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A microcomputer-based real-time data system for radio wave propagation studies

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A microcomputer-based real-time data system has been implemented and tested for data collection and processing. The paper presents the main system components, together with special features tailored for radio propagation studies.

The computer system is designed to control a data acquisition system (DAS) and to perform other data processing functions. The system is built using Hewlett-Packard hardware: the low-cost HP9825 microcomputer together with the HP3497 automatic data acquisition and control system. The main features of the system are: (i) Menu-driven system, (ii) user friendly interactive operation, (iii) optimized tape utilization and DAS scanning speed, (iv) on-line help facility.

The paper starts by introducing the system layout and then describes the system hardware, which includes the microcomputer, the data acquisition system and the various sensors. System design is then presented with emphasis on tape and speed optimization. It is hoped that the present paper will be useful for engineers and scientists planning environmental, meteorological and engineering studies involving real-time data acquisition.

1. Introduction

A field trial, aimed at studying the propagation of millimetric radiowaves in arid land climatic conditions, is presently under way in Riyadh city, Saudi Arabia. The study involves the continuous monitoring of the received signal from five radio links and relating the variations in signals level to meteorological parameters.

At millimetric wave length, rain, sand and dust storms and multipath fading are expected to set the limit on the hop length and system reliability in an arid land climate. In order to determine the individual effect of each of the three offenders, rain, dust and fading, rain intensity must be recorded minute-by-minute. On the other hand, the occurrence of multipath fading may last from a few seconds to several hours, requiring fast scanning of the various radio channels for its detection.

Figure 1 illustrates the experimental set up in which five radio links of varied hop length operate with receivers on the roof-top of the communication laboratory at King Saud University. Received radio signals as well as signals from a meteorological station which shares the same roof with the radio receivers, are fed directly into a data acquisition system which enables fast scanning of various channels. Sampled signals are digitized and made available for reading by the computer. While an enormous amount of data are collected by the system, only relevant data are stored for further off-line processing.

The purpose of this paper is to present the real-time microcomputer-based system

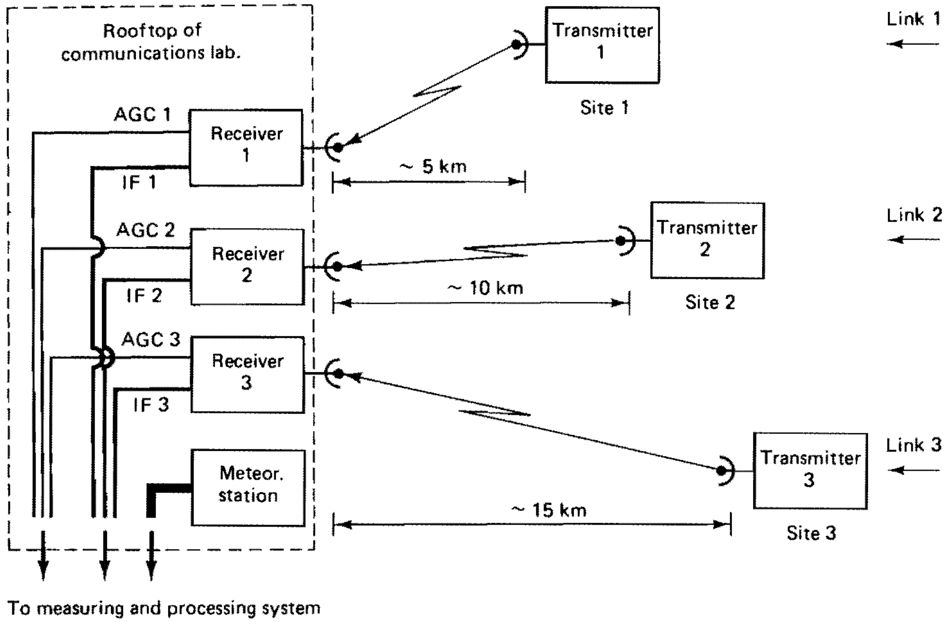

Figure 1. Layout of millimetre wave links and meteorological station.

used in the study of millimetric wave propagation. A complete system description, together with various concepts in millimetric wave radio design are found elsewhere (Ali, 1983). Since the number of radio signals and meteorological sensors is fairly small, it was felt that a small, low-cost microcomputer system could be used to control the data-acquisition system and handle various data processing activities. Two alternatives were available; (i) a low-cost board computer which requires a sizeable effort and time in programming or (ii) a microcomputer system with a higher initial cost but which requires less effort to interface to real-world devices. A reasonable compromise was that of low-cost microcomputer, an HP9825. Besides the low cost and adequate handling of data processing, the microcomputer can also work as a terminal controller for other devices such as a spectrum analyser, an RF power sweeper and an X-Y plotter, all of which are connected via an HP-IB bus (Lipovski, 1980).

