THE MICROPROCESSOR AND THE MINICOMPUTER FOR EARTH TERMINAL AND NETWORK CONTROL

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ABSTRACT

The capability of modern satellite earth terminals has increased, expanded, and benefited from the development and application of both microprocessor and minicomputer components. Microprocessors with intrinsic low cost and capability limited only by the imagination of engineers are now key components in the fundamental communications performance of earth stations. These components are now an integral part of antenna, modem, multiplexers, status and control, and communications control hardware.

The concepts of unattended earth stations, remote controlled earth stations, and smart earth stations would not be practical without the availability of microprocessor and minicomputer components.

Earth station network control concepts have been developing over the last five years to solve the issue of increasing the utilization of large capital investment in Satellite Communication(SATCOM) systems. The ability to double the communications capacity of a SATCOM system without adding new satellites or earth stations has been proven. Small minicomputers integrated into earth station configurations have made this possible.

Microprocessor and minicomputer technology will continue to play an increasingly important and key role in future earth station hardware design and capability.

This paper describes some of these applications and speculates on the future role of those components in earth station hardware.

INTRODUCTION

Figure 1 is a block diagram of a typical satellite communications earth station. The earth station equipment consists of an antenna subsystem; RF equipment subsystem consisting of low noise amplifiers, high power amplifiers, and up and downconverters; baseband equipment subsystem consisting of modems and multiplexing equipment; and status/control.

The antenna subsystem, low noise amplifier, downconverter (i.e., the receive subsystem), and the upconverter and high power amplifier (the transmit subsystem) are the main elements that determine the G/T and EIRP of the earth station. The baseband equipment processes the data or voice signals into the desired format for transmission (or reception) by the RF and antenna subsystem.

With the large growth in satellite communications systems, the increasing complexity of earth station equipment (particularly in the baseband systems), and the high cost of operation and maintenance personnel, a twofold problem has developed: the need for efficient management of the earth station resources, i.e. , the ability for the station operator or the network controller to know the state of each equipment and the ability to control them, and secondly, the costly implementation of complex baseband equipment such as multiplexers and modems. By providing a system for effective management of the earth station, the concept and meaning of network control discussed in this paper can become a reality.

In concert with the goal of network control, real-time adoption of communication throughput, and efficient use of satellite resources, smart modems and multiplexers are required. Fortunately, both these system and equipment issues can be resolved with the introduction of the microprocessor (MPU) and microcomputer into the design of earth stations.

Figure 2 depicts the areas in the satellite communications earth station where minicomputers and microprocessors are utilized. These are discussed in further detail.

Status and Control Consoles

Earth stations in the past emphasized hardwired logic and analog interfaces for status and control of the terminal. Manual controls at the control console normally were hardwired to the equipment to implement somewhat limited central control capability by the terminal operator. Status reported to control consoles at the earth station would include a variety of contact closures, voltage levels for on/off and failure alarm indications, and analog servo interfaces for manual control of the terminal antenna. It is common for status data to require processing prior to display. For example, an alarm indicating a failure of an online high power amplifier (HPA) would be critical, whereas the failure of a standby offline HPA would be non-urgent. Any such conditioning of status inputs has frequently been implemented with hardwired logic in the console. Thus, changes to station configurations (adding or deleting equipment or changing equipment configurations) could require rewiring and electrical modifications to the station control console. Processed status would be displayed on a light panel, with a minimum amount of data being recorded for history logging purposes or for remote monitoring of ground terminal condition. Centralized control of a cluster of earth stations would rely heavily on manual coordination and verbal enhancement of the limited amount of status reported to a System Control Center (SCC). Real-time centralized power control on a link-by-link basis (to compensate for atmospheric-induced fades, equipment performance degradations, jammer interference, etc.) was not possible.

With the advent of reliable, low cost small scale computers, processing equipment began to phase into ground terminal implementations. The Air Force Satellite Control Facility and NASA STADAN and DSN tracking stations were among the first applications of computers to perform not only data and telemetry processing but also station equipment control. Initial uses included preprogrammed control of the antenna during the acquisition mode, and the collection of selected status for display on a cathode ray tube (CRT) display. Status processing capability in the minicomputer meant that changes in processing logic (due to equipment reconfiguration) could be easily accommodated through software modifications. Display formats were developed to permit the operator to access and understand an order of magnitude more status information than before. This would not be possible if only light panels were available. Original implementations primarily limited the use of the onsite processor to display generation, antenna acquisition pointing, and command transmission to the satellite (tracking stations). Telemetry data could also be recorded on magnetic tape and relayed back to a central site.

Present earth terminal implementations rely heavily on processing equipment to permit maximum automation, resulting in minimum operator attention. Further, centralized control of multiple communications earth station configurations is now possible to maximize the utilization of system resources (HPA power at each site, uplink data bandwidth, satellite downlink power, etc.). Extensive use of <u>intelligent</u> components at the earth station as well as at the System Control Center provides this capability for automation. Modern earth stations include minicomputers and/or microcomputers to support control console operation. Figure 3 shows a simplified block diagram of a NATO III earth terminal built by Ford Aerospace.

The processing elements at the earth station include redundant minicomputers and peripherals for station control, and a microprocessor for the system control center interface. Characteristics are:

Minicomputers

a. Quantity: Two(one in standby, automatic switching if online system fails)

b. CPU throughput; 350K instructions per second (KIPS)

c. Memory: 192K bytes, fault corrected

d. Word size: 16 bits

e. Peripherals:

1. One maintenance CRT/keyboard with cassette tape reader and microprocessor controller.

2. TWO color CRT/keyboards with microprocessor controller.

3. Analog/digital converters.

Microprocessor

a. Quantity: One

b. CPU throughput: 250 KIPS

c. Memory: 4K bytes RAM, 4K bytes EPROM

d. Word size: 8 bits

e. Interfaces: 9600 baud, RS-232C, asynchronous: 600 baud, RS--232C, syncrhanous

The minicomputer performs analog to digital conversion on 400 discrete status inputs and, by Boolean processing of the discrete status, is able to rapidly detect anomalous alarm conditions. Measured parameters can be processed to detect degradations beyond preset thresholds. The minicomputer includes algorithm for automated control of the equipment without the need for human intervention. Typically 200 control commands of various types may be provided. At a communications earth terminal the processors control carrier level on an individual link basis, HPA power level, modem data rate, multiplexer channel selection (individual control of channels on/off, interface mode), and connectivity. Redundant equipment strings can be placed on line automatically upon detection of a critical hard failure or detection of a significant performance degradation. Further, the onsite computer provides status to, and can receive control commands from, the SCC. Thus, the station can operate under the control of an operator at the earth terminal automated control console (see Figure 4), or under remote control from the SCC. Site personnel are still required in the remote control mode to resolve anomalous conditions and to maintain equipment.

