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A DESIGN STUDY FOR A METEOROLOGICAL INSTRUMENTATION SYSTEM FOR --ETC(U)
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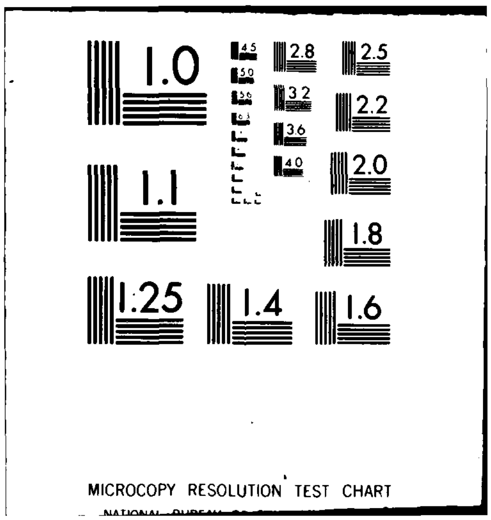
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AUSTRALIA

# DEPARTMENT OF DEFENCE

## DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

## AERONAUTICAL RESEARCH LABORATORIES

MELBOURNE, VICTORIA



Structures Technical Memorandum 332

# A DESIGN STUDY FOR A METEOROLOGICAL INSTRUMENTATION SYSTEM FOR AN OMEGA TOWER

A.K. PATTERSON

Approved for Public Release.





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SUMMARY

A design proposal for a meteorological instrumentation system for the OMEGA tower in South-East Victoria is described. The system includes sensors on booms at five tower levels, and additional sensors at the ten metre level and at ground level, transmitting data by radio link to a computer based data logger located in the Omega buildings. Emphasis has been placed on flexibility, ease of adaptation to different experiments, ease of use, reliability, and serviceability.

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16. ABSTRACT:

A design proposal for a meteorological ins· ·ation system for the OMEGA tower in South-East Victoria is described. · system includes sensors on booms at five tower levels, and additional sensors at the ten metre level and at ground level, transmitting data by radio link to a computer based data logger located in the Omega buildings. Emphasis has been placed on flexibility, ease of adaptation to different experiments, ease of use, reliability, and serviceability.

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## 1. INTRODUCTION

The Omega tower at present under construction in East Gippsland presents a unique opportunity in Australia for long term studies of the first 400 metres of the atmosphere. Of particular interest to ARL is the possibility of acquiring data relevant to low level turbulence and its effect on aircraft operations. Discussions have been held between ARL and a number of other organisations interested in using the tower for atmospheric investigations and the Department of Housing and Construction (responsible for construction of the tower), and the Department of Transport (operators of the Omega station).

As a result of these, the Department of Housing and Construction has designed a retractable instrumentation boom, and funding has been made available jointly from ARL, the Bureau of Meteorology, and the State Electricity Commission for the installation of booms at 5 levels. In view of concern by the Department of Housing and Construction about any increase in tower cross section, an early decision was made that all data from these booms should be transmitted by radio telemetry, avoiding the need for any additional tower wiring. The Department of Transport has also agreed to provide space for recording equipment in the Omega buildings and to perform routine operations such as changing magnetic tapes.

In the following, an instrumentation system is proposed which meets the ARL requirements. However the system is flexible, capable of accepting more or fewer transducers, and can operate at a range of sampling rates which can cover any likely requirement. Number of channels, sampling rates, and sampling formats are all controlled by firmware or software, and can easily be changed. Signal conditioning is proposed which will allow the use of most meteorological transducers.

An outline description of the proposed system is given in the following section. This will be followed by a discussion of the design requirements, a more detailed description of the major subsystems, a description of an optional facility for the control of smoke generators, and a brief discussion of maintenance and management considerations. Cost estimates are given in Appendix A. A listing of tasks involved in implementation and operation of the system is given in Appendix B.

## 2. SYSTEM OUTLINE

### 2.1 System Structure

A block diagram of the proposed system is presented in Figure 1. The system can conveniently be considered in three sections:

(a) Measurement stations, including transducers, signal conditioning, and support electronics.

(b) Telemetry links, which transfer data from measurement stations to the recording station.

(c) Recording station, where the data are operated on as necessary and recorded onto a permanent storage medium, consisting of a small digital computer system using magnetic tape for data storage.

In the following, seven measurement stations are considered, consisting of the five tower booms, one ten metre mast adjacent to the tower, and one ground level station. The five tower booms are at heights of

52m, 136m, 219m, 301m, 342m.

Boom length is 4m. Additional measurement stations could be added, if, say, an array of ten metre masts was required, but would require minor additional hardware in the recording station.

The measurements required by ARL are:

(a) At each tower level,
Wind speed
Wind direction
Vertical wind speed
Temperature.

(b) At the highest tower level, in addition to the above,
Relative humidity.

(c) At the ten metre level,
Wind speed
Wind direction
Vertical wind speed.

(d) At ground level,
Rainfall
Pressure
Relative humidity
Temperature.

## 2.2 Measurement Stations

Equipment at each measurement station can be classified as:

(a) Transducers.

(b) Signal conditioning electronics, which converts each transducer output to parallel digital form.

(c) Data acquisition and control electronics.

The proposed system will accept most types of transducer without difficulty, provided appropriate signal conditioning is provided to interface with the data acquisition and control section.

The data acquisition and control electronics is a digital, programmable, bus oriented system with an address bus, control bus, and a data bus, each of which is routed to all transducer signal conditioning. Each transducer and signal conditioning composite has its own unique address, to which it responds by outputting its current measurement to the data bus, from which it is read by the data acquisition electronics. The control bus is used to select between normal operation and calibrate and self test modes.

As proposed, the address bus accomodates eight data sources, this being the minimum hardware configuration, but expansion is practicable. The data bus is eight bits wide, providing a measurement resolution of one part in 256, which is considered sufficient for nearly all parameters. Where better resolution is required, as, say, with some temperature measurements, two addresses will be allocated to the transducer, one for the least significant eight bits of the measurement and one for the remaining bits.

Wherever practicable it is proposed that each transducer and signal conditioning combination should have a self-contained self test and calibration facility, which can be activated by signals on the control bus. A maximum of eight control bus states is available, one of which, of course, represents normal data.

Data words are read by the control electronics at a constant rate, with the sequence in which readings are taken from the various transducers controlled by a program stored in read only memory. Maximum data rate is about 50 words per second and it is proposed to operate the system at a normal rate of 30 words per second, which would allow, for example, three single precision transducers and one double precision transducer to be read six times per second.

Data collected by this system is organised into frames, consisting of a frame descriptor, which defines the data following, followed by a set of measurement readings in the sequence in which they were taken. Typically, the frame descriptor would indicate whether the following frame contained normal data or self test or calibration data, and would be followed by an integral number of sampling patterns. Thus in the above example, a frame might consist of a frame descriptor followed by 30 data samples, giving a frame period of one second and six repetitions of the sampling pattern in each frame.

Frames of data are output bit and word serially in conventional asynchronous serial line format, each frame being preceded by a break character to allow frame synchronisation at the receiving end of the telemetry link. The formatted bit serial data are then applied to a frequency shift keying modulator to produce a signal consisting of two audio tones for transmission by the telemetry link.

Key features of the above system are the use of address, data, and control buses, and stored program control of sampling pattern and frequency. The former allows the easy addition or removal of data sources and the latter allows the sampling pattern and sampling interval to be easily changed to suit a different transducer array or measurement requirement.

### 2.3 Telemetry Links

Data will be transmitted from the tower by radio, operating in the 1470 MHz band, using narrow band frequency modulation and an input signal bandwidth of about 3 kHz. Transmitter power will be 10 milliwatts. A receiver system at the recording station end of the link will reproduce each of the independent data streams.

Data from the 10 metre mast and ground level stations can be transmitted by either wire or by radio.

### 2.4 Recording Station

The recording station can be subdivided as follows:

(a) Demodulators and preprocessor.

(b) Main processor.

(c) Data storage.

In the first section signals from each of the seven telemetry links are demodulated from frequency shift keyed form to serial binary levels and then decoded from serial line format to parallel form and presented to the preprocessor. The preprocessor is a microprocessor dedicated to servicing the seven unsynchronised inputs and generating from the input data ordered files of data for transfer to the main processor. Included in these data are status and error information, indicating individual word errors, error statistics, calibration and self test data.

The main processor is a small general purpose digital computer whose main functions are:

(a) To select and prepare the data to be stored.

(b) To control the storage device.

(c) To maintain a file of status information which can be interrogated by a remote terminal.

The data available from the preprocessor will normally have a temporal resolution better than required, and typically would be averaged over a number of samples to reduce the quantity of information to be stored. The data must also be blocked into convenient records and files for the output device and appropriate supplementary information appended. As all these operations are determined by software in the main processor a great deal of flexibility is available. Thus while most data will be averaged over a period of, say, five seconds, provision can be made for recording short periods of high speed data, such periods being triggered by the occurence of particular events as detected by examination of the incoming data. Summarised meteorological data can also be recorded for comparison with standard Bureau of Meteorology observations.

The proposed storage medium is magnetic tape, using the nine track 63 bit per mm format. For the transducer array described in 2.1, recording five second averages of each variable, a recording period of approximately 20 days is available on a normal 730 metre tape.

It is proposed that the system be operated with as little intervention by local Department of Transport staff as possible, such intervention being normally limited to loading and unloading of magnetic tapes, probably on a weekly basis, and daily entry of standard meteorological observations. It is proposed that daily observations of barometric pressure, rainfall, humidity, max/min temperatures, and wind be made by Department of Transport staff and added to the recorded data via the main processor.

In order to allow for early detection and rectification of failures, it is proposed that the recording station be equipped with a serial line interface and modem for communication with a remote terminal at ARL over the normal telephone network. A status file containing information on the operation of each component of the system, statistics on error rates, and summarised meteorological data will be maintained by the main processor for access by the remote terminal. A remote terminal also introduces the possibility of some degree of remote control.

