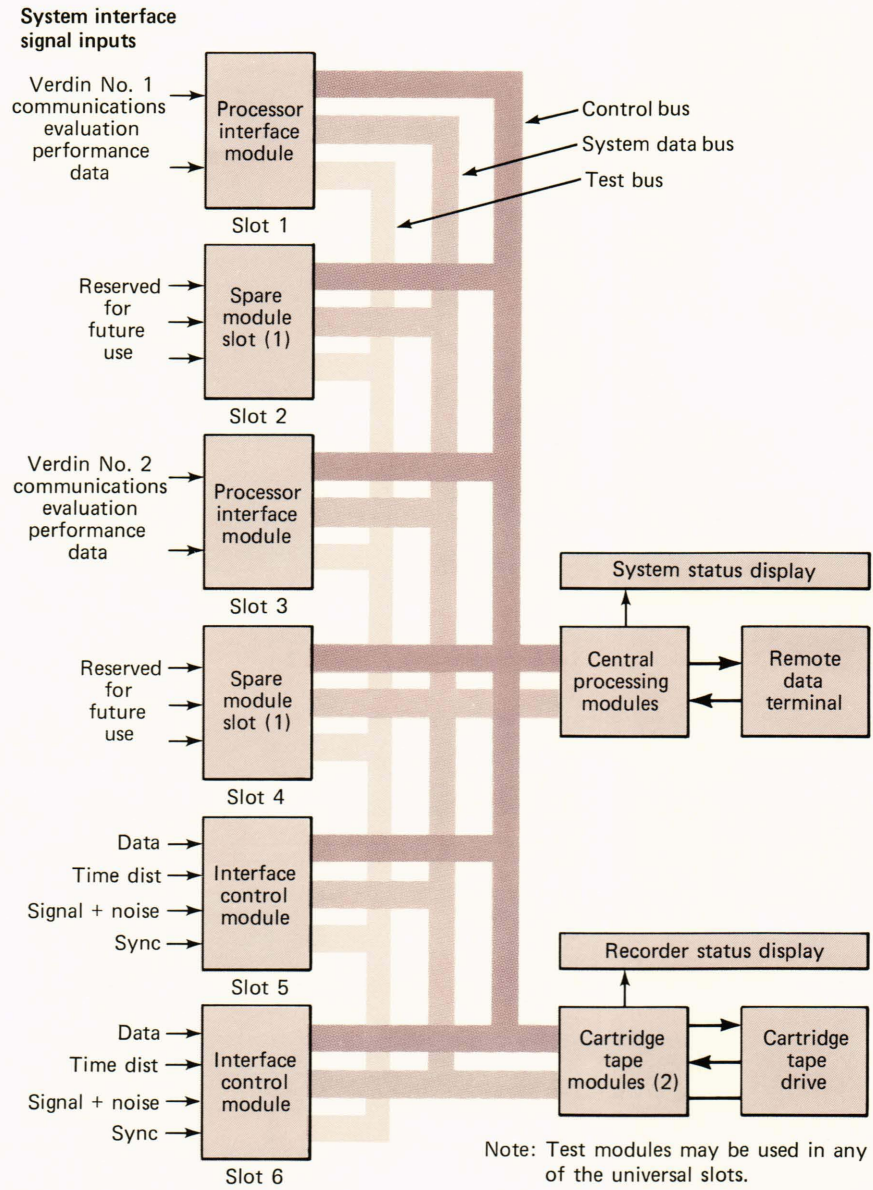
**Figure 5** — Simplified block diagram of a typical SSBN installation of the Modular Data Collection and Recording System.

measures bit and character errors, time distortion, and signal plus noise for each technical test message. In addition, two types of test module were developed to exercise the system to ensure that the operational modules function as specified. These modules, the processor interface test module and the interface control test module, provide user interaction to permit testing in any or all modes of operation. The test messages generated by the test modules were designed to exercise all functions of the operational system.

The interface control test module outputs test messages that are specified by the user. The module is interactive via a data terminal and prompts the user in setting up the desired tests. Various test messages are output to exercise the interface control modules' ability to measure accurately the error rate, time distortion, and signal plus noise.

The processor interface test module outputs simulated Verdin communication evaluation performance data in the proper formats for the selected modes of operation. Two-word, 9-word, and 16-word data are output at the option of the user.