A function not normally subject to remote control is antenna pointing. The station minicomputer is provided with extensive antenna control capability, including servo mode control (scan, slew, autotrack) as well as pointing angle control during acquisition based on velocity and acceleration curves programmed in software. Sophisticated steptrack tracking techniques are employed based on measurement of the received beacon level. By sampling the beacon at a reasonably high rate (10 samples/second or higher) and averaging in the processor over 2.5 seconds or more, changes as little as 0.25dB can be detected and used to position the antenna (independently in azimuth and elevation). Pointing accuracy under software control is better than 0.01 degrees per axis.

In addition to automated control, reported status must be processed and significant events logged on magnetic storage media (disk or tape). This can occur at the central SCC, since all pertinent status data is transmitted to the control center. In the NATO SATCOM program, each of the 21 earth terminals reports status as follows:

a. Total transmit power, system noise temperature, beacon power level, receiver gain: once/2 seconds.

b. Received E_m/N_o once/4 seconds

c. Hardware status: once/8 seconds

   1. Six parameter values
   2. 350 discrete statuses

Status can be processed by the SCC minicomputer to report all hardware failures as well as record instantaneous and hourly averages of:

a. Transmit carrier level

b. Received E_m/N_o

c. Total transmit power

d. Received beacon level

e. System noise temperature

f. Receiver gain

In addition to providing data for historical recording of status and the use of status in the automated control algorithms, at the SCC the earth terminal minicomputer filters and formats status data for presentation at the control ccnsole display device. This is an intelligent terminal capable of supporting display generation in eight colors, as well as supporting the preparation and full editing of input messages from an operator to the minicomputer.

The station status and control processing elements in future earth terminals will rely more and more on microprocessors and high density, low cost memory. The earth terminal transmit and receive equipment will be provided with chip level microprocessors interfacing via an automated bus to the main station processor for equipment status and control. This will permit the equipment to provide more status, at higher rates, than is currently possible. The microprocessor chips on the equipment side will not require a separate printed circuit (PC) board; they will be packaged along with, and as part of, other uplink and downlink equipment components and circuits.

The functions of the station minicomputer will be distributed among several powerful microcomputers. By 1990 it is expected that throughputs of 1000 to 1500 KIPS per microprocessor will be commonplace, making them fully competitive in processing speed with current day minicomputers.

The microprocessors will be packaged two per PC board, with redundancy switching circuitry on the board. Thus, CPU component failure protection will be provided resulting in extremely high availabilities. Although microprocessors using 32-bit wide word widths will be common, many applications will only require the less complex 16-bit implementations. The microprocessors will be packaged on one printed circuit board along with interface circuits and 128K to 256K 16-bit words of high speed, fault connected memory (a combination of ROM and RAM). Additional high speed memory boards could be provided if required; however, it is more likely that additional memory would consist of another printed circuit board with several megabytes of slower speed memory. This solid state slower speed memory would serve as a mass storage media for the site data base (i.e., disk and tape drive replacermnt). Access times of several milliseconds would be an order of magnitude faster than a rotating disk, but would have none of the reliability problems of an electromechanical device. Slow speed storage implementations using such techniques as bubble memories are within the current state of the art. Mass storage capability for status data will not be necessary since all status to be recorded will be reported to the System Control Center in real time. The cost for the high speed microprocessor CPUs and very large high performance memories should be in the range of current microprocessor costs within 10 years (after normalizing for inflation costs).

As mentioned above, several high capacity microprocessors will replace the current station minicomputers. Since they are compactly packaged, the printed circuit boards will be placed in equipment chassis wherever convenient. Typically one microprocessor system will be allocated the data collection and dissemination function (including analog/digital converter control), one microprocessor will be responsible for display generation and processing of keyboard inputs, and one microprocessor will contain the data base (mass storage) as well as communications interfaces to the System Control Center. The varied assignments of functional responsibility will be readily accommodated by off-the-shelf operating systems and support software expected to be available in the next 10 years. No longer will it be necessary to program in assembly language or use high order languages with inefficient compilers. Efficient Fortran, Pascal, and ADA compilers will allow minicomputer programmers to easily transition to the programming of microcomputers. The microprocessor implementation above is expected to result in a cost savings per station of at least 500% over the equivalent minicomputer implementation.

Remote Supervisory Control Hardware

With the advent of the microprocessors, remote status and control of satellite earth stations is being achieved with supervisory status/alarm and control subsystems.

These subsystem are presently being implemented in various forms by different earth station suppliers and are also available commercially.

A typical state-of-the-art supervisory control and data acquisition system (SCADA) available from Granger Associates can provide the building blocks for a customized status and control architecture for any earth station.

A multilevel order of hardware intelligence is employed to ensure the required security and error detection for the effectiveness of unattended operation.

The application of the SCADA ranges from a single master unit in a remote terminal to a host minicomputer at a master control station supervising the operations of many regional master units, each of which may have up to 56 remote units with up to 256 single functions each.

The basic building block is composed of component cards operating under the control of a 6800 microprocessor. A standard chassis consists of the MPU card, power supply, alarm function and modem cards, and 16 optional slots for status acquisition and/or control function. Each optional card can service 16 analog or digital functions.

The master station sequencially interrogates the remote stations for indications of changes of input conditions. Each remote station responds only to its address code. Communications between the remote and master units are accomplished via voice grade modems with single channel full/half duplex operation, and FSK modulation is used. Data rates can range from 300 to 2400 bauds. Error detection is provided by the use of a BCH code.