## 3. DESIGN CONSIDERATIONS

Some of the factors which have led to the above proposal are discussed in the following section.

### 3.1 Operational Requirements

Significant system characteristics required are as follows:

#### 3.1.1 Flexibility

The system must allow for changes in transducer types, number of transducers, sampling patterns, and sampling rates. The programmable, bus oriented measurement stations and software controlled recording station described above provide a great deal of flexibility in this respect.

3.1.2 Real Time Data

There is no requirement to transmit real time data to ARL or any other remote location. It is sufficient to accumulate data at the Omega site for transfer to ARL or some other body at perhaps weekly or greater intervals. There is thus no requirement for a dedicated land line or radio link from the Omega station to Melbourne.

3.1.3 Down Time

It is not necessary for the recording system to be operational at all times, although the operational duty cycle should approach 100%. It is thus not necessary to provide full hardware redundancy to allow for continued operation during failures and servicing. However prompt indication of failures and good reliability are necessary to ensure a satisfactory operational duty cycle.

3.1.4 Command System

There is no requirement for a generalised remote control system for controlling tower measurement stations from the ground. However there is a possible requirement for the remote firing of smoke generators from each tower level. The proposal outlined in section 2 and elaborated in the following does not cover this requirement, but can be readily adapted to include it. The additions required to do this are discussed in section 7 and costed separately in Appendix A.

3.1.5 Operator Control

The system should require a minimum of intervention by local Omega staff.

3.1.6 Status Reporting

It should be possible to obtain a remote real time status report from the system, containing information on transducer and subsystem faults, error rates, and a summary of recent data collected. This will allow failures to be detected and rectified sooner than would be possible if detection was left to the data analysis stage or to regular service visits.

3.2 Reliability

Reliability is obviously an important factor in the design of a long term remotely operated data collection system. It is particularly important in respect to the boom systems in that, although there is reasonable access to the tower, servicing and trouble shooting on the tower will present considerable physical difficulty. In order to maximise reliability emphasis should be placed on the following aspects, particularly in regard to tower hardware:

Minimum component count
Conservative design
Self contained calibrate and self test
Error detection
Environmental factors.

### 3.3 Environment

Equipment to be used on the tower will be subjected to temperature and humidity conditions beyond the operating range of normal laboratory equipment. Tower equipment should operate under the following ambient conditions:

Temperature: -10 degrees to 50 degrees Celsius, for equipment shielded from radiation heating, with a maximum of 70 degrees Celsius for non-screened and ventilated equipment.

Humidity: non-condensing.

## 4. TRANSDUCERS AND DATA COLLECTION

In the following, the transducers, signal conditioning, and control electronics are considered in detail.

### 4.1 Control Electronics

A block diagram of the control electronics is presented in Figure 2. As described previously, the control electronics communicates with the transducer signal conditioning electronics on address, data, and control buses. Operations on these buses are controlled by a microprocessor, with supporting memory and control logic, which also controls the transfer of data to the telemetry link.

The three transducer buses are all eight bits wide. Both address and control bus are loaded by latches driven by the microprocessor The address bus latch is loaded with a new address for each new sample, and the control logic assumes that the addressed device puts data on the transducer data bus by a time approximately 40 microseconds before the end of the sample period, and then holds the data constant until the end of the sample period. Data are read from the transducer data bus by the microprocessor via the bus receivers. The control bus latch is loaded with a new control word for each new data, self test, or calibrate state.

The microprocessor system will consist of:

(a) Microprocessor.

(b) Read only memory, in the form of an Erasable Programmable Read Only Memory (EPROM) for program storage.

(c) Rand Access Memory (RAM) for temporary data storage.

(d) A Universal Asynchronous Receiver Transmitter (UART) for data formatting and transmission.

(e) Support logic.

The control functions executed by the microprocessor system could be equally well implemented with discrete logic. The reasons for choosing a microprocessor control are as follows:

(a) Reduced component count. A draft design for a discrete logic system yielded a system requiring 22 integrated circuit packages for the control unit, as compared to 12 for a microprocessor control. As cost and reliability both improve as package count is decreased the microprocessor approach has a definite advantage.

(b) Flexibility. Although the discrete design would provide for read only memory controlled programming of address sequence and frame size the microprocessor design allows additional flexibility in timing and control.

A great many microprocessors could be used to implement such a system. However the temperature range required (-10 to 50 degrees C) means that normal commercial and industrial range devices (0 to 70 degrees C) are unsuitable. A limited number of MOS processors are available in the military temperature range of -55 to 125 degrees C, such as the Motorola 6800 and Intel 8080 and some of their derivatives, but the CMOS processors, such as the RCA 1802 and Intersil 6100 have a sufficiently wide operating temperature range in the usual commercial forms, giving them a price and availability advantage. CMOS has the additional desirable features of low power consumption and good noise immunity. In the light of these factors it is proposed to use a CMOS processor and CMOS logic to implement the control system. Of the available processors the RCA 1802 has the most convenient instruction set and more than adequate speed.

A simulated measurement station has been assembled using standard RCA 1802 development system components and software written to test the feasibility of this approach. The results have confirmed the suitability of the proposed system. Software for a typical installation is easily accomodated in a single 4096 bit CMOS EPROM, and RAM requirements can be met by a single 32 word, 8 bit RAM.

Data collected by the microprocessor are assembled into frames. Typically a frame would consist of a number of repetitions of a predetermined transducer sampling pattern, preceded by a frame designator character which defines whether the following data are normal data, self test, or calibration data. The frame designator is the same as the control bus output at the start of the period during which the data in the frame are gathered. This frame designator may be changed during the frame period if desired, for example, if a self test state is required for only part of the frame. An example frame format is presented in Figure 3.

Frames of data are presented a character at a time, to the output UART, which appends the start, parity, and stop bits characteristic of the asynchronous serial line format and outputs the data in bit serial form. The parity bit will be used to detect errors introduced in telemetry. Frames of data are separated from one another by breaks in the asynchronous serial line format, a break being a space or binary zero on the line which persists for more than one character period. These breaks indicate to the receiving equipment the start of a new data frame. Examples of frame and character format are presented in Figure 3.

The microprocessor program, including the sampling sequence and control word sequence, are stored in a single 256 byte EPROM. To allow for changes in software an EPROM eraser and programmer will be attached to the main computer of the recording station. Supporting software for the EPROM programmer can be arranged so that most changes to the measurement program can be effected by simply entering the measurement sequence required. That is, no particular knowledge of the microprocessor instruction set and programming techniques will be required.

## 4.2 Signal Conditioning

As outlined above signal conditioning must interface with the transducer address, control, and data buses. Signal conditioning required depends of course on the particular transducers used, but the following limited set of functions will meet most needs. All must have a parallel eight bit bus compatible output.

### 4.2.1 Integrating Counters

These simply accumulate a count of input pulses, the output being the total count, recycling after a count of 256. They are convenient to use with pulse or pulse rate output devices such as cup anemometers or propellors. For fixed propellors the counters should be up/down counters or allocate one bit to propellor direction.

### 4.2.2 Analogue To Digital Converters

An analogue to digital converter is required for all analogue output transducers. This should preferably be of the dual slope integrating type with resolution and accuracy matched to the transducer concerned. A number of single chip integrated devices are available, such as the CMOS Intersil 7109, which can be used to 12 bits plus sign with commensurate accuracy, and which would meet most requirements. It is considered that one analogue to digital converter of this type per transducer is preferable to a multiplexed analogue to digital converter in this application.

#### 4.2.3 Synchro To Digital Converter

This is another form of analogue to digital converter which would be required for use with a wind vane with synchro output. Suitable synchro to digital modules are readily available in suitable packaging. However extended temperature range devices, probably only available in the -55 to 125 degrees C range, would be required.

#### 4.2.4 Bridge Amplifiers

High gain direct coupled amplifiers will be required for resistance temperature sensors, the outputs of which will be digitised by an analogue to digital converter. Integrated circuit instrumentation amplifiers are proposed for this application, with due attention to packaging and protection.

#### 4.2.5 Power Supplies

General purpose power supplies for transducers, analogue signal conditioning, and digital electronics are required. Supplies for resistance bridges and potentiometer transducers and/or synchros will also be needed.

### 4.3 Self Test and Calibration

Self test and calibration facilities are required where practicable to test the functioning of individual signal conditioning and transducer combinations and verify the calibration of the signal conditioning devices. The general self test principle is to produce a known change in signal conditioning input, if possible by causing the transducer to produce a known change in output. However the degree to which this principle can be implemented and the technique to be used depends very much on the particular transducer and signal conditioning combination. Some particular signal conditioning cases are considered in the following.

#### 4.3.1 Integrating Counters

These are difficult to test completely without excessive hardware. However most failures can be detected by detailed examination of the data, for example, by checking for monotonicity and extreme changes. A test of the output section and bus communication can be effected by arranging for the self test mode to drive the bus to a known state.

#### 4.3.2 Resistance Transducers

These will normally involve a resistance transducer, such as a temperature transducer, in a bridge circuit with an amplifier and an analogue to digital converter. Such systems are conveniently tested and calibrated by shunting one arm of the bridge with a known resistance. A comprehensive test is obtained by shunting in turn opposite bridge arms and then removing the bridge supply to check for zero drift.

#### 4.3.3 Shaft Angle Transducers

Synchro/resolver systems can conveniently be tested by inverting the phase of the synchro excitation, producing a 180 degree change in the output. Similarly potentiometer output devices can be checked by applying a known change in potentiometer excitation. Digital shaft angle transducers cannot be checked directly, but a test of the output stage and bus communication may be practicable.

#### 4.3.4 Status Monitoring

Some status monitoring may be necessary in the self test operations. An example is checking the functioning of aspirators associated with temperature and humidity transducers.

### 4.4 Transducers

The range of possible transducers is large and in some cases a definite recommendation has not been made pending further investigation. As the effects of a transducer change do not propagate further than the signal conditioning stage a final choice does not have to be made at this point. In the following some transducer configurations are considered.