Either test module can function in a recorder test mode by seizing the cartridge tape module data bus and feeding patterned data to be recorded on the cartridge tape. This provides a semiautomatic way to test quickly the entire recorder system.

The basic layout of the Modular Data Collection and Recording System was designed to permit virtually any instrumentation task by means of modular adaptation to the input sensing device(s). The system can be, and has been, used to generate communications test messages for use in area HF communication evaluations. The basic hardware enclosure contains the necessary power, bus structure, and elements to

The Modular Data Collection and Recording System keeps time by use of a crystal oscillator that outputs 1 pulse per second to the nonmaskable interrupt of the microprocessor and simultaneously increments a counter that is accessible by the microprocessor as part of the power-up initialization routine. Current time of the year (by Julian date) is preserved in nonvolatile memory and updated each second. The oscillator, counters, and nonvolatile memory are operated from a battery bus supplied by three alkaline cells. Also stored in nonvolatile memory is the start-up time of the system (as entered by a field engineer). When power fails, the microprocessor is alerted by a power fail signal from the power supply and conducts an orderly power-down prior to the loss of all voltages from the power supply. The battery bus is switched in via germanium diodes to maintain memory and to keep the oscillator and counters active. When power is restored, the reset initialization routine collects the count from the counters and adds it to the start-up time to calculate current Greenwich Mean Time (GMT). The system also displays current GMT on the system status display on the front panel.* Any power outage will cause a power- down of at least 2 seconds to permit the power line to stabilize before restarting the system.

The accuracy of the clock is dependent on the adjustment of the crystal oscillator and is typically accurate to a few seconds per month. The system has an input for a precise 1 pulse per second from an external frequency standard, such as a cesium beam type. When an external 1 pulse per second is present, the system will automatically be switched to the external standard and maintain precise time.

*Time of year is displayed as YR DAY HR MIN SEC = "GMT 83 291 22 30 15."

provide digital cartridge tape recording from almost any source, either from modules within the enclosures or from external devices. The use of a standard universal microprocessor module with appropriate software and input and/or output circuitry is all that is required for different tasks.

The remote data terminal is the operator interface to the Modular Data Collection and Recording System. It is an "intelligent" terminal that is used to supply system configuration information to each of the six operational module slots. Remote data terminal data, entered by the operator, are sent to the proper module via the central processing modules. Status signals from each operational module as well as the system configuration for any slot are displayed on the remote data terminal. The module for which data are to be displayed is selected by a SYSTEM SELECT switch on the front panel. The remote data terminal is self-prompting for ease of operator entry and is programmed with checks to minimize entries of invalid data.

Receiver interface units are provided for each radio receiver instrumented in the communications suite. These units provide analog voltage signals from the receivers' intermediate frequency amplifiers or from the detected automatic gain control voltage to the modular data collection and recording system. The analog voltages are nominally proportional to the signal-plus-noise level present during test conditions.

## System Operation

The Modular Data Collection and Recording System is programmed to write digital data to tape in 2K × 8-bit data records. The recorder actually writes a serial 16K-bit data record. There are four tracks available on the cartridge tape. The conversion of parallel to serial records is handled in the cartridge tape modules. At present, three different types of data record are written by the system. Each module that can write data has a specific header; for example, each of the interface control modules writes a header with 8 F's, a one-digit slot number, and a slot sequence number (FFFFFFFF2016). The F's identify the type of module, the 2 means that the module residing in slot 2 wrote the data record, and the 016 means that this is the 16th record written since initialization. In the case of the processor interface module, the header is A's; the slot and sequence number are similar.

The central processing modules also write data records but are headed with 10 B's. There are no slot or sequence numbers for the central processing module records since the times recorded in the data record are sufficient. The central processing module data records are called "power failure" records, although this does not necessarily mean that a power failure has occurred. There are three different reasons for writing power failure records. One is, of course, after a power failure, to indicate the periods of time that the system was without power. Another type of power failure record (called a dummy) is written merely to identify the cartridge tape; it is the first data record written onto a new tape. The third type of power failure record indicates that one of the operational modules requested permission to write data when the recorder was not available because, for example, the tape was rewinding, another module was writing data, the data tape was full and required changing, or the tape was removed from the recorder. The periods of nonavailability are recorded in the data record. Also recorded in the power failure record are such statistics as the times that each slot last used the recorder. Information such as the system identification, the communications systems instrumented, the module configuration, and the type of software installed in each module is also recorded in the power failure record.