Remote control and status reporting may be viewed by a computer controlled CRT monitor with a keyboard for selected status viewing and control command entry.

All control functions require that the command control operation be verified by the remote and an execute command message from the master be transmitted before the control function is completed.

Ford Aerospace has recently completed a design of a large unattended TT&C earth station utilizing the Granger System 8000. A simplified block diagram is shown in Figure 5.

In operation the supervisory network performs both monitoring and control functions. For the monitoring operations, status/alarm information from the monitored equipment is received by the remote units. Each remote unit is sequentially interrogated by the master unit for the current status/alarm status. The status information is then serially formatted and routed to the earth station computer where the data is stored in data base records and also redirected to the computers. Display of the status/alarm information is accomplished by means of intelligent color graphic terminals. Graphic terminals are located at the master command station to monitor the equipment status at all earth stations in the network.

Earth station equipment control operations are initiated at the graphics terminals. In normal operations, configuration control commands are entered at the terminals located in the master control station. The command is then routed to the respective earth station computer and onto the master supervisory unit. The master unit addresses the appropriate remote unit that activates designated relays to set or modify the earth station configuration. Although the primary mode of operation is to control the earth station from the master control station, each earth station can also be configured by its own local supervisory graphics terminal if the need for the backup operation arises.

Future designs of earth stations will carry the above described supervisory status/alarm and control subsystem even further. All earth station equipment will be designed and implemented with built-in smart MPU control and data acquisition capability.

The remote control and status interface in the equipment will become a part of the total network control system and will operate over a standard network control bus system.

Unattended Earth Station Bus Hardware

The advent of the microprocessor and its wide applications as an imbedded hardware component has given a new connotation to the term bus. Today it is not the connection line for the distribution of signal, power, mid ground, but a system of interconnecting microcomputer components or subsystems. Only in the context of system use is a particular bus understood. At the board component level it is the connection of devices, at the backplane level it is the connection of boards, and at the network level it may be the connection of equipment to a computer or computer to computer.

In any context related to microcomputers it is the method of transfer of information, be it address, data, or control. This method takes many forms but to be useful within a system, a standard interconnect must be established. From this point the system designer may develop his architecture and select his components from the product line of many manufacturers supplying “bus compatible” equipment.

The unattended earth terminal context of bus structure is one of interconnecting equipment for the monitoring and controlling of all functions with no human intervention. To date there is no universal standard and each system is at best similar.

Current earth terminal equipment is not designed with standard interfaces for remote control and status/fault reporting. The problem of how this interfacing is to be accomplished is decided by the terminal system designer. Many types of interfaces must be accommodated (analog and digital, relay contact, serial and parallel) with only point-to-point wiring between the supervisory unit and the terminal equipment.

Four basic methods of interconnect networks have been used: nonstandard point-to-point, loop, party line, and standard point-to-point. The most common is the nonstandard point-to-point (Figure 6) due to the wide range of signal types currently used in earth terminal equipment.

The nonstandard point-to-point network consists of a one to one wiring for each signal and must accommodate any of the many types of signals. Equipment with many status/control points requires many lines and may even be limited by connector space. Software overhead for this type of network is low.

The standard point-to-point network is similar to the nonstandard except for the requirement of the terminal equipment to convert the many different types of signals to one standard type. Thus, all interconnect lines would conform to the standard interface -- TIL, RS232, IEEE 488, or what the selected standard is. The software overhead is low, but implementation is difficult with existing equipment because of the required signal conversion.

The party line network interconnects all equipment in parallel on one bus driver/receiver circuit. All equipment must have the common circuit designed in, or an intermediate device to encode and decode the signal line interface to those required by the equipment. The software overhead for management and data protocols is high and the network can communicate only in the half-duplex mode.

The loop network connects all equipment in series and communication is undirectional around the loop in a half-duplex mode. Here also, a common circuit must be designed into the equipment, or an intermediate device must intercept for the equipment. Each equipment must be able to be removed from or insert itself into the loop (physically and electrically) without breaking or disturbing the loop. Higher software overhead is involved than is any of the other three methods. The current method of unattended operation of earth terminals is the use of the nonstandard point-to-point network with either commercial supervisory systems or custom design for each terminal in a system.

The network buses most common in earth terminals are the RS232 and IEEE 488, which provide serial communications and parallel test equipment interfacing respectively. A standard network bus for the total status and control functions of all terminal equipment does not currently exist. The major change in earth terminal network buses will be the addition of microprocessor controls designed into terminal equipment to provide remote status/control functions on a common bus structure.

Demand Assignment Multiple Access (DAMA) Equipment

Single channel per carrier (SCPC) emerged in the 1970’s as an excellent low cost communications technique for domestic satellite systems. To take full advantage of SCPC communications in satellite networks, the demand assignment multiple access technique (DAMA) is employed to optimize the use of the available satellite power and bandwidth capacity. The emergence of microprocessors coincided with the needs for DAMA systems, Thus, microprocessors become the major components of satellite earth station DAMA systems.

Figure 7 is a block diagram of a DAMA system developed by Ford Aerospace. The DAMA system primarily serves the domestic type satellite communications networks using SCPC modems to pass telephony traffic. The function of the DAMA system is to assign frequencies to the SCPC modems when the need arises. To do this, the DAMA system must detect the telephone call origination request (offhook), determine the call destination (dialed telephone number), search for the available satellite frequency slots, and assign the frequencies to both the origination and the destination station SCFC modems. These functions are distributed between DAMA equipment at the remote stations and the master control station. The remote station DAMA equipment is composed entirely of microprocessors while in the master control station, microprocessors and/or minicomputers are used.

At the remote station, the DAMA equipment consists of a terrestrial interface processor (TIP) for each traffic modem and a system interface processor (SIP) for each station. The TIP interfaces with the terrestrial circuit, the SCPC modem, and the SIP. The TIP is designed and programmed to be compatible with the signaling scheme of the incoming terrestrial telephony circuit. With originating calls, the TIP receives the entire telephone number before requesting service from the SIP. The SIP formats the message and transmits the message to the master control station.