#### 4.4.1 Wind Velocity

Transducers which have been considered for this parameter are:

Sonic anemometer
Vortex shedding anemometer/vane
Bivane and propellor.

While these all have particular advantages it is considered that the best compromise between performance cost, and reliability is offered by a combination of conventional cups and vane for wind measurement in the horizontal plane and a fixed propellor for measuring the vertical wind component.

#### 4.4.2 Temperature

The temperature measurement requirement is particularly demanding. For the determination of lapse rate, temperature differences between tower levels must be measured. This would normally be done by combining sensors at each level in a common bridge to give an output depending on the temperature difference. As this cannot be done in the present situation the temperature sensor signal conditioning electronics are required to have double the stability of offset and scale factor that would otherwise be required. Assuming a resolution and accuracy of 13 bits and a temperature range of 60 degrees C, the signal conditioning will limit the accuracy of temperature difference measurements to 0.015 degrees C.

It is proposed that the temperature sensors should be aspirated platinum resistance sensors. Although aspiration adds additional mechanical complexity and sources of unreliability it is considered necessary for two reasons:

(a) Static radiation shields are not sufficiently effective for lapse rate measurements in low winds.

(b) Both the magnitude and variability of self heating effects in the resistance sensor are greatly reduced, eliminating a source of transducer error and allowing operation with higher bridge voltages, reducing the demands on offset drift in the bridge amplifier.

As the temperature measurements will depend on the correct operation of the aspirators it will be necessary to monitor their operation. This can be done with a pressure or flow sensitive switch or a device for sensing blower rotation, whose status is read during the self test sequence.

#### 4.4.3 Humidity

It has proved difficult to make a clear choice of humidity transducer, and the range of devices available suggests that there is no transducer which is clearly optimal. Some of the transducer options which have been considered are:

Lithium chloride dew point sensors.
Cooled reflective dew point sensors.
Thin film capacitive sensors.
Styrene copolymer resistance sensors.
Wet/dry bulb sensors.

Key factors which have proved difficult to assess are reliability, long term stability, and ease of self test and calibration. It is proposed that further investigation be made in this area, and that trials be conducted with the more attractive systems.

#### 4.4.4 Pressure

Suitable pressure transducers are available from a number of manufacturers. As it is difficult to guarantee the long term drift of an absolute transducer to better than a few tenths of a millibar, emphasis should be placed on proven stability and a standard barometer should be provided at the Omega station for periodic checks of the transducer. A special static pressure head designed to eliminate wind errors will be required. To provide sufficient resolution for the measurement of small pressure changes it is proposed that a 13 bit measurement covering a range of 80 millibars either side of the mean atmospheric pressure be made, although this resolution will greatly exceed the accuracy of the instrument.

4.5 Environmental and Physical Aspects

Some aspects of environmental protection and packaging are briefly discussed in the following.

4.5.1 Electromagnetic Environment

Equipment on the tower may be subject to large transient voltages due to lightning strikes on the tower. While it is impossible to protect against the unlikely event of a direct strike on a boom all input and output wiring will be fitted with protection sufficient to prevent damage being caused by nearby strikes and discharges through the tower.

All measurement equipment will be exposed to strong fields at the Omega frequencies of 10.2, 11.33, and 13.6 kHz. To ensure that these fields do not affect the instrumentation, careful attention to grounding techniques and to screening and shielding of wiring and electronics will be necessary, and all input and output wiring will be filtered. It is proposed that all equipment be tested in equivalent fields in the laboratory before design finalisation and again before field installation.

4.5.2 Physical Configuration

The quantity of electronics required is small, and could be packaged in a volume of a few litres. However in the interests of ease of use and servicing it is proposed to use a standard 482.6 mm card file, with electronics on standard 100 mm by 144.5 mm Eurocard size printed circuit cards, with system buses implemented in a wired back plane. A tentative physical configuration is presented in Figure 4. The housing will include adequate insulation and ventilation to prevent excessive rise of internal temperature or moisture condensation. Input connectors will be shielded from normal rainfall. Total volume will be of the order of 25 litres.

4.6 Power Supply

Standard 240 volt 50 Hz power is available at each tower level. Additional 240 volt power wiring to the electronics for the ten metre mast and the ground level measurements may be required. All electronics will be self resetting in the event of temporary power loss.

## 5. RADIO LINKS

Following discussions with Telecom and possible equipment suppliers a system operating in the 1470 MHz band is recommended.

Each link will consist of a transmitter at the measurement station and an independent receiver at the recording station. The low data rate can be easily transmitted over a standard voice channel, so that standard, readily available transmitters and receivers can be used. The equipment proposed has a bandwidth of three kHz, using narrow band frequency modulation, and an output power of ten milliwatts. Frequency shift keying will be used to encode the data for transmission.

Because of the short wavelength (200 mm) antennae structures are small. Transmitter antennae will consist of quarter wave vertical whips and will have to be positioned on the tower so that they are in direct view of the receiver antennae, and will thus probably need to be separate from the electronics housing. Receiver antennae will consist of quarter wave dipoles in cavities pointed at the tower.

## 6. RECORDING STATION

A block diagram of the recording station is presented in Figure 5. In the following, the processor structure is discussed and the major components are considered in detail.

### 6.1 Processor Structure

A significant feature of the recording station is the proposal to split the data processing between a preprocessor and a main processor. This has been done to separate the time critical tasks of servicing data transfer and other signals from the telemetry receivers from the task of preparing data for permanent storage. This offers the advantages that system software for the main processor will be greatly simplified and hardware and software failures will be easier to locate and remedy.

A consequence of this is that the operation of the preprocessor can be completely transparent to the programmer writing software to prepare data for permanent storage. This software can thus be written using a standard operating system and a high level language. Changes required for a new experiment or change in transducers can be implemented with relative ease.

The preprocessor tasks could be included in the main processor. however when interface problems are considered, the difference in hardware costs is not significant, and more than offset by the savings due to the above advantages.

### 6.2 Data Input and Preprocessor

The output of the data link receivers consists of frequency shift keyed data in asynchronous serial line format. Each such output is first demodulated from frequency shift keyed form to binary levels and applied to an Asynchronous Communications Element (ACE) to convert the asynchronous serial line formatted data to a series of parallel eight bit characters. The ACE also detects the occurrence of breaks for frame synchronisation and detects and signals the occurrence of most transmission errors. Data characters, synchronisation information, and error signals are all transferred to the preprocessor.

In the preprocessor, data characters are organised into data files, one for each parameter from each measurement station, consisting of the sequence of measurements for that parameter with certain status information added to each measurement. The added status information includes bits indicating the presence of communications errors, self test and calibration states, and frame position. These data files will be in the preprocessor memory. They will be transferred to the main processor, using direct memory access, on request from this processor, and will then be overwritten in the preprocessor memory by the next file. A file of communication error statistics can also be maintained by the preprocessor.

The preprocessor tasks are reasonably simple and could be done by most microprocessors. However the Texas instruments 9900 processor is proposed in view of its unique interrupt handling and context switching system which make it particularly well adapted to the task of servicing the data receivers and organising the incoming data into separate files. It also has the added advantage of a 16 bit word. Supporting cross software is in use at ARL. Standard Texas Instruments microprocessor cards can be used for the processor and memory requirement.

### 6.3 Main Processor and Data Storage

In the following, the tasks to be performed are described and the hardware and software requirements are discussed.

#### 6.3.1 Main Processor Functions

The principal tasks of the main processor are to abstract, by selection or calculation, data to be stored from the data files constructed by the preprocessor, and to transfer these data to the permanent storage medium. A small minicomputer system with magnetic tape for permanent storage is proposed for this function. System timing will be derived from the main processor real time clock, with absolute time taken from an independent battery supported real time clock. The task of preparing data for storage is not difficult in most cases and is dependent on the particular experiment. It will not be discussed further, except to note the flexibility provided by the use of a minicomputer.

In addition to the data logging functions it is proposed that the software generate a system status file and a data summary file which can be interrogated by an operator from either a local or remote terminal. The system status file would contain statistics on errors detected by hardware or software and details of apparent failures or anomalies in individual data channels and results from self test and calibration operations. It is considered that this data, supplemented by the contents of the data summary file described below, will allow detection of nearly all transducer and electronic subsystem failures. This should both reduce system down time and the frequency of service visits.

The data summary file is intended to contain sufficient information to allow the experimenter to assess the interest or value of the data recorded in the current magnetic tape. Typically it would consist of statistics derived from the recorded data. It should also be of assistance in detecting transducer and other failures.

As a further aid to failure detection and diagnosis and to data assessment the software will allow for short blocks of data to be output to the interrogating terminal, either as raw data from the pre-processor or data prepared for permanent storage.

### 6.3.2 Data Storage

The proposed data storage medium is magnetic tape, using the 9 track 63 bit per mm format. Storage capacity of a single tape is of the order of 10,000,000 measurements, giving, for example, a recording period of 20 days for a system recording five second averages of 30 transducers.

To minimise system down time, it is proposed that the system be provided with two magnetic tape units to allow continued operation during service and maintenance of a tape unit.

### 6.3.3 Software Preparation

Provision for main processor software preparation has a significant impact on the system configuration. For the system to be adaptable to the requirements of different experiments it is essential that facilities be provided for on site program preparation or change. Two approaches are available:

(a) Prepare software in assembly language and assemble locally with a stand alone assembler, text editor, and debugger. This approach minimises the hardware requirement but is very expensive in programmer time.

(b) Provide sufficient hardware to operate with a standard operating system and high level language compiler from the hardware supplier. Hardware required is increased but software preparation and correction is greatly simplified. This approach is considered to be the most cost effective and is therefore recommended.

A third possibility, namely compilation of high level software on a larger computer, such as the ARL site computer, using a cross compiler, has been considered. This approach would probably be viable for a one off never to be changed experiment, but appears to be too inconvenient if significant program changes are envisaged.

#### 6.3.4 Hardware

The processing tasks are within the capabilities of the low end minicomputers of most major manufacturers. The final choice will thus be determined by pricing details, peripherals, software, and convenience factors, so no firm recommendation has been made.

