DP-1529

SOLAR-POWERED ENVIRONMENTAL DATA COLLECTION SYSTEM

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PREPARED FOR THE U. S. DEPARTMENT OF ENERGY UNDER CONTRACT DE-AC09-76SR00001

Printed in the United States of America
Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

Price: Printed Copy A02; Microfiche A01

726187 ✓

DP-1529
Distribution Category: UC-37

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Publication Date: February 1980

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ABSTRACT

A solar-powered system consisting of a multipurpose remote data collector, a radio data link, and a data receiving station has been designed to acquire data from various remote areas at the Savannah River Plant. A prototype system has been built to monitor gamma radiation at the plant perimeter. It is operating satisfactorily and will be installed to monitor gamma radiation or other environmental parameters at many remote locations on the plant.

CONTENT

SOLAR-POWERED ENVIRONMENTAL DATA COLLECTION SYSTEM

INTRODUCTION

A solar-powered system has been designed to collect data from various sites at the Savannah River Plant (SRP) and to transmit the data by radio to a central area. The system consists of a multipurpose remote data collector and a data receiving station.

The data collector uses a solar power supply for operating power and a low-power consumption microcomputer for controlling functions, data storage, and data transmission. It can be remotely operated in locations away from normal electrical power sources. Programmability of the microcomputer and flexibility of the signal measurement electronics give it sufficient versatility to collect data for many different environmental monitoring tasks. Operating programs have been written so that they can be revised easily to perform different tasks. The collector is capable of measuring analog voltage and digital pulse signals from a variety of environmental sensors.

The data receiving station receives data from any number of remote collectors. The station decodes digital data from incoming radio signals, stores the data temporarily, and then assembles it into proper format and sends it to a computer for permanent storage and processing. (In environmental monitoring applications needing only storage of data and tests for alarm conditions, the receiving station can be used alone and without a computer.) The receiving station has a microcomputer that can be programmed to convert incoming data to a format appropriate for analysis on a larger computer.

A prototype instrument to demonstrate the data collection system has been built and tested as a gamma monitor. A data collector is used with a scintillation detector to measure gamma radiation from background to 5 R/hr. The monitor also measures solar power generation levels, power supply voltages, temperatures, and solar radiation intensity for self-checking and fault indication. The monitor has been installed and is operating near the plant perimeter. Field operation has been satisfactory to date, and operation of the data collector from a car showed a maximum data transmission range of ten miles without radio repeater stations. Design plans and schematics of the monitor are shown on SRP drawings S5-G-376 through S5-G-386. A data receiving station was built for the gamma monitor and connected to a DEC/PDP 11/40 computer. This station is capable of receiving data from up to fifty remote data collectors. Since perimeter gamma monitoring will probably require about twenty collectors, the perimeter monitor and other environmental monitors could be accommodated by this receiving station.

DISCUSSION

System Concept

Remote data collectors can be installed at various plant sites to accumulate data and transmit radio signals to a central data receiving station. Each remote collector will be self-sufficient and will operate from solar-generated power under the control of a programmed microcomputer. Design concept of the data collection system is shown in Figure 1.