The master control station, based on the destination telephone number in the message, identifies the destination station. The master control station also selects a pair of available satellite channels and assigns these channels to both the originating and the destination stations through their respective SIPs. The originating station SIP passes the frequency assignment to the originating TIP, which in turn commands the corresponding SCPC modem to turn to these frequencies.

The destination station SIP, after receiving the frequency assignment and the destination telephone number from the master control station, selects an appropriate TIP to accept the call. The selected TIP then assigns the frequencies to its corresponding SCPC modem. After the originating and the destination station SCPC modems have established connections, the TIP passes the signaling information to the terrestrial circuit. At the end of the call, each TIP reports to the master control station via the corresponding SIP so that the master control station can place the satellite channels back into the unused pool.

The use of a microprocessor enables the TIP to monitor the call progress, provides proper signaling interfaces, and permits the recording of elapsed time for billing. In addition, telephone number discrimination can be programed into the TIP, such that each TIP can serve specific trunks.

Although the functions of the tip and the SIP are different, their hardware circuitry is almost identical. Each TIP and the SIP cards are 4-1/2 by 9-1/2 inches. A standard 5-1/4 inch chassis can hold seven of these cards plus the power supplies as shown in Figure 8. Using PC boards, the chassis can hold 15 cards to accommodate up to 14 SCPC channels (14 TIPs) plus one SIP.

Each card is composed of approximately 30 IC components, including a 6800 Series microprocessor CPU. Without the microprocessor, it is estimated that approximately 200 discrete DIPs on four such PC cards would be required to perform the same functions. As more advanced microprocessors become available, the IC count would be drastically reduced. It is projected that in the late 1980’s, only a few ICs would be incorporated into the respective SCPC modem. Thus, the microprocessor would be truly a component of the modem. Table 1 summarizes the microprocessor application in DAMA systems.

Antenna Control and Tracking Equipment

The servo control and tracking hardware perforns the function of accurately controlling the beam of the antenna toward the satellite to minimize signal loss. The satellite earth station antenna control panel usually includes operating mode selection switches, fault indicators, position, and velocity controls. Previously, the mode selection and fault logics were implemented first with relays, and later with discrete logic circuits. Although these logic operations are relatively simple, the trend is to replace the discrete components with microprocessors for reason of cost, simplicity, and flexibility. With antenna systems using the steptrack autotracking technique, the microprocessor with an A/D converter also performs the tasks of integrating the received signal level, comparing ths signal levels before and after each antenna step, making the decision as to which direction the antenna should move next, and in some cases, controlling the movement of the antenna. The microprocessor is also used to store antenna pointing information as function of time and to direct the antenna accordingly in program track mode of operation.

Figure 9 shows the antenna control microprocessor based servo control circuit card showing the microprocessor and A/D circuitry. This card along with a simple antenna control panel combines the functions of the old standard antenna control panel and antenna position ,display panel, with extra functions, such as a 24 hour program track, 72 hour special reacquisition, and automatic modem switching.

The use of a microprocessor in an antenna control panel reduces the parts count, thereby increasing reliability and reducing cost. A microprocessor inherently allows the use of memory that enables the antenna control to store ephemeris data and to track on such stored data in the event the normal tracking data source is disabled. Thus, the use of a microprocessor can reduce the size of a chassis or enhance its capabilities.

The microprocessor also adds flexibility. Changes can be made in the operation of the panel by changing the operating program residing in read only memory (ROM). Thus, changes can be made to conform to new customer requirements or to adapt the sane hardware for many different customers by merely reprogramming and/or replacing a ROM.

As the state of the microprocessor art improves, more functions will be incorporated into fewer ICs, such that four or five ICs will replace the 35 or so ICs used in the digital portion of the microprocessor based antenna control illustrated here.

RF Hardware

The inclusion of imbedded microprocessor components in RF hardware has greatly increased the fault monitoring and diagnostics capability. An important benefit is the reduction of circuitry that was necessary to perform these monitoring and control functions which in the past have been implemented via relays and logic circuit. The cumulative benefit is one of improved technical performance, less circuitry to improve reliability, smaller equipment size, and lower cost.

Modem and Multiplexer Hardware

Digital signal multiplexing and modulation functions in the earth station have probably been the most impacted by microprocessor components.

A simplistic description of the multiplexer function is that it converts parallel digital streams into a single multiplexed digital stream and the reverse function for the demultiplexer.

The modem takes data from the multiplexer (as a computer or a terminal device) and converts it into signals for transmission to the earth station RF equipment(or over telephone lines). Demodulation reverses that process.

In recent years digital processing has gained increasing ground in replacing analog transmission. Digital circuitry is implemented either in hardwired logic components or in the form of custom designed large scale integration (LSI) circuits. Such LSI circuits can be regarded as special purpose digital processes. With the availability of the microprocessor, a low cost general purpose digital processor has become available. Figure 10 is a block diagram of a low speed modem utilizing the Motorola MC6860 chip. The MC6860 modem interfaces with an MC6800 MPU based system via an MC6850.

The design of a software controlled hardware yields a very flexible system, By means of software modification, important functions such as modulation spectrum shaping and demodulation can be programmed. With the rare powerful bit-slice type of MPU available today, inplementation of high speed data modems and signal processing can be realized.

A high performance microprocessor based system Intel 2920, for processing analog signals in real time, is now available from Intel. Figure 11 shows the functional block diagram of the 2920.

The 2920 is a totally self-contained processing system that contains both analog and digital circuit on a single chip. The ship is a general purpose device that can be used as a single chip system or as a combination of several 2920s. The 2920 signal processor (Figure 11) is a complete real-time, digital signal processor. It provides A/D and D/A converters, a high speed MPU, RAM and EPROM memory, and input and output multiplexers. All the user has to supply is a capacitor, an external clock or crystal, power supply, and voltage reference.

The arrival of the Intel 2920 provides a new approach for signal processing. The majority of signal processing up to now has been realized using discrete analog components. The 2920 can replace many discrete analog components, offer digital accuracy, and save board space.