Total main processor hardware requirement is as follows:

Processor and memory (64 kbytes)
Magnetic tape units, 2 off, with controller
Printing terminal for local use
Serial line interface and modem
Remote terminal and modem
Processor real time clock
Absolute real time clock and display
Preprocessor interfaces
EPROM programmer
Hard disc and controller
Paper tape reader/punch and controller.

The last two items are required to allow local operation with a standard operating system and high level language.

## 7. SMOKE GENERATOR CONTROL OPTION

As indicated in section 3.1.4 there is a possible requirement for a facility for remotely controlling smoke generators. In the following, this requirement is described and possible implementation discussed.

### 7.1 Requirement

Batteries of smoke generators are to be mounted at each tower level and are to be fired under remote control from the ground, either individually or in groups of levels. For each station the firing sequence will consist of an arming command, which selects the next generator for firing, followed by a firing command. A reset command for disarming an armed device is also desirable.

### 7.2 System Outline

The above requirement is readily implemented with a single radio transmitter sending coded commands to receivers at each of the five tower levels. If an eight bit command word is used five bits can be allocated to selection of the levels to be operated on, leaving three bits available for encoding the command to be executed, allowing eight distinct commands. Command words can be encoded to asynchronous serial line format, transmitted, received, and decoded to eight bit parallel form using hardware essentially the same as that described in previous sections. In addition a facility for command entry is required at the recording station and a command decoder is required at each receiver. Protection against errors in addition to that normally provided in asynchronous serial line receivers may be required. Such protection could be provided by requiring two consecutive distinct command words to initiate a firing, or, with more complexity, echoing the command word to the base station for confirmation.

The command system could also be used to control the photographic equipment used to record the movement of the smoke trails. Timing information, which would allow exact synchronisation of the photographic record with data recorded by the recording station, could also be transmitted using the same command structure.

A block diagram of such a system is presented in Figure 6.

### 7.3 System Implementation

The control system is best implemented as part of the main instrumentation system. This allows use of the main processor terminal for command entry and simplifies interactions with the data recording process. Hardware content is minimised by the use of common elements in the encoding, formatting, and data transmission areas.

The control system could also be added at a later date at somewhat greater cost and inconvenience.

## 8. MAINTENANCE AND SERVICING

Some aspects of servicing and repair procedures are discussed below.

### 8.1 Test Equipment

Where feasible test rigs will be constructed to facilitate testing of all transducers and measurement station electronics. These will be kept at the Omega site, together with necessary basic electronic test equipment.

The measurement stations and preprocessor will incorporate provision for signature analysis for fault tracing and appropriate test equipment will be provided.

If desirable some basic test equipment, tools, and spares, can be stored at each tower level.

8.2 Spares

The following spares holdings are suggested:

(a) Transducers: 100%

(b) Measurement, data link, and preprocessor electronics: A minimum of one spare circuit card of each type, rising to 20% spares for multiple use items.

8.3 Service

It is proposed that most failures be detected by interrogation of the system status file and data summary file with the remote terminal, and that such failures be rectified as they are discovered. In addition regular service visits will be required for certain routine maintenance, probably at intervals of one to three months.

Maintenance of the main processor is most effectively done by the processor supplier. To ensure a sufficiently rapid response a permanent maintenance contract may be required for this part of the system.

## 9. PROGRAM MANAGEMENT

For management purposes the program can be divided into two phases:

(a) System implementation.

(b) System operation.

Most aspects of management are considered to be outside the scope of this report and only the following points will be made.

(a) In the interests of both efficiency and the production of good hardware the tasks of hardware development and implementation, software, system integration, and commissioning should be the responsibility of a single organisation.

(b) Emphasis should be placed on good documentation of both hardware and software. Good documentation will be critical to proper use of the completed system.

(c) The design of the management structure for the operation of a multi-user system of this type is critical to its success.

A breakdown of the tasks involved in implementing and operating the proposed system is presented in Appendix B.

## 10. CONCLUSION

In the above it has been shown that the OMEGA tower can be effectively used as a support for meteorological instruments for studies of the lower 400 metres of the atmosphere. Further the instrumentation system can be designed and implemented to provide:

(a) Flexibility in transducers and data recording to cater for a wide range of experiments.

(b) Operation with a minimum of on site attention.

(c) Remote reporting of system status and summarised data.

(d) Facilities for control of smoke generators.

Estimated cost of production of the system, including A.R.L. development effort, spares, and support equipment, but not including site installation, is approximately $137,950 in 1979 dollars and is detailed in Appendix A.

Problems of archiving, analysis, and operational management have not been addressed in this report.

# APPENDIX A

## COST ESTIMATES

In the following, cost estimates are presented for the implementation of the hardware described above. These costs include A.R.L. labour and other costs for electronic development where necessary, equipment costs, spares, test equipment, and A.R.L. labour and other costs for software and system development. Booms, boom mounts, installation, maintenance, archival, and data retrieval costs are not included.

These estimates are best estimates with no allowance for contingencies. Costs are in 1979 dollars.

Costing is based on the measurement requirements listed in section 2.1, with radio links used with all seven measurement stations.

| | | | |
|---|---|---|---|
| 1. | MEASUREMENT STATIONS | | |
| | Transducers | $18500 | |
| | Signal Conditioning | $ 2500 | |
| | Data Acquisition and Control | $ 7050 | |
| | Total | $28050 | $28050 |
| 2. | DATA LINKS | | $ 5600 |
| 3. | RECORDING STATION | | |
| | Demodulator and Preprocessor | $ 4700 | |
| | Main processor: | | |
| | Processor and Memory | $10000 | |
| | Magnetic Tape Units and Controller | $17000 | |
| | Disc and Controller | $12000 | |
| | Terminals, clock and miscellaneous interfaces | $ 6000 | |
| | Paper Tape Reader/Punch | $ 3000 | |
| | EPROM Programmer | $ 2000 | |
| | Total | $54700 | $54700 |
| 4. | SPARES | | |
| | Transducers | $18500 | |
| | Electronics | $ 3100 | |
| | Total | $21600 | $21600 |
| 5. | TEST EQUIPMENT | | $ 8000 |
| 6. | SOFTWARE/SYSTEM DEVELOPMENT | | $20000 |

APPENDIX A (CONTD.)

7. SMOKE GENERATOR CONTROL

| | |
|---|---|
| Integrated in total system | $ 4150 |
| As an independent item | $ 6900 |

8. TOTAL COST (excluding item 7) $137950

## APPENDIX B

### TASK BREAKDOWN

A list of discrete tasks involved in implementing and operating the proposed instrumentation system follows.

1. Procurement, development, manufacture, and testing of hardware.

2. System software development.

3. System integration.

4. Documentation.

5. Site installation.

6. Commissioning.

7. Transducer calibration.

8. Supply and installation of Omega station standard meteorological instruments for manual observations.

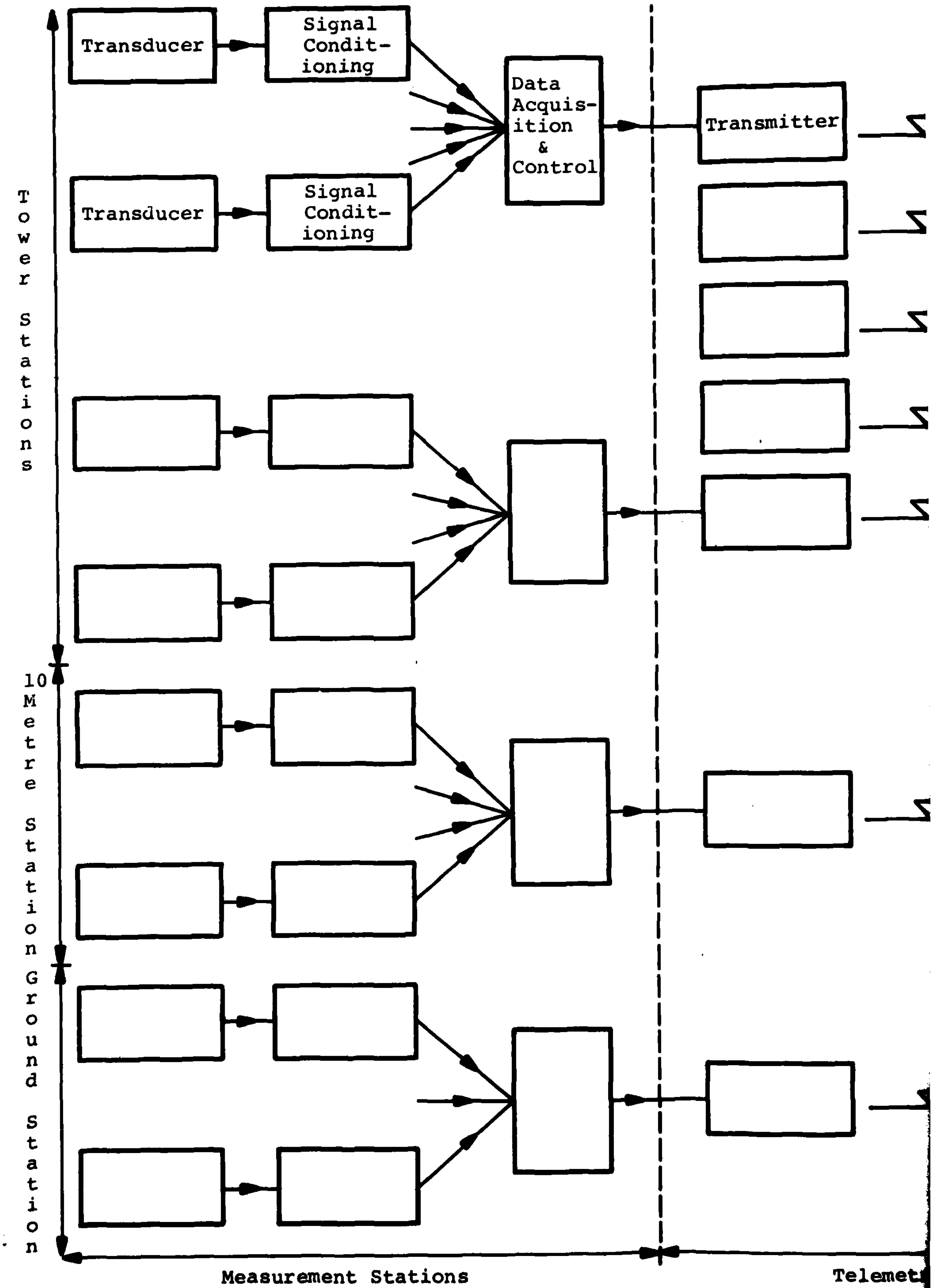
9. Routine operation, including tape changing, manual meteorological observations, and similar tasks.