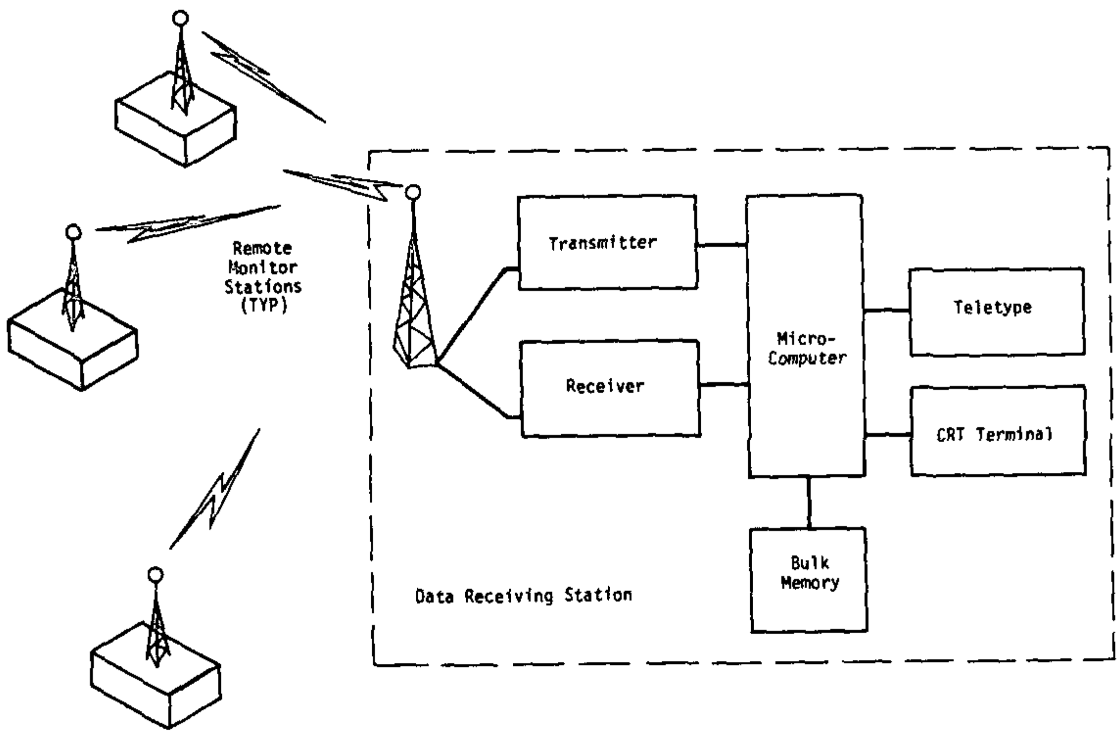

FIGURE 1. Data Collection from Remote Monitors

Signals from various environmental sensors can be coupled to the data collectors through electronic data conversion circuits. Data will be obtained at five- or ten-minute intervals and stored in the solid state memory of the microcomputer in each collector. At specified time intervals, each collector will monitor for a radio signal from the receiving station requesting transmission of the latest data. The collector will then encode and transmit data and resume measurement operations.

At the receiving station, incoming data will be decoded, stored temporarily in a microcomputer, then sent to a readout terminal such as cathode ray tube or teletype or to a data processing computer. Programs in the data processing computer will assimilate data, store results for long-term records, and print out any periodic graphs or reports that may be desired. Operation of both the microcomputer and the data processing computer will be done according to software programs written for the various environmental measurements.

Remote Data Collector

The remote data collector consists of a signal converter, microcomputer, radio transmitter, and solar power supply. Each collector will accept signals generated by transducers or measurement devices appropriate to the monitoring tasks. These signals can be connected directly to a signal input converter in the collector as shown in Figure 2.

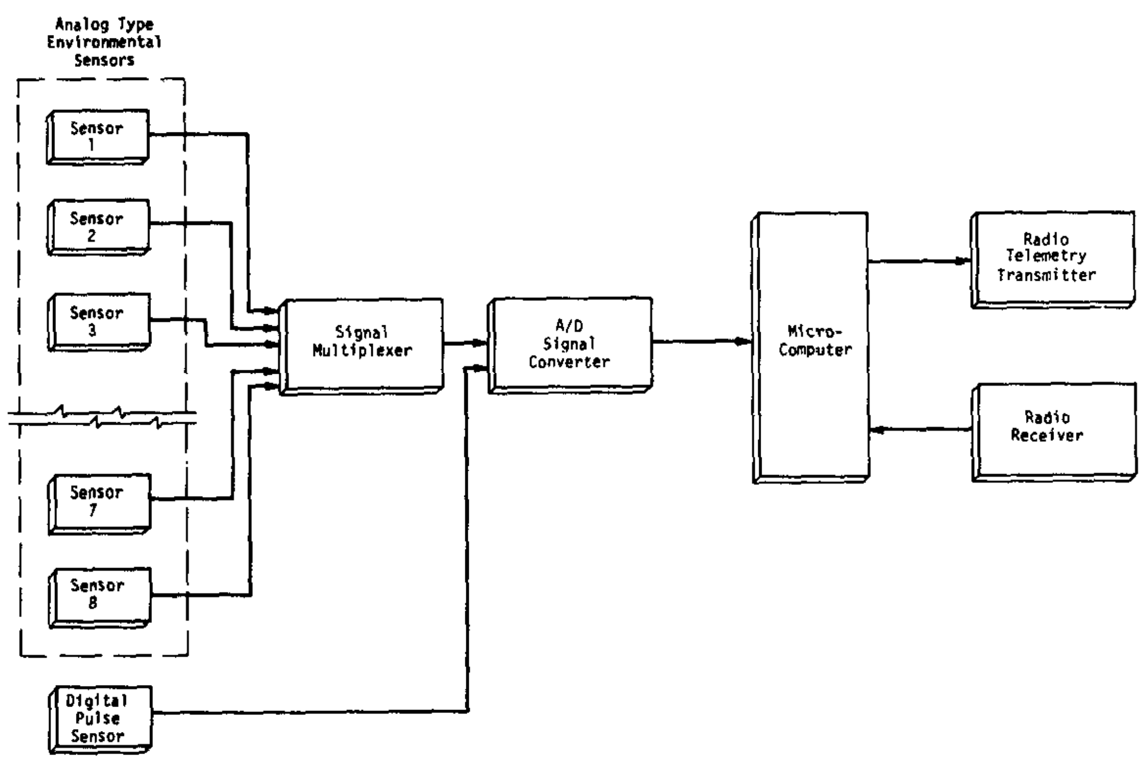

FIGURE 2. Environmental Data Collector

The signal converter will accept up to eight analog input signals and one digital pulse* signal. The analog signals connect directly to a high-impedance multiplexer that couples them, one at a time (under microcomputer control), into an analog-to-digital (A/D) converter. The A/D converter generates a digital output number from 0 to 4096 that is directly proportional to the input analog voltage. This digital number is read by the microcomputer and is stored in memory.

The pulse signal connects directly to a counting input of the A/D converter. Input pulses are counted for a preset time and are then read from the digital output lines by the microcomputer. The maximum number of pulses that can be read without resetting is 67×10^6. Maximum pulse rate is 40 million per second (40 MHz).