2. System hardware

The hardware used for the experiment consists of a microcomputer equipped with a thermal printer, a cassette tape recorder and an X-Y plotter. The microcomputer is interfaced to the set of meteorological sensors and radio channels via a data acquisition system (DAS).

2.1 *The microcomputer*

The microcomputer hardware consists of 24 kbyte of random access memory (RAM), one cassette tape drive of 285 kbyte capacity, a small internal printer, a thermal printer and a small X-Y plotter.

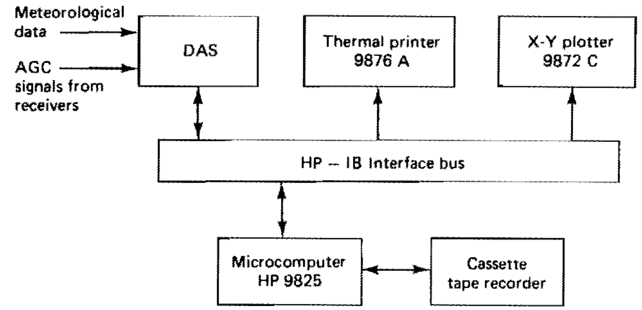

Figure 2. The MMW hardware components.

The programming language is HPL, which was developed by Hewlett-Packard (HP, 1980) to be used for controlling some HP computerized (software controlled) test equipment. The language has some features of an assembly language with some BASIC-like commands.

2.2 *The data-acquisition system (DAS)*

The data-acquisition system used in the present arrangement is an HP3497A device (HP, 1982*a*), which can be readily interconnected to the HP-IB bus. Figures 2 and 3 show an overall system block diagram and a block diagram of the DAS (Epstein & Heger, 1981), respectively.

2.3 *Sensors*

Three types of sensors are connected to the data acquisition system, (i) radio channels which give a steady d.c. signal proportional to the gain provided by the automatic-gain control (AGC) amplifier. At fade events, however, such a signal may show fast time variations; (ii) meteorological sensors yielding a steady, slowly varying, d.c. voltage

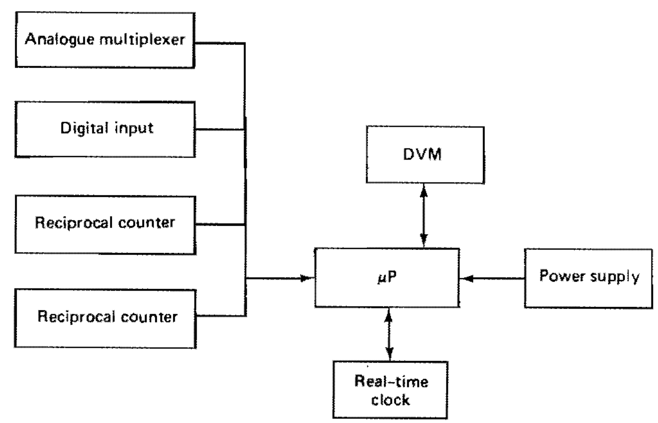

Figure 3. DAS components.

signal (thermometer, wind velocity meter, humidity and pressure gauges etc.), and (iii) rain gauges yielding a series of voltage pulses, the count of which is proportional to rain intensity. The first two are fed into the DAS via an analogue multiplexer, whereas the digital counter is used to receive the impulsive signals (HP, 1982*b*).

3. System design

3.1 *Design concepts*

An automatic data acquisition system for the radio propagation experiment must be capable of detecting fast fade events lasting for several seconds. Field experiments showed that the speed of the HP9825 microcomputer sets the limit on the system scanning rate. Thus, in order to maintain a sufficiently fast scanning speed, only the absolute minimum amount of processing may be performed during data acquisition. On the other hand, the data acquisition system has some built-in intelligence, which enables a limited amount of data processing. This may be utilized to improve system throughput.

Although the actual number of channels that will be connected to the DAS is expected to be around 20, the design allows for 40 channels. Each channel may be scanned in one of the available scanning modes, viz., fast, slow, operator selected, counter and adaptative scanning.