10. Initial data processing, checking, and archiving.

11. Data analysis.

12. Maintenance, including main processor maintenance contract, other electronic and transducer maintenance, and transducer calibration.

13. User services.



Transducer
Signal Condit- ioning
Transducer
Signal Condit- ioning
Data Acquis- ition & Control
Transmitter
Tower Stations
10 Metre Station
Ground Station
Measurement Stations
Telemet

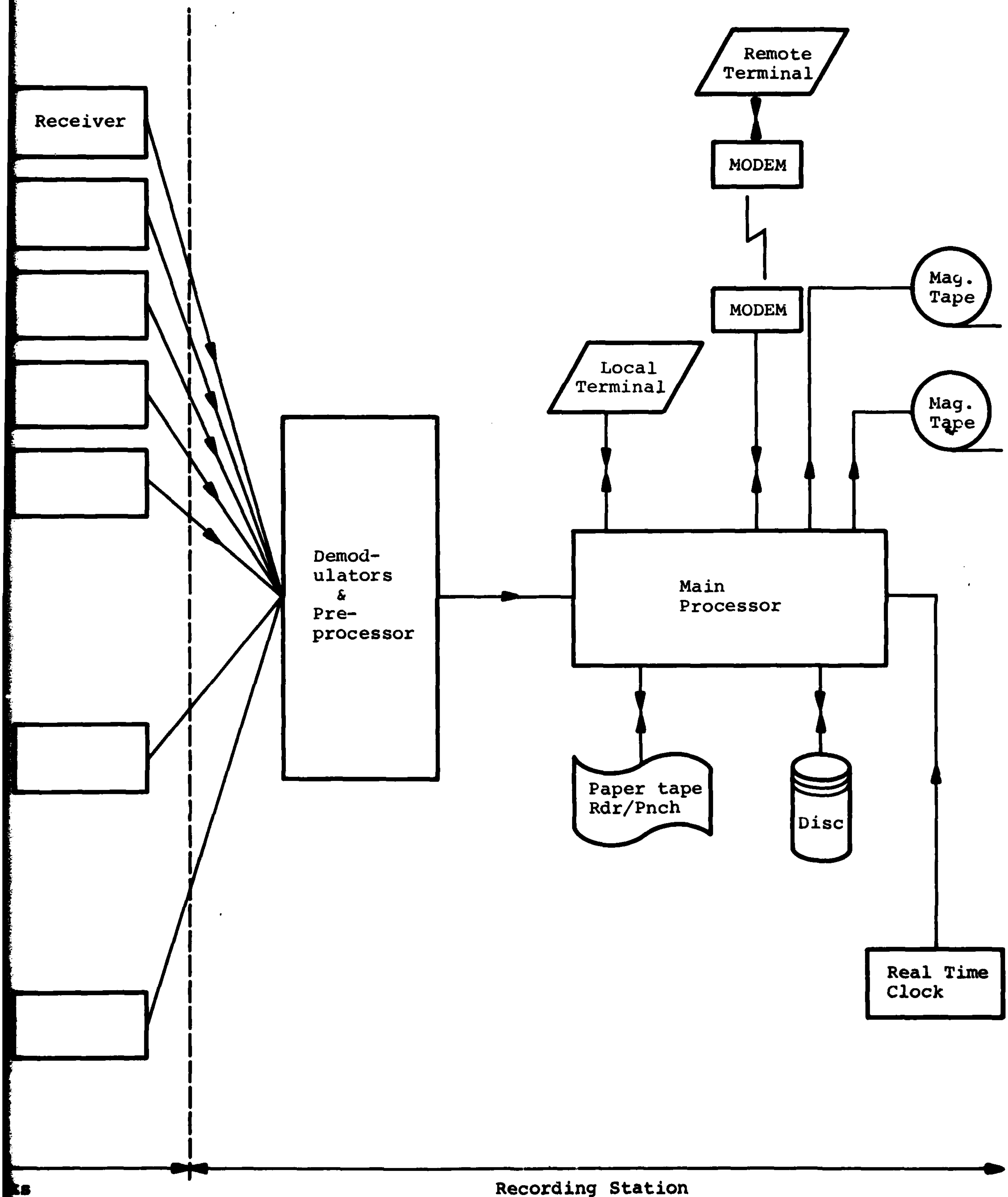
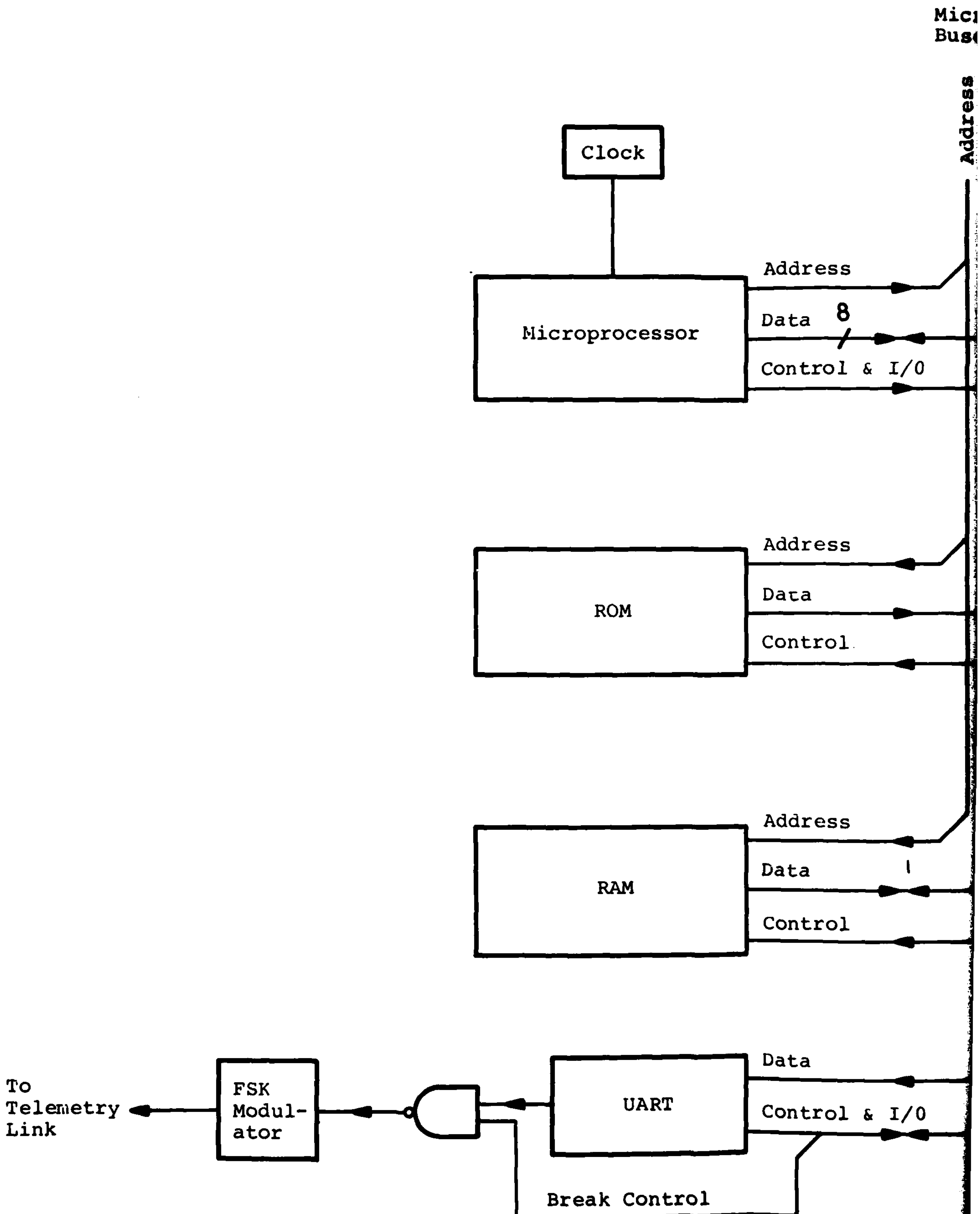



FIG. 1 SYSTEM BLOCK DIAGRAM



Micı
Bus(
Address
Clock
Microprocessor
Address
Data
8
Control & I/O
ROM
Address
Data
Control
RAM
Address
Data
Control
To
Telemetry
Link
FSK
Modul-
ator
UART
Data
Control & I/O
Break Control