The microcomputer consists of a microprocessor, memory circuits, input and output circuits, and status indication lights. It controls collector operations according to instructions in program memory** and stores information obtained in data memory.† Digital information such as that from the signal converter is communicated into or out of the microprocessor by input and output ports that convert voltages from constant DC levels to timed sequence pulses. The microcomputer reads input data from the input ports and sends out signals to control data acquisition, storage, and transmission through the output ports. To minimize power consumption, the microcomputer and all data acquisition electronics are complimentary metal oxide semiconductor, CMOS circuits that require very little power for operations.

The radio transmitter broadcasts data encoded in radio signals at 161 MHz with an RF output power of 2.5 watts. Data to be transmitted are encoded as standard RS-232 bit patterns which are then audio encoded and sent to an FM radio transmitter as tone bursts. The audio encoding is done in synchronism with the microprocessor crystal clock.

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* Expansion of the output converter to 256 analog and 32 digital pulse input signals can be done easily. Generally, though, five analog signals are adequate for remote monitoring tasks.

**Program memory consists of 514 steps of "read only memory" (ROM) and 1024 steps of "programmable read only memory" (PROM). ROM and PROM memory cannot be changed during operation, nor is it erased by loss of power.

†Data memory consists of 4,000 words of random access memory (RAM) that has data recorded or read into it by the microprocessor; RAM data are lost if power is lost.

A solar power supply converts sunlight into electricity in silicon solar cells which are arranged on an insulating panel and connected in series to provide 30 watts peak power at 12.5 volts. This peak power is adequate to keep a storage battery charged year round at the SRP geographic location while supplying an average of 5 watts to operate the remote terminal. A voltage regulator connected between the solar panel output and the battery prevents overcharging during bright sunny weather. A DC to DC voltage converter converts the nominal 12.5 volts DC from the storage battery into three voltages needed to power the microcomputer and other electronics. It supplies +15 and -15 volts at 0.045 ampere and +5 volts at one ampere.

Central Data Receiving Station

The central data receiving station consisting of a radio receiver, decoder, microcomputer, and central computer interface is diagrammed in Figure 3. Incoming radio signals are received by an FM receiver which reproduces the audio tone bursts sent from the collector. A synchronous demodulator reproduces the original RS-232 bit patterns from the tone bursts and sends these to the microcomputer which decodes the data and stores it in RAM. When a full set of data have been received, the microcomputer adjusts the coding of data to match the main computer and transmits the data through an interface circuit to the computer. Alternatively, the data can be sent directly to a teletype or cathode ray tube display terminal.

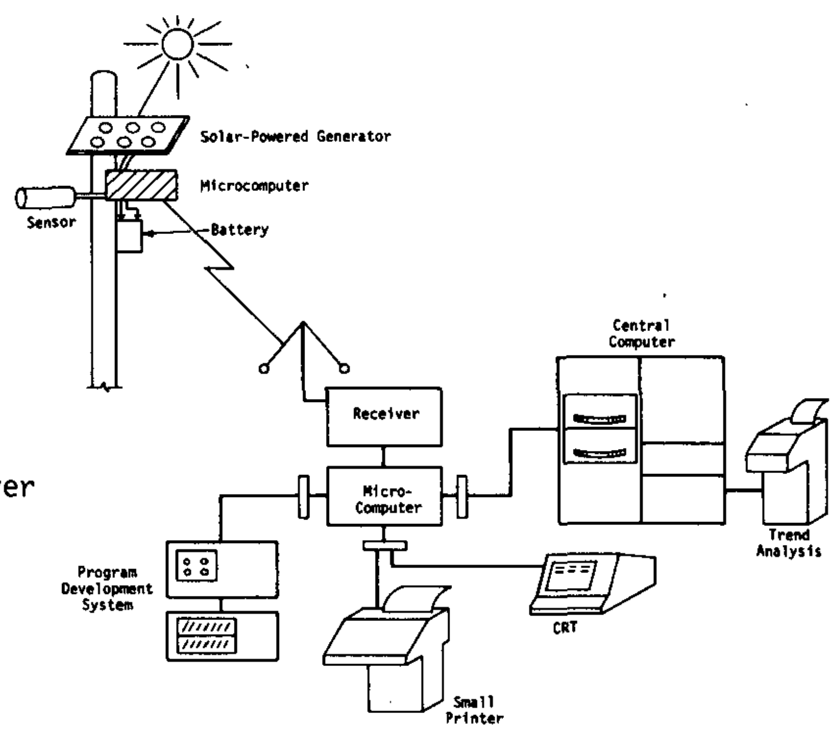

FIGURE 3. Solar-Powered Monitor and Receiver

In applications that do not require long-term data storage and processing, the receiving microcomputer can be programmed to check incoming data against limiting values and to generate alarm signals and special message printouts when alarm conditions occur.

Prototype Gamma Monitor

A gamma monitor was built as a demonstration prototype instrument to accomplish the following design objectives:

- Measure gamma radiation flux at remote locations with a range of background to 5 R/hr.
- Operate from a solar power supply.
- Telemeter data to a central plant location.
- Measure five or more analog signals.