Summing up the circuit features of the 2920, there are four input channels and eight output channels. A/D and D/A circuits are on the chip. It has 9-bit resolution which mans a 54dB dynamic range. There are 40 RAM storage locations with 25-bit accuracy. The inputs and outputs can handle both analog and serial digital signals, and the outputs can be converted to TTL compatible. The 2920 is a single chip signal processor that comes in a 28 pin package. It requires ±5 volt supply voltages with a typical power consumption of 600 mW. The chip is realized in NMOS technology.

A comparison of digital signal processing vs analog circuitry is summarized below.

• Digital LSI	• Analog Circuits
• Digital accuracy	• Precision components Matching, tracking
• Flexibility thru programming	• Individual design for each application

- Single chip
- Design on development system using software simulation

- Many devices
- Breadboard

Ford Aerospace recently supplied modems and multiplexers for two large digital earth station programs.

Figure 12 is a block diagram of the multiplexer, which is composed of four major elements, each containing a Motorola 6800 MPU. These four elements are the supervisory card, frame sync card, mux memory card, and demux memory and clock output card.

The supervisory card via the front panel coordinates and initiates all action required by the multiplexer.

The three other MPU-based cards process data in real time. The frame sync card extracts the proper frame and changeover information while the MUX and DEMUX cards provide the multiplexing and demultiplexing function.

The multiplex/demultiplexer architecture can operate at an aggregate data rate up to 60 kb/s and accept up to eight channels.

Microprocessors also play a key role in the modem design. One key design issue in very low data rate modems operations in extremely low signal levels is acquisition. This is one problem Ford Aerospace has solved efficiently with a microprocessor controller.

The other modem functions performed in the Ford Aerospace modems were quasi-real-time functions, such as automatic power level control and variable data rate operation.

Ford Aerospace design engineers based their design for modem acquisition circuitry on the Motorola 6802 microprocessor, which has 128 byte of RAM and clock. The microprocessor based acquisition system used a “hill climbing” and “sweep and remember” concept to determine the center of the signal spectrum to be acquired.

An estimated 75% saving in hardware was realized using the microprocessor approach vs IC hardware. With the additional cost of software, an estimated cost savings of 40% was realized. Additional benefits include system flexibility; e.g., modifications can be incorporated without hardware changes and with improved reliability,

CONCLUSIONS

The future trends of microprocessor and minicomputer components in earth stations will expand dynamically.

The following can be expected:

- Earth Stations will become transparent communication network elements.
- Unattended earth station self-sufficiency will be extended, even to self-healing.
- Baseband hardware will dramatically increase the use of microprocessors.
- Every terminal will be networked by minicomputers, even to adaptive network communication functions.
- Earth stations will function like future satellites, as processing communication network nodes through the use of minicomputers and microprocessors.
- Earth station capability will increase and costs decrease.

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Table 1. DAMA Microprocessor Applications

DAMA SEGMENT	MICRO PROCESSOR USED	FUNCTIONS PERFORMED	COMPARISON OF DESIGN APPROACHES		
			1970	1980	FUTURE
MCS PROCESSOR	8809 OR 68000	SYSTEM CONTROL CONTROLS FRE-QUENCY OF TRANS-MISSION FOR Up TO 2000 SEPARATE CHANNELS	1000 IC’s 20 PC CARDS	40 IC’s 2 PC CARDS	10 IC’s 1 PC Card
IF	6800	MCS I/O INTER-FACE: MESSAGE FRAMING AND BUFFERING.	200 IC’s 4 PC CARDS	30 IC/s 1 PC CARD	(PART OF MCS PROCESSOR)
SIP	6802/ 6808	REMOTE STATION I/O INTERFACE: MCS TO REMOTE STATION (CSC/ BCC).	200 IC’s 4PC CARDS	30 IC’s 1 PC CARD	4 IC’s PART OF SCPC
TIP	6802/ 6808	USER TO SCPC INTERFACE	200 IC’s 4 PC CARDS	30 IC’s 1 PC CARD	4 IC’s PART OF SCPC