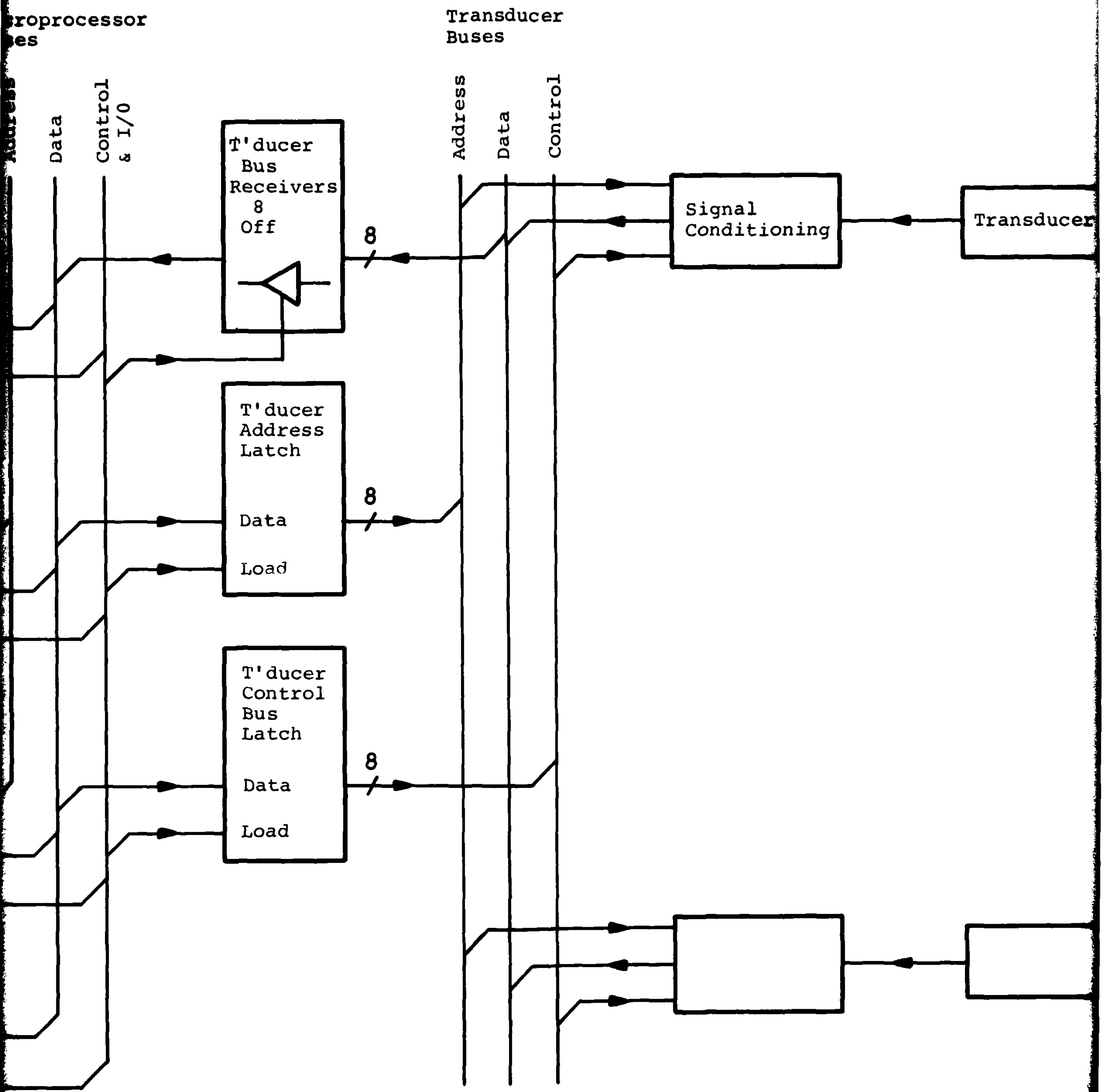
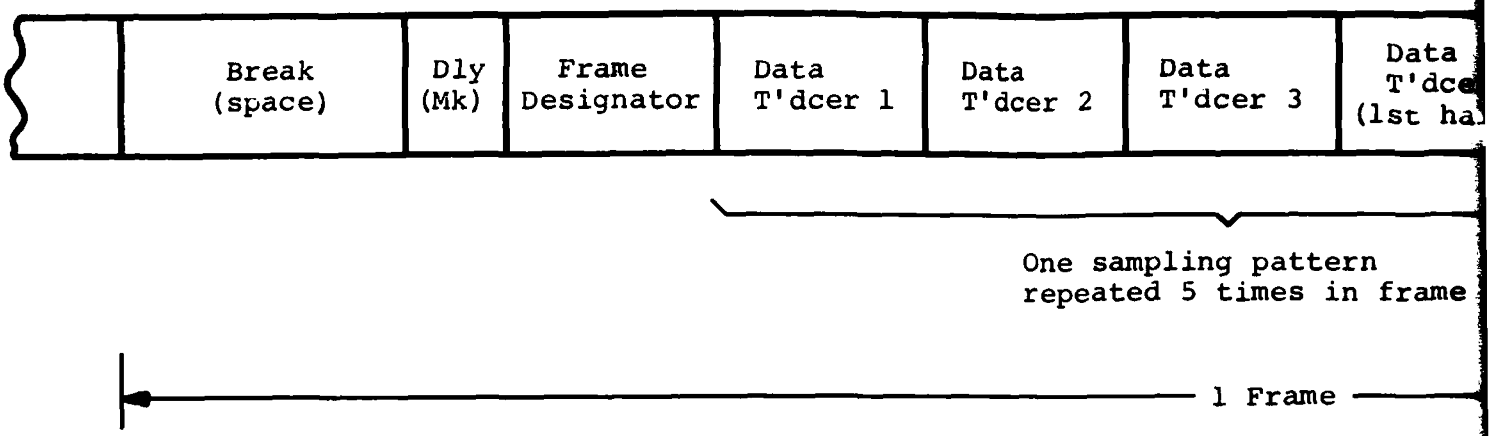
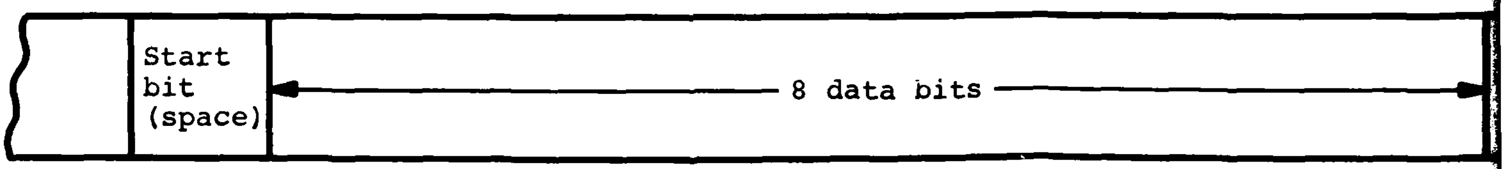



FIG. 2 MEASUREMENT STATION BLOCK DIAGR




Frame period: 1 sec
Transducers: 3 single precision
1 double "
Sampling rate: 6/sec.