The monitor is shown in block diagram in Figure 4. Gamma radiation is detected by a scintillation detector and electronic discriminator. At low radiation levels, gamma counts are accumulated in a register of the A/D converter. At gamma levels above 25 mR/hr, a direct current signal is generated, which is connected to one of eight analog signal inputs. This signal and seven other analog voltage signals are coupled through a multiplexer into the analog input of the A/D converter.

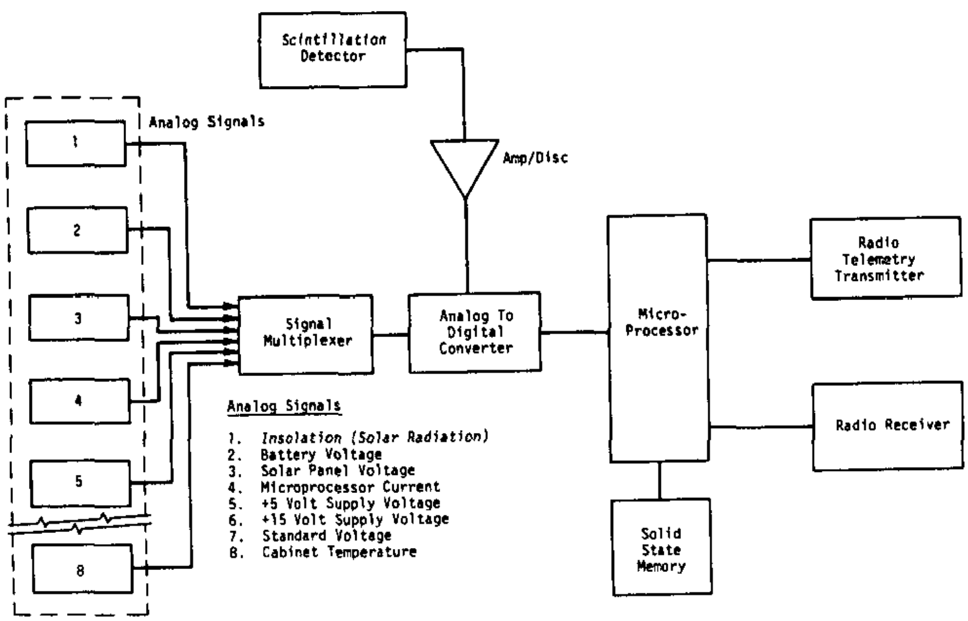

FIGURE 4. Block Diagram of Remote Gamma Monitor

The microprocessor reads data from the output of the A/D converter and stores it for processing and transmission. All data are converted to straight hexadecimal numbers. These numbers are tone encoded by the synchronous encoder and then transmitted by the radio telemetry transmitter to the data receiver. Gamma count rate values are stored at the data collector in RAM so data can be retrieved if the data link or central computer becomes inoperative. Enough RAM is provided in the collector to store two weeks of data, so the last two weeks of data will always be available. Figure 5 is a picture showing the gamma detector, microcomputer and transmitter mounted inside a weather tight enclosure at the remote location. A view of the gamma monitor is shown in Figure 6. Gamma count capabilities are listed in Table 1. The microcomputer used in the prototype monitor is an RCA Corporation CMOS type, model number 1802.

TABLE 1

Gamma Count Capabilities of the Gamma Monitor

• Resolution	0.025%
• Digital Range	Background to 6×10^6 C/Min
• Analog Range	25 mR to 10 R
• Stability	±5% + Statistics Of Count

As many as 50 monitors similar to the prototype can be installed by using a single radio channel with the prototype receiving station and multiple remote data collectors. The microprocessor can be programmed to analyze data by itself to reduce the amount of routine data collected. For example, long-term minimum, maximum, mean, and standard deviation of data can be computed. Software programs to do such computations have already been written and used with the prototype monitor.

Gamma Monitor Programs

Computer programs for the microcomputer were developed at SRP for operating the gamma monitor. These programs were written and compiled by using a software development system, Figure 7, consisting of a microcomputer, a "floppy disc" memory system, and a cathode ray tube display. All programs are stored on magnetic floppy discs and can be read out by the development system microcomputer. A typical program requires about 1000 steps; up to 250,000 steps can be stored on a single magnetic disc. Special "direct memory addressing" circuits were built for rapidly transferring programs to the gamma monitor computer from the development system.