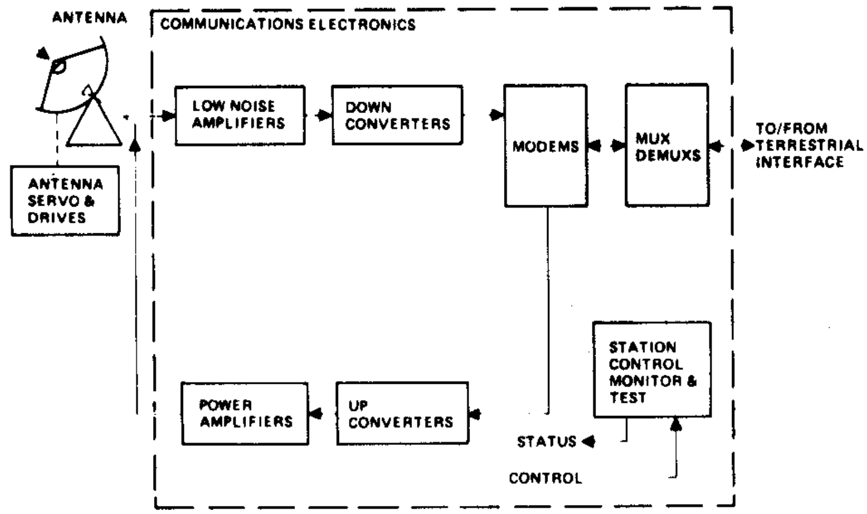


Figure 1. Earth Terminal Hardware

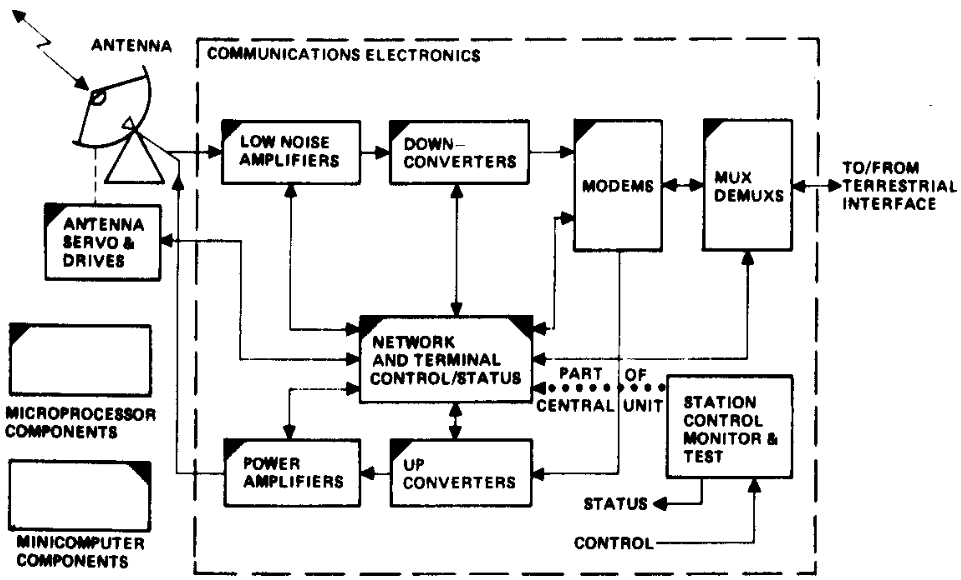


Figure 2. Earth Terminal Hardware Using Minicomputers and Microprocessors Components

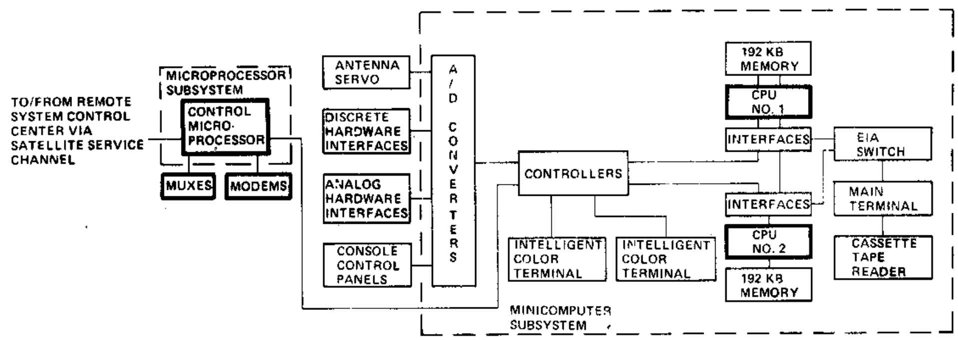


Figure 3. Earth Terminal Processor Components for Station and Network Control (FACC)

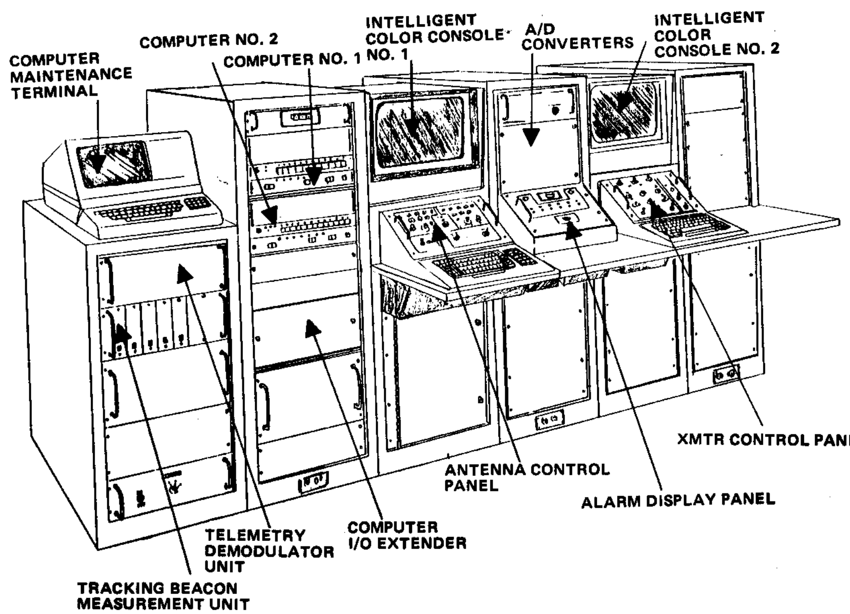


Figure 4. Computerized Earth Terminal Control Console (FACC)

