A Study on the Development of a Wireless Climate Monitoring System

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Abstract: The aim of this study is to develop a wireless-controlled meteorological station. For this purpose, a microcontroller evaluating climatic factors such as air temperature, relative humidity, wind velocity, wind direction and rain was used. The data obtained from the sensors were transmitted to a climate-monitoring unit located in a control room, through a radio modem. Data, received from meteorological station, monitored on a LCD, were loaded into an EEPROM that is in microcontroller and sent to a PC via RS232 interface. All data transferred to PC also allows to save climate data over a longer period and to display data in graphs. In addition, if the air conditions come too close to peak point such as strong wind velocity, heavy rain and high temperature, an alarm is generated,.
Key words: Wireless, microcontroller, radio modem, sensor, temperature

INTRODUCTION

Climate conditions are quite important as well as soil in agricultural production. Climate conditions affect the plant growth directly or indirectly. Hence, climate conditions should be controlled carefully in agricultural production. Especially, early frosts occurring in growing season has negative effect on the plant growth. Economical yield losses are possible if the frosts occurs early or late in spring season. For these reasons, climate factors should be known well. Using meteorological station and early warning systems help us to conduct agricultural production against undesired climate conditions. By controlling climate conditions, plants can be protected from fungus or harmful organisms. Therefore, the farmers can be ready to adapt for undesired climate conditions by using these kinds of systems. Climate stations and early warning systems, which is being used widely in the developed countries, are becoming popular in agricultural fields in Turkey. Today, precision of the automation devices are increasing by developing technologies. In addition to this investment, costs are decreasing year by year. Although these systems are very useful in agricultural production, it might be encountered some problems such as inadequate technical services and spare parts.

In this study, some climate control systems that are considerably cheaper and easier to construct, and user-friendly climate monitoring system suitable for use in agricultural area are presented.

MATERIAL and METHOD

The system developed consists of two sections:

- Meteorological station unit
- Climate monitoring unit

General scheme of wireless climate monitoring system is as shown in Figure 1. Meteorological station located in field at a 3 meters height. This unit includes sensors such as air temperature and relative humidity, wind velocity, wind direction and rain. Climate monitoring unit located a control room and it received data from meteorological station through a couple of radio modems. In addition to these, received data are displayed on liquid crystal display (LCD) logged in this unit. Distance between two units is about 500 meters. In this project, 12 V_{dc} is the operating voltage. When the power cut, the power was supplied from a 12 V_{dc}/7Ah battery.

Signals obtained from all sensors are converted analogue to digital