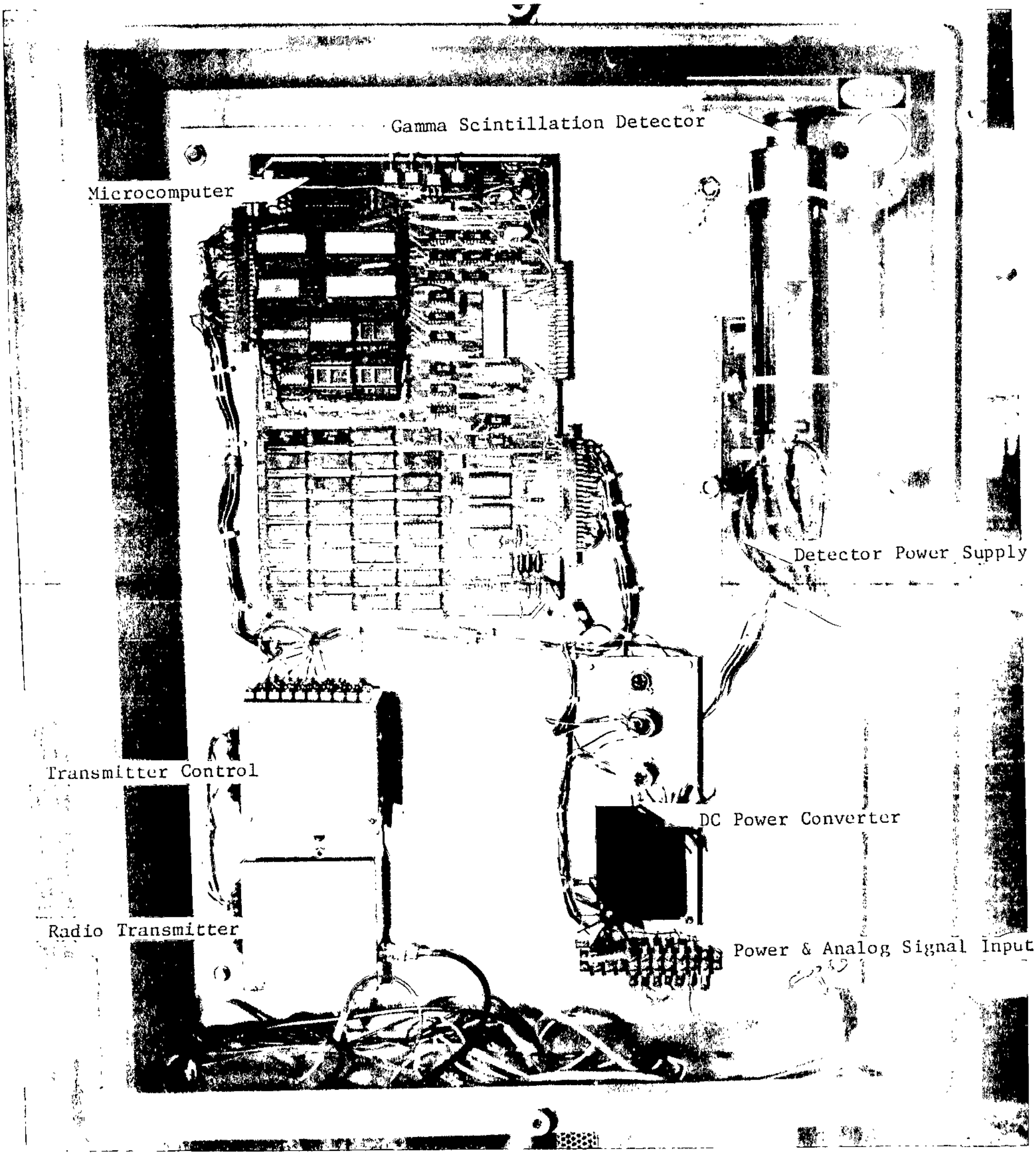

FIGURE 5. Gamma Monitor in Weather Tight Cabinet

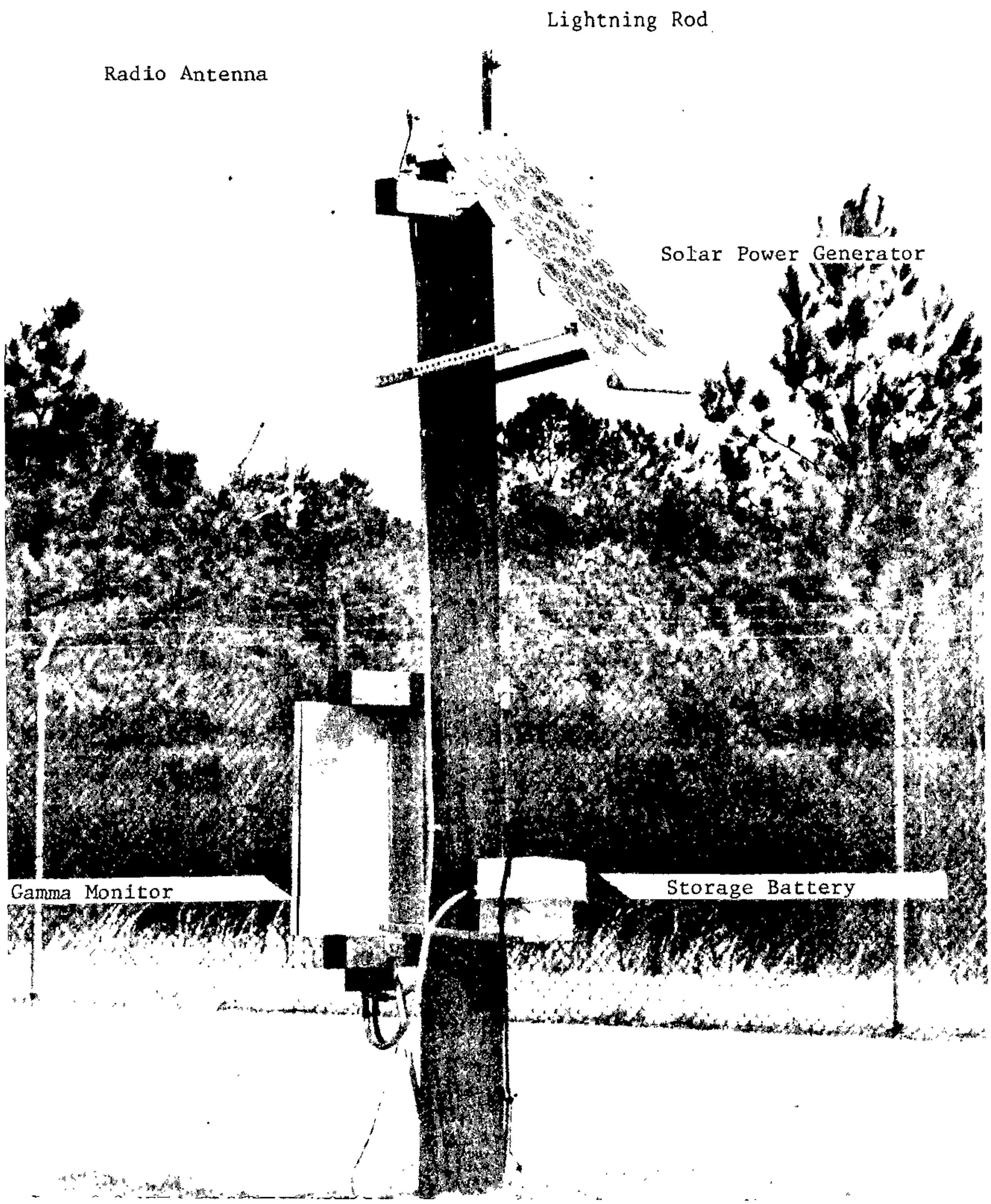

FIGURE 6. Remotely Located Gamma Monitor

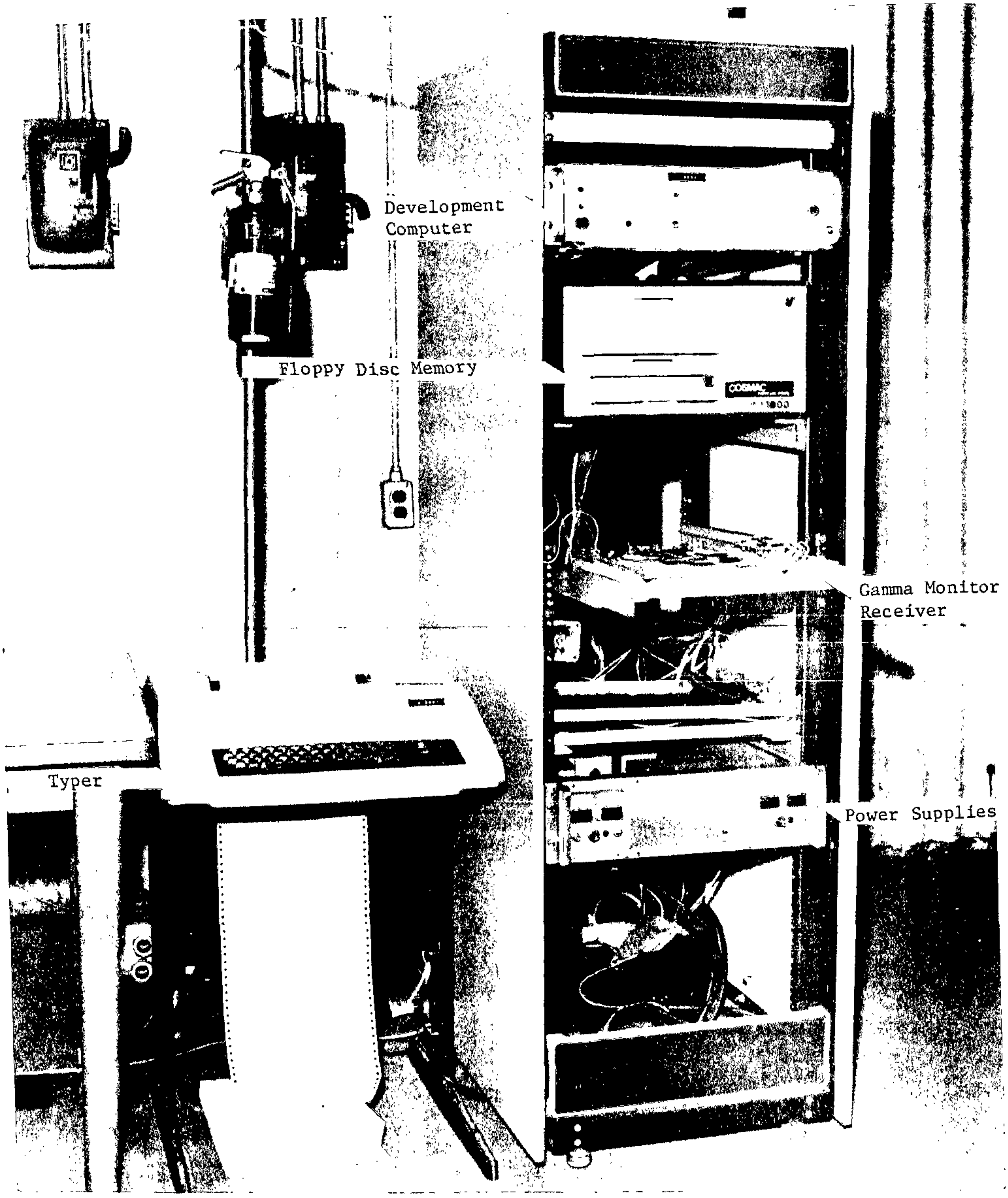

FIGURE 7. Software Development System

Receiving Station

At the data collection station, radio signals from the data collector are received, decoded by a synchronous demodulator, and then sent to a microprocessor (Figure 8) that stores the incoming data. This processor then assembles the data in a computer compatible format and sends it by teletype signals to a data acquisition computer (DEC PDP-11/40). This computer (shown in Figure 9) stores the data and can process data as required. At present, a program is provided to print the last 100 values of all variables and to plot the value of the last 100 readings of any of these variables as a function of time.

Other Applications for the Data Collection System

The remote data collection system can be used for a wide variety of monitoring tasks, some of which are listed in Table 2. In addition, the radio data link to central computers will simplify many "one-time" data acquisition problems where data need to be taken at one location and analyzed at another. Also, the signal conversion available in the collector can save time and expense in building specialized equipment for each problem.

Though built for remote operation, the data collector can be used conveniently anywhere. The data can be sent over telephone lines by connecting the audio signal to an inexpensive commercial telephone coupler. No modification would be required at the data collector or the receiving station to obtain data transmission over long distances by telephone. In applications requiring acquisitions of less than 24,000 bits of data, the data can all be stored in the microcomputer. No data link would be necessary.

TABLE 2

Immediate Applications of the Remote Environmental Data Collection System

- Water Quality Monitor
- Meteorological Monitors
- Reactor Neutron Monitor for C&D
- Process Gamma Monitors
- Reactor Startup Neutron Monitor
- Portable Data Acquisition System
- Gamma Monitors for SNM Control