## AIRBORNE TRANSMITTER MONITORING AND RECORDING SYSTEM

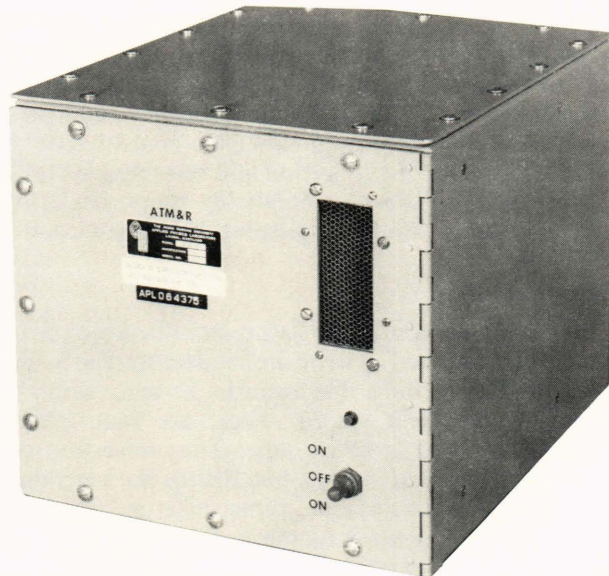The Airborne Transmitter Monitoring and Recording System (Fig. 6) was developed to instrument

**Figure 6** — The Airborne Transmitter Monitoring and Recording System.

the TACAMO (an airborne very low frequency relay system) aircraft that is used to relay emergency messages from the National Command Authorities to the Fleet ballistic missile submarines. The aircraft is outfitted with a high powered, VLF radio transmitter and a very sophisticated communications suite to ensure high reliability even in a hostile environment. Two trailing-wire antennas are used for the VLF transmissions. Several different transmission modes

are available to optimize transmission security and enhance reliability. Radio frequency antenna voltage and antenna current produced by the transmitter are measured by the Airborne Transmitter Monitoring and Recording System and are recorded, as are the trailing-wire tensions.

The principal purpose of the system is to measure and record automatically the transmitter parameters that can be used to analyze quantitatively the effectiveness of TACAMO communications.

## Design and Development

The Airborne Transmitter Monitoring and Recording System (Fig. 7) is a small, compact, multimodular system that contains a flight-certified recorder. It is designed with one of the modules functioning as the central processor and cartridge tape control, while four other universal module slots can operate autonomously, with common facilities available to them for time, intercommunications, and recorder access. The system is designed to use high-performance microprocessors and high-capacity static random access memory that can be operated with battery backup to preclude the loss of data when power is off or has failed.

Three different types of module have been developed for the system. One, the control interface module, is used for cartridge tape control and data formatting as well as system control and generation of time of year. The analog interface module is used to monitor the VLF transmitter output and to record the parameters required for later analysis. The third