(a) Example frame format




(b) Character format

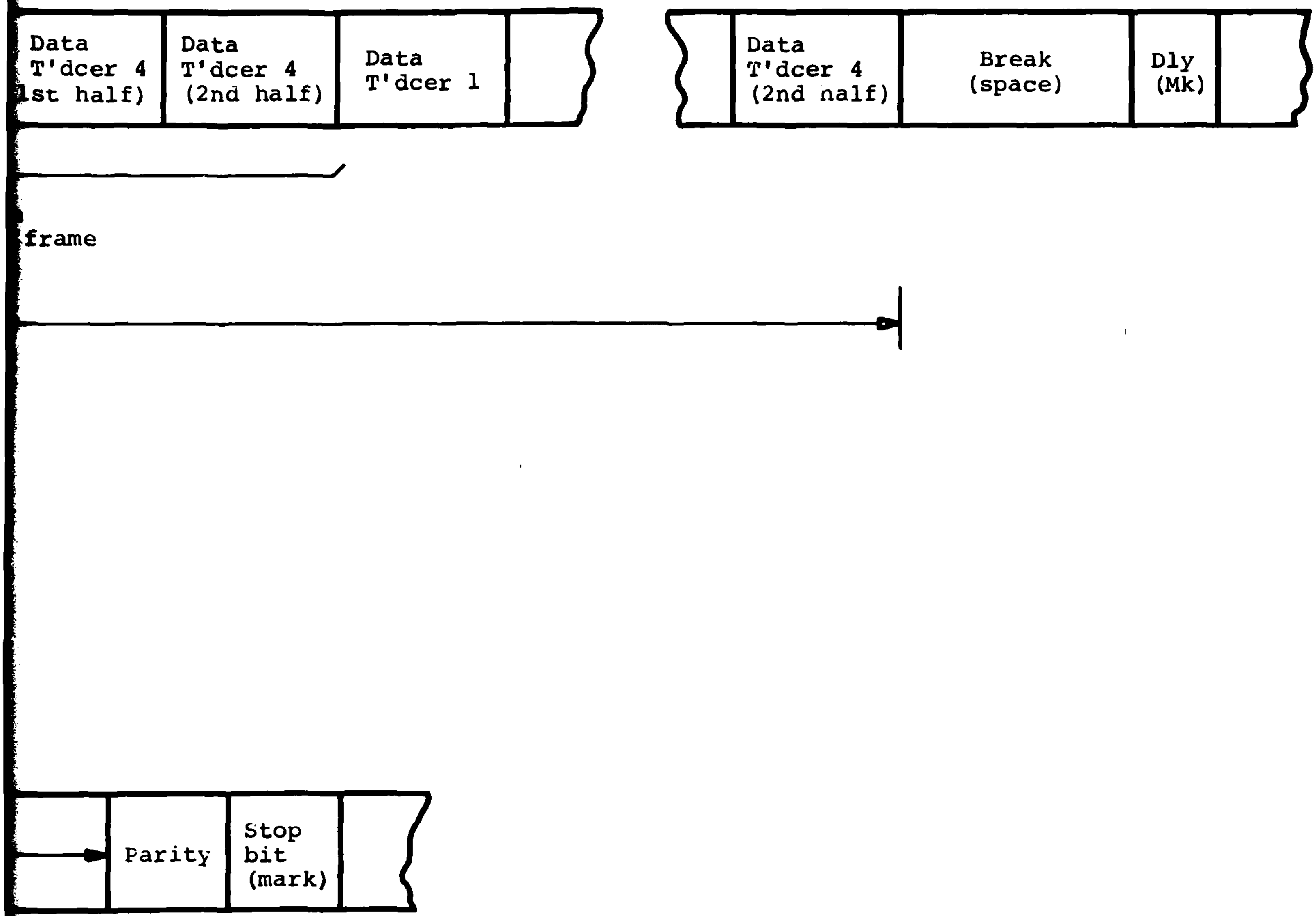
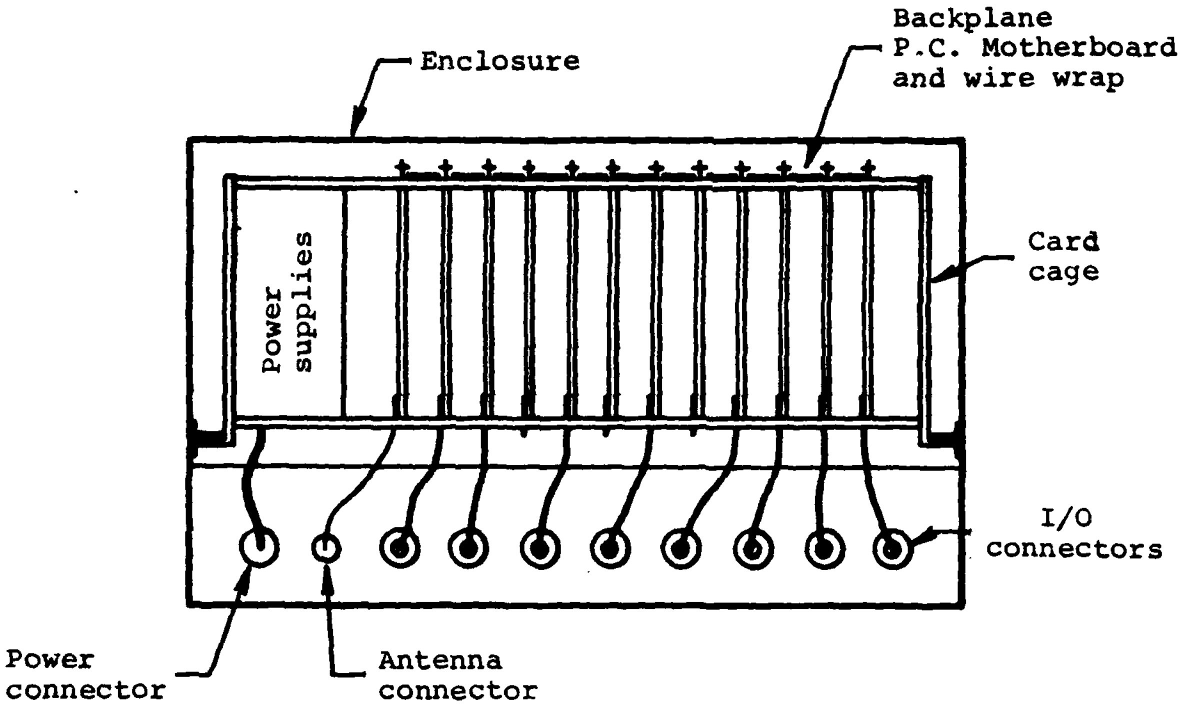
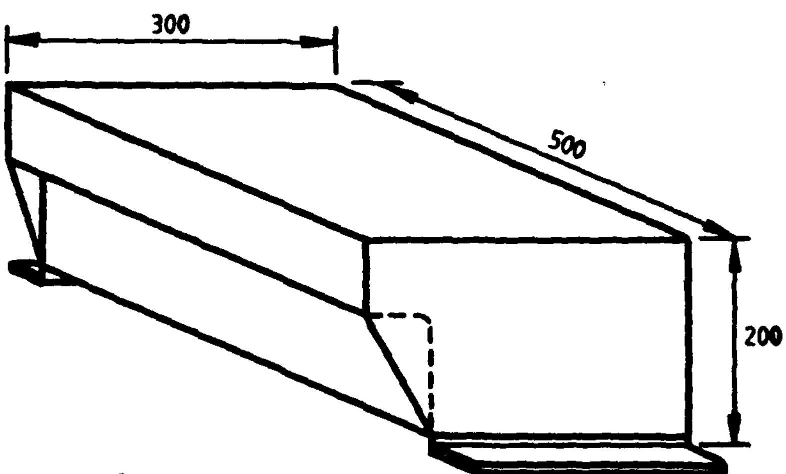


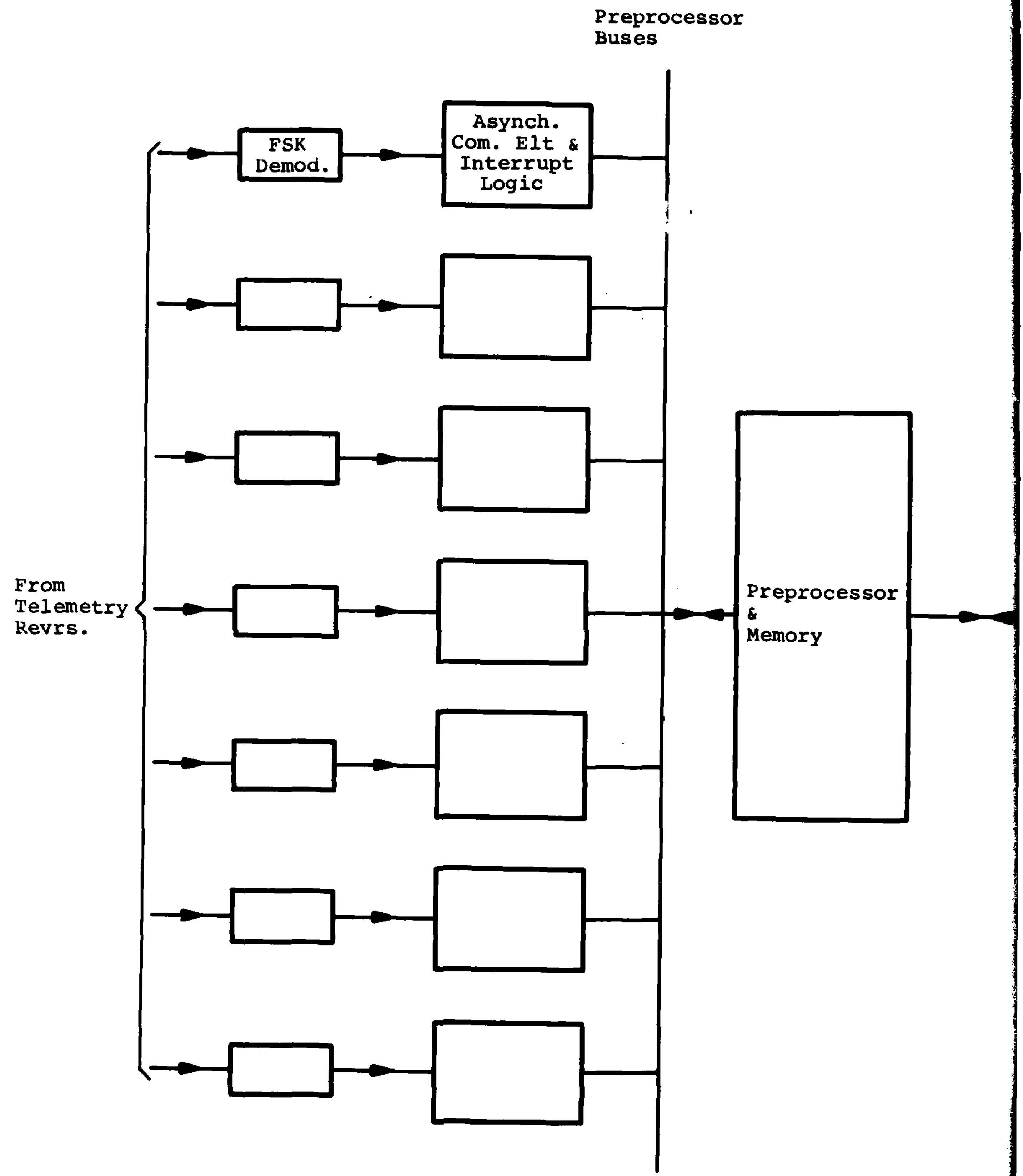

FIG. 3 FRAME AND CHARACTER FORMATS




Not to scale

FIG. 4 TOWER ELECTRONICS HOUSING



Preprocessor
Buses
FSK
Demod.
Asynch.
Com. Elt &
Interrupt
Logic
From
Telemetry
Revrs.
Preprocessor
&
Memory