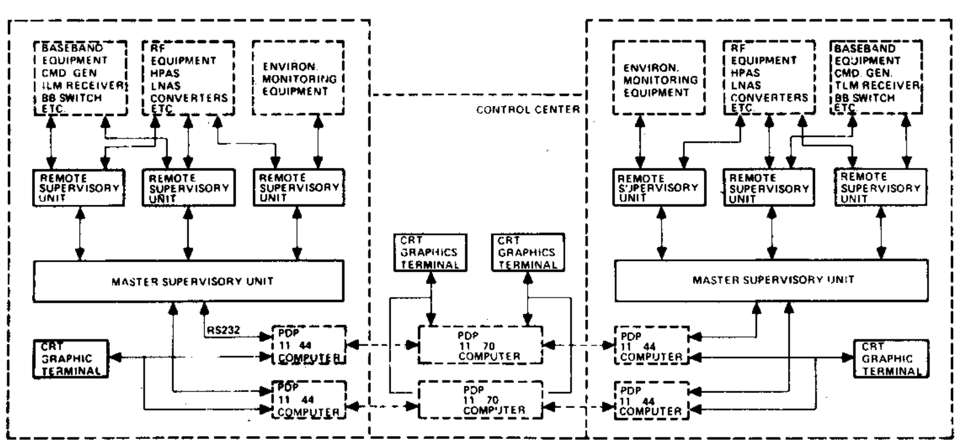


Figure 5. Supervisor Network Functional Block Diagram

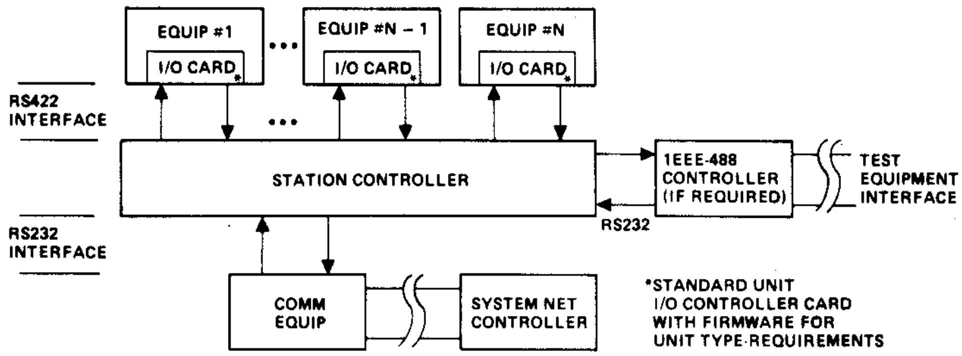


Figure 6. Terminal Hardware Controller via Microprocessors (FACC)