**Figure 7** — Simplified block diagram of the Airborne Transmitter Monitoring and Recording System.
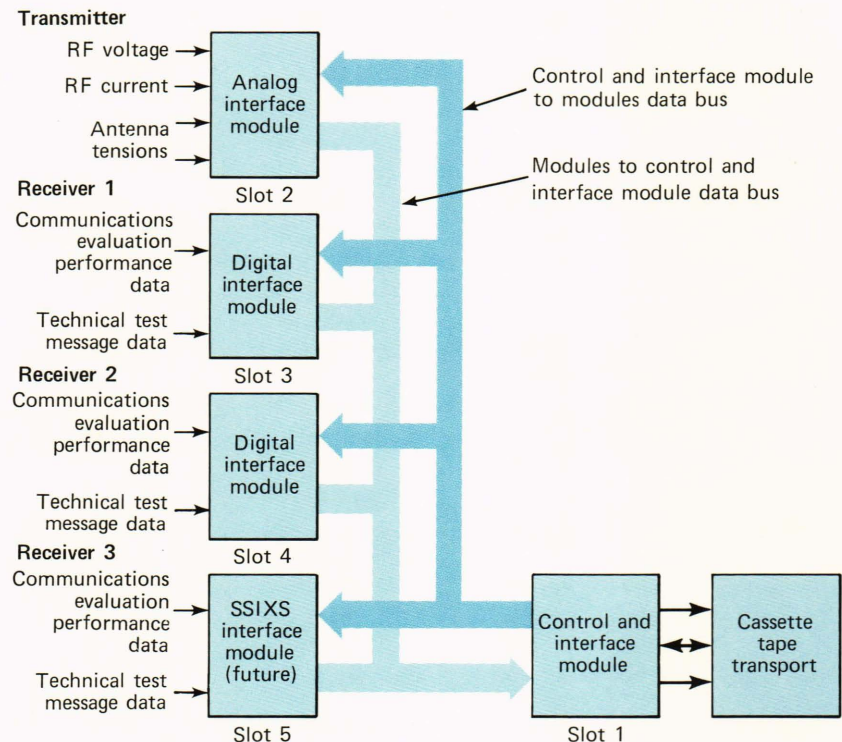
module, called a digital interface module, is still undergoing development testing. It can interface and monitor up to four digital communications channels simultaneously. The module operates, depending on its operational software, as the processor interface for processing performance data or in an error-rate measuring function when used with special test messages. It can also accept up to eight analog signals for separate data collection requirements. Thus, the digital interface module alone can interface and collect performance data from such very versatile communications systems as the Verdin system.

All of the microprocessors used in the Airborne Transmitter Monitoring and Recording System are commercially available, high-performance microprocessors that permit a wide range of applications. For development of operational modules for the system, a standard design was adopted as a universal module. That is, the microprocessor hardware, address decoders, buffers, memory, etc. are configured exactly the same on each module. The difference between operational modules is the interface with the outside world and the necessary peripheral hardware and sensors to accomplish a given task. Thus, the design of modules for new tasks is partially complete, including computer cards for the wiring. Wire-wrap technology was adopted in the airborne transmitter monitoring and recording system because of the high density of parts and the limited number of systems to be built.

During development of the electronics, very large scale integration technology was advancing to the extent that it was possible to obtain static random access memory chips that provided large amounts of memory in a small space. These chips draw extremely low current in their quiescent mode and function well with battery backup when power is off.

## Equipment Description

The Airborne Transmitter Monitoring and Recording System is contained in a single aluminum case having a power switch as its only operational control. A light emitting diode on the front panel indicates when power is applied and when all power supply voltages are correct. The system has been designed to be completely automatic. Inside the front panel, a display is used for test and initialization. A selector switch permits a data terminal interface to address any of the module slots in the system. The system as it is now used contains only two operational modules: the control and interface module used to generate system timing and to control the cartridge tape recorder, and the analog interface module used to interface the VLF transmitter's RF antenna voltage and current sensors to provide the measurements to be recorded. The analog interference module also measures and records the phase angle between the voltage and the current. It also checks and records the wire tension of both the long-and short-wire antennas. A check is made for harmonic distortion in the transmitter output. The measurements are processed, and the module forms data records in the random access memory. When the memory is full, the module(s) transfers the formatted data record in memory to tape via the control interface module and the digital recorder.

Each module in a system is used to interface with the system to be instrumented and can make all the desired measurements autonomously. The modules collect, preprocess, and form data records in random access memory. When the memory is full, the modules gain access to the digital recorder and dump their memory to tape in a formatted data record.

## Testing Status

All operational tests have been conducted using Fleet Air Reconnaissance Squadron Four aircraft from the Patuxent River, Md., Naval Air Station. The flight tests were conducted in an operational aircraft, and the data collected indicated that the module design was highly satisfactory. The first operational flight for development testing was made in August 1981. All of the test data were evaluated, and the system performed flawlessly.

## SUMMARY

Both data collection systems are reliable, versatile, and easily adaptable to changes in operational requirements and new performance parameters. The advent of the standard universal microprocessor module enhances development of new functional modules easily and inexpensively, with software development being the key factor.

NOTE

[1] "Verdin" is the U.S. Navy communications system that is used in very low frequency and low frequency bands to provide multichannel and multimode capability for submarine broadcasts. It combines quadrature phase keying with high-resolution signal processing to achieve usable results under extremely poor signal-to-noise conditions.