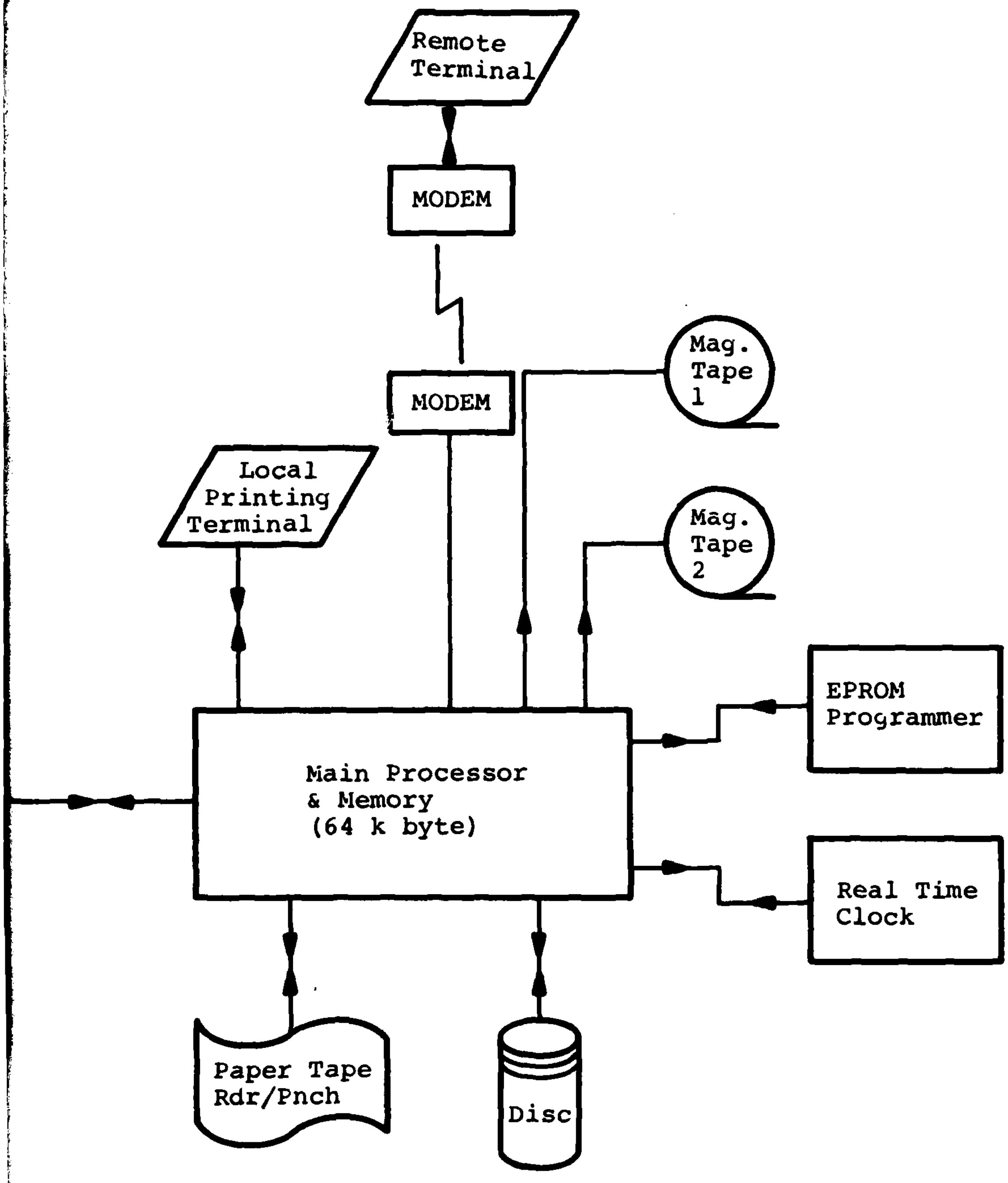
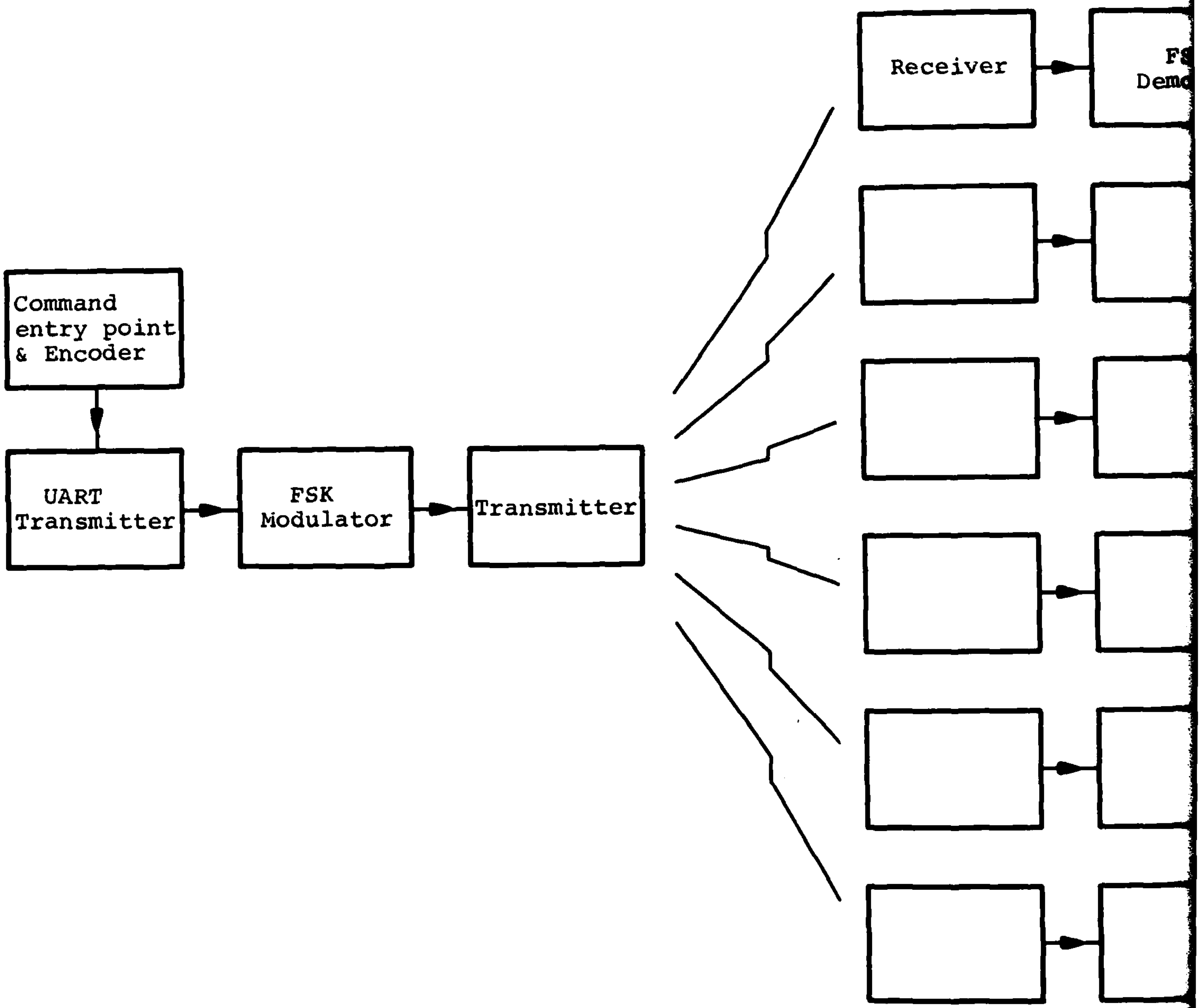



FIG. 5 RECORDING STATION BLOCK DIAGRAM



Command entry point & Encoder
UART Transmitter
FSK Modulator
Transmitter
Receiver

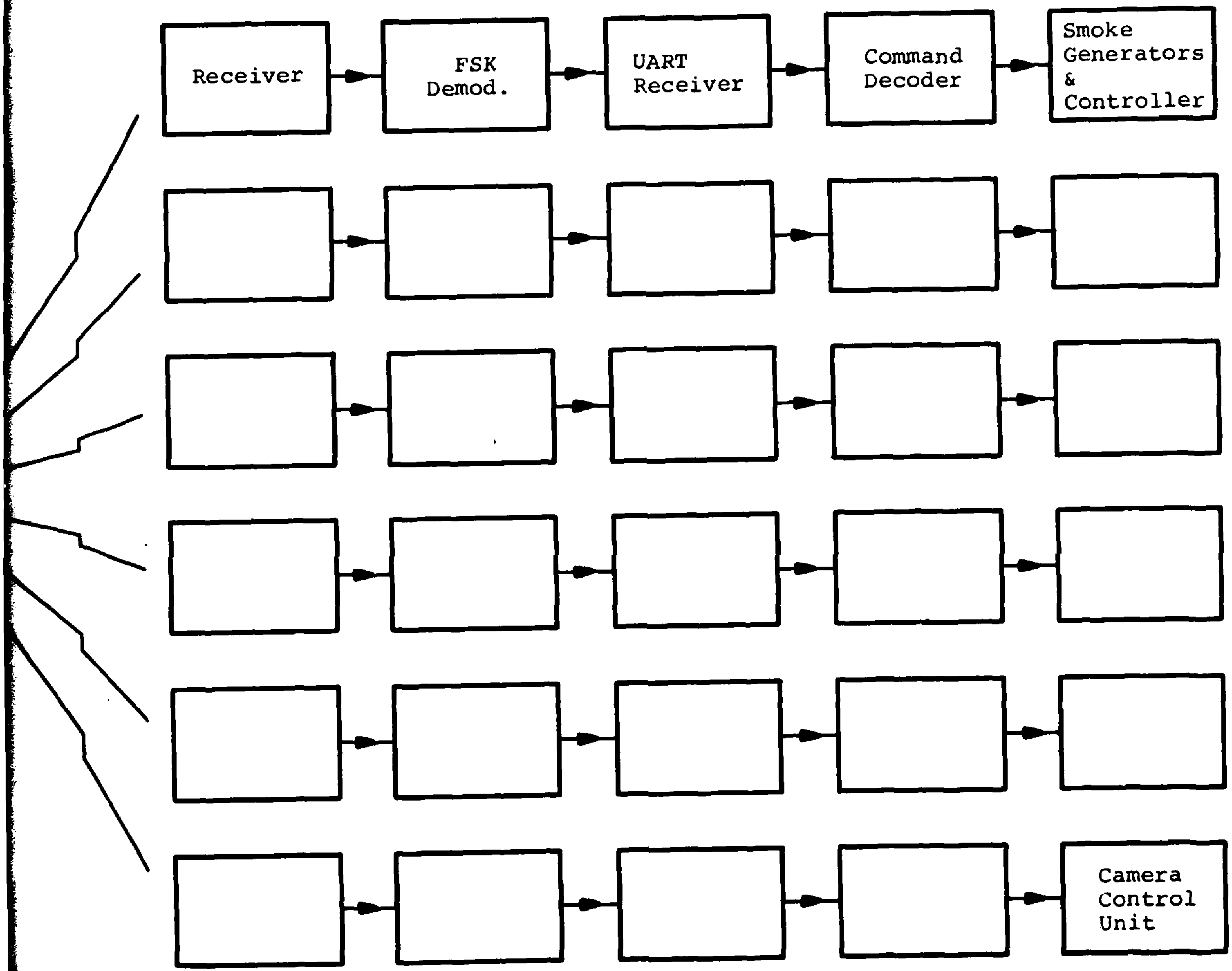



FIG. 6 SMOKE GENERATOR CONTROL SYSTEM

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