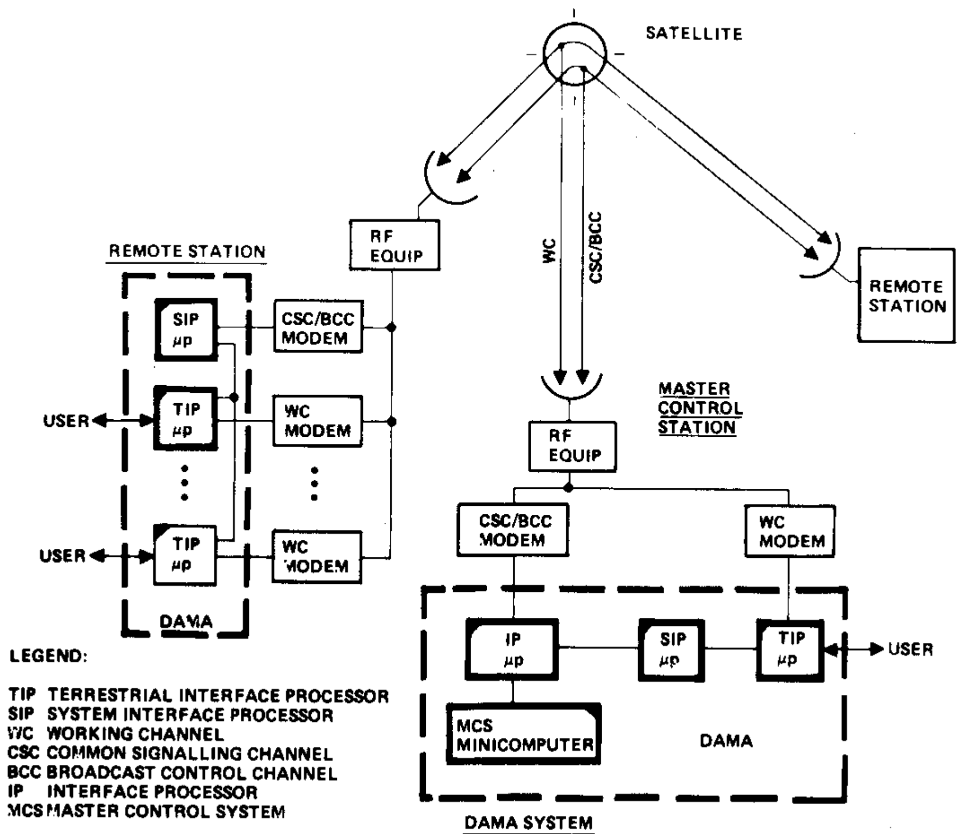


Figure 7. DAMA System

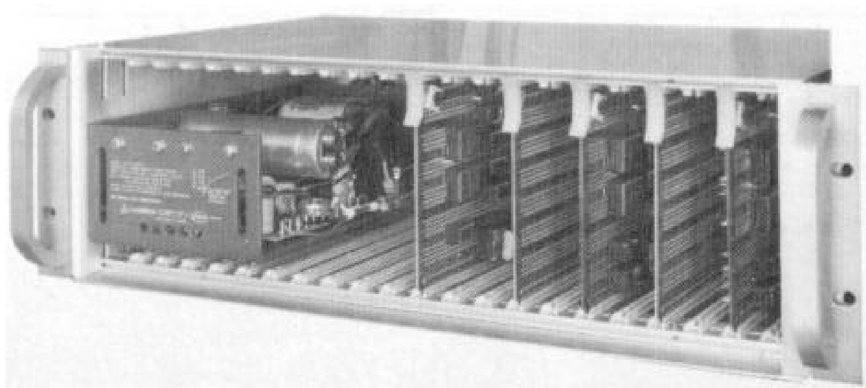


Figure 8. DAMA Remote Station Chassis

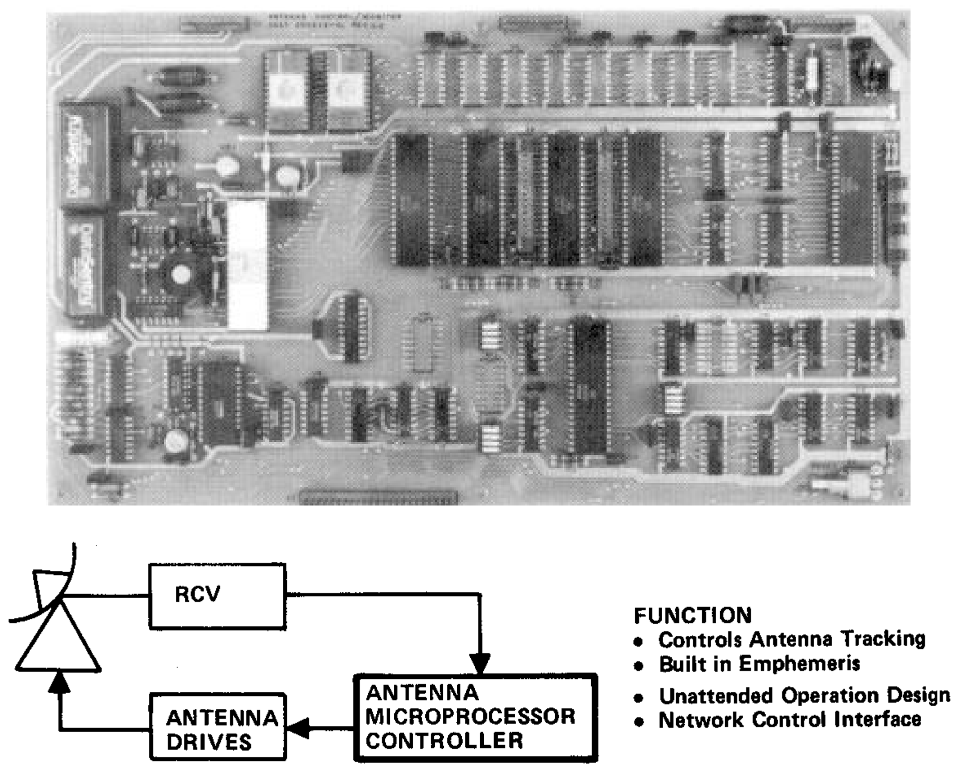
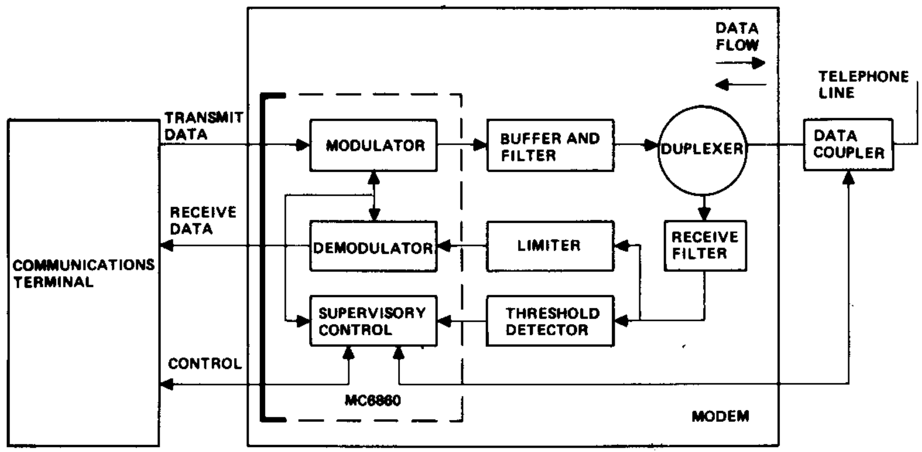


Figure 9. Antenna Control Circuit Board



MOTOROLA'S MC6860 CHIP (DASHED BOX) PROVIDES ABOUT HALF THE FUNCTIONS NECESSARY TO FORM A SIMPLE, LOW-SPEED, FSK MODEM FOR USE WITH THE FIRM'S M6800 MICROPROCESSOR. THE MC6860 TRANSMITS 8-STEP, SYNTHESIZED SINE WAVES AND USES FILTERS ONLY ON RECEIVING.

Figure 10. Motorola's Modem Chip

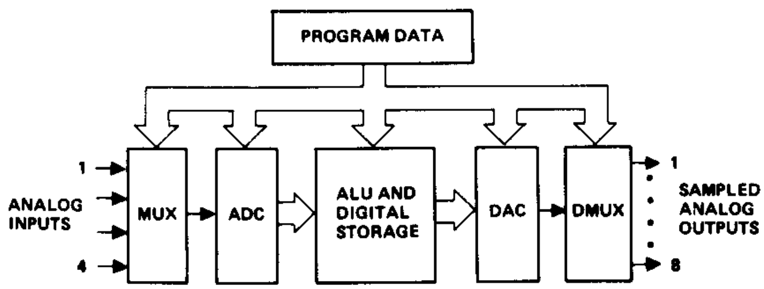


Figure 11. 2920 Signal Processor Functional Block Diagram

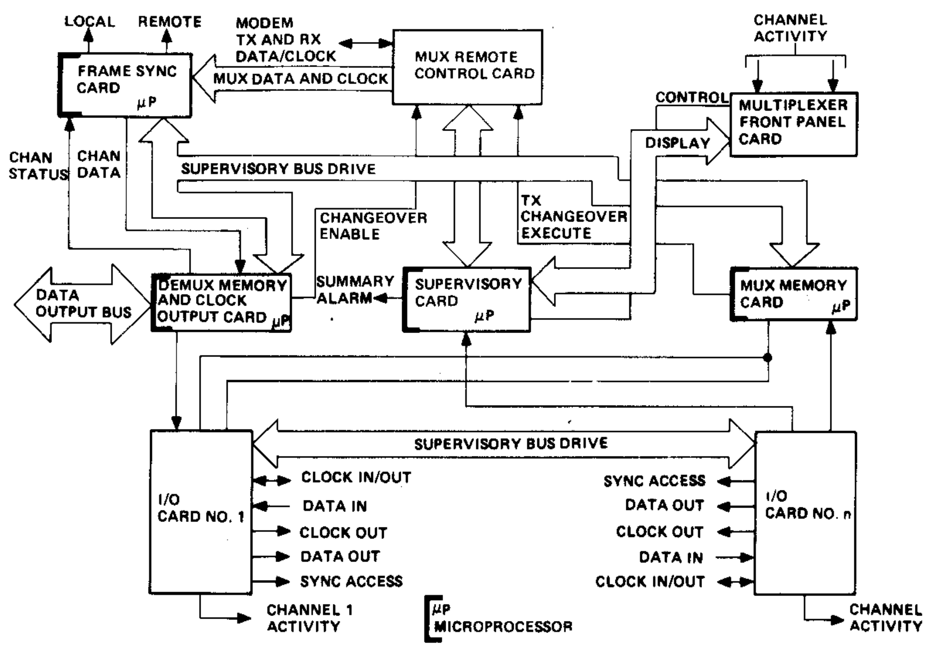


Figure 12. Ford Aerospace Smart Multiplexer Block Diagram