The fast scanning speed is the highest speed the system may allow and depends on the number of scanned channels and the scanning mode for each. The slow scan is arbitarily taken here as one scan per hour and the operator mode is left to the operator choice, within the system speed limit. The counter mode is used for counter driven events e.g. rain gauges. The adaptive scanning allows a scanning rate that vary with the speed of variation of the sensed signals themselves.

Figure 4 illustrates the system flow chart. Each data acquisition run is considered as a separate test. Preparations of these runs include the determination of the channels to be scanned, mode of scanning, threshold percentage of readings variation and other reference data. These parameters are set in a preparation phase called the 'define run parameters'. When satisfied with the channel configuration this information is saved on a cassette tape which is to be used later during the actual data acquisition phase. When the time of the test is due, another program is activated to drive the DAS and store relevant information on the cassette tapes. Later, processing of the collected data is also performed in separate runs. The main reasons for separating the three phases of a test are as follows:

(i) The 'define run parameters' phase allows the configuration of the system before the actual data collection takes place.
(ii) The data collection run is dedicated to pure data acquisition which results in the fastest possible scanning rates.
(iii) Because of memory limitations of the microcomputer it is not efficient to combine the three different functions into a single run.

3.2 *Tape utilization*

Two types of tapes are used in this system: program tape and data tapes.

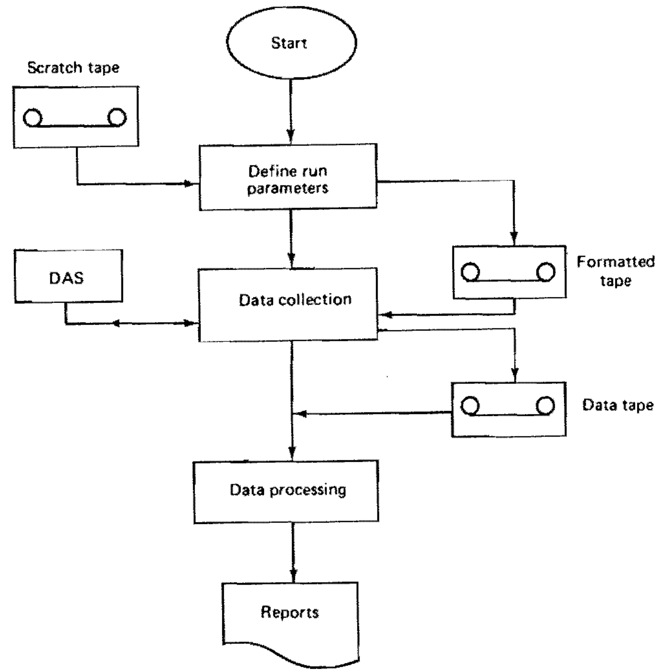

Figure 4. System flow-chart.

1.3.1 *Program tape*. This tape contains a set of the system programs which in the current version enable the choice of run parameters, data collections, data retrieval, statistical analysis, tape listing, tape identification and system management. The first file on this tape is a tape header file which identifies the tape as being a system program tape.

1.3.2 *Data tapes*. These tapes contain three different files.

(i) Tape header file: this is a one record file which contains tape identifying information, in particular tape serial numbers. The header also contains a 'reel' serial number. This number is maintained by the computer for the multi-tape files, i.e., a file spanning over several tapes. The last reel is designated by −1 as a 'reel' serial number.
(ii) Run parameters file: this file contains one record that stores the reference information of the data acquisition run.
(iii) Data files: these are the files containing the collected data in real-time from DAS. The tape utilization is optimized to reduce tape movement and thereby improve the maximum speed of scanning.

3.3 *Conversion tables*

The sensors used in this work output a d.c. or pulsed voltage which is proportional to the actual measured data. Mapping from the d.c. voltage to the real world data is accomplished using conversion tables. The current version of the system can house 10 different conversion tables for the various sensors used. The conversion tables are stored as a data file on the program tape.

3.4 *System parameters*

3.4.1 *Scanning speeds*. The system is designed to support five scanning modes. These are: fast, slow, operator selected, counter and adaptive. From the characteristics of the DAS and number of channels in operation it is possible to evaluate the maximum scanning speed (fast) for a particular test configuration.

For the counter mode sensors, since rain events are very rare in Riyadh, it is not economic to make continuous scanning for the counters as the radio links. When rain starts only the counters are scanned for a period of time Δt to compute the rain intensity. A reasonable value of the integration time Δt is between 1 to 5 min. The system computes a 'sleeping factor' Q for which the counter is not scanned while other channels are scanned.