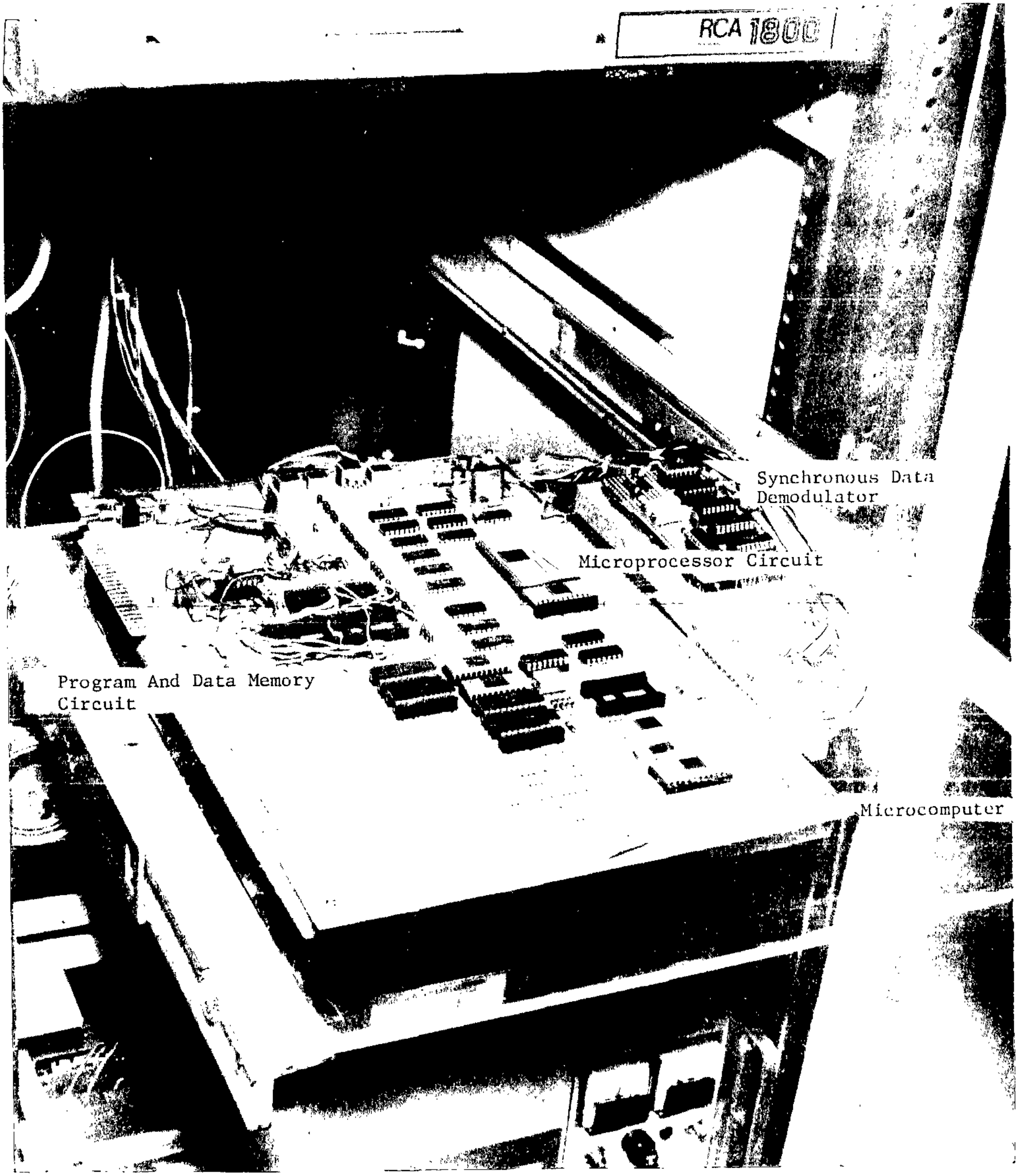

FIGURE 8. Receiver Microcomputer

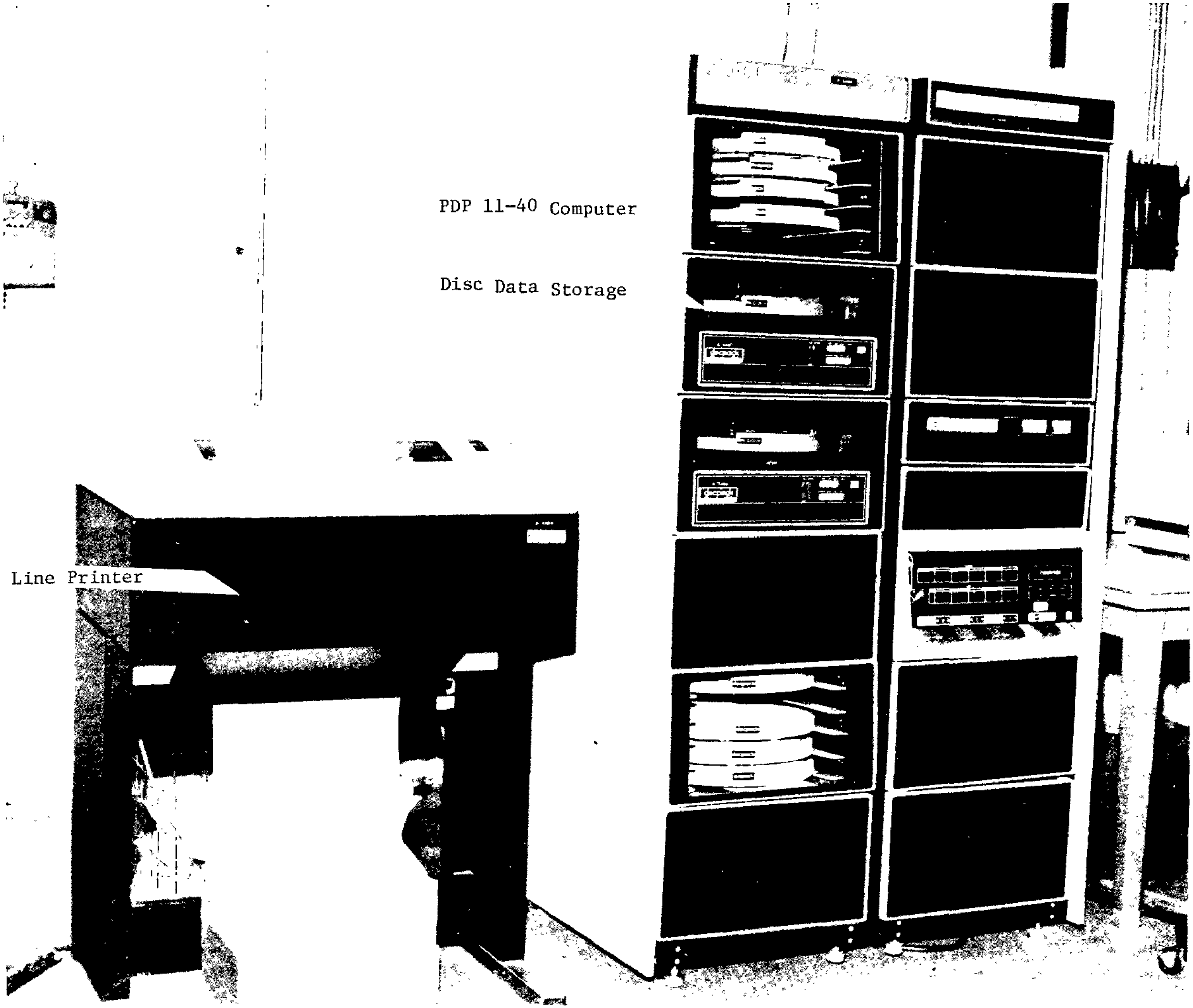

FIGURE 9. Data Acquisition Computer