3.4.2 *Optimizing tape utilization*. Since the only available external storage media is one cassette tape drive it is essential to optimize its utilization in order to minimize the need for frequent change of tapes. Several techniques have been used in order to realize this goal. These include:

(i) Data are kept in memory to the maximum available size of RAM and recorded on tape in batches.
(ii) Only relevant data are kept in memory. A measured data element is considered to be relevant if the percentage of relative deviation from the previous measured data from the same channel is greater than or equals the prescribed threshold for this particular channel.
(iii) Data are stored on the basis of event recording rather than systematic recording of data. In other words, if one channel value is changing faster than others, more entries will be allocated to this channel. No predetermined allocation of space to channels is assumed.
(iv) All data items of the same type (characters) are grouped together in a continuous string to minimize the string overhead.
(v) All integers stored in the system are stored in a short precision format rather than the normal storage of numerics. This saves 6 bytes for each integer without any loss of precision.
(vi) Whenever feasible, floating point numbers are stored in short precision format rather than in the normal storage mode of numerics. This saves 4 bytes for each number. Only six significant digits are saved using this method rather than the standard 13 digits.

3.5 *System management functions*

The aim of system management is to ensure error-free handling of data and to recover from some exceptional cases. The system management programs handle:

(i) Tape identification and listing: this is used to identify a tape as a scratch tape, non-system tape, program tape or a data tape. It is also possible to list the contents, either in full or partially, of any tape.
(ii) Conversion table maintenance and reporting.
(iii) Recovering a corrupted data tape. Three reasons can cause a data tape to be corrupted.
   (a) Premature end of the data collection run which could be due to power failure.
   (b) Tape parity error.
   (c) Physical tape damage.

Error detection is enabled when performing an I/O operation with the tape. This will transfer control to an error handling recovery routine. The recovery procedure itself is dependent on the cause of error. If power failure occurs; a memory dump is performed for the whole set of readings in the computer memory and an end of file mark is written on the same tape. However, for physical damage of tape a new tape is needed and a copying procedure starts from the old tape to the new one.

3.6 *Reporting*

Different reports can be produced from the system. They can be grouped into two major divisions:

(i) Data retrieval;
(ii) Statistical analysis.

In the data retrieval reports, the measured physical quantities are reported against date, time and channel number. It is possible to have selective reports based on particular channels and/or particular ranges of data. The current available statistical analysis is fairly simple and provides for means and standards deviations of different channels. More statistical measurements are underway together with graphics presentations of their values.

3.7 *Programming*

Developing real-time applications is generally recognized as the most difficult kind of programming (Henry, 1981). The HPL language was used which does not possess the necessary instructions for structured programming. However, in order to develop well structured programs, the following strategies were adopted:

full self-documented programs;

the building of a library of common routines used throughout the whole suite of programs;

Pseudo structuring (Turner, 1978) within the HPL language to implement the IF-THEN-ELSE and WHILE-DO constructs.

3.8 *User interface*

One of the main challenges in any interactive computer system is the man–machine interface. This issue is particularly apparent in real-time applications. In order to have a smooth man–machine interface in the current system the following approaches have been used (Huysmans, 1985: Sharaf Eldin, 1985):

(1) The system is a hierarchical menu-driven one.
(2) On-line help facilities are available for all functions.
(3) The user is prompted by a self-explanatory message for any input. All the user input formats are consistent.
(4) Unified terms are used throughout the system. For example although two slots in the DAS are used to house the two rain gauges, the actual slot numbers are hidden from the user and the term 'channel' is used as the only source of real-time data.

(5) Tape handling is automatically monitored by the system and all tapes used within the system have a predefined format. Formatting of scratch tapes is also done by the system.
(6) Whenever the computer receives a signal from any channel which is not considered correct, an error message is printed and this channel is automatically taken out of service until it is repaired. On repair its readings will be considered again automatically.

4. Conclusion

The paper has presented a computer system for real-time data handling. Among other features, the system can scan up to 40 channels with different scan modes and speeds. Only significant information is stored on tapes to optimize tape utilization and scan rate. The system includes conversion tables to map sensed d.c. voltage values into the actual data domain. The system is capable of detecting channel failures and/or errors. A warning message is issued and automatic restoration is established when the faulty conditions cease. The computer system is suitable for implementation on the simplest micros and has been working satisfactorily on a field study run by the authors in Riyadh city, Saudi Arabia. The study is intended to identify the effects of meteorological conditions on the propagation of millimetric radio waves used for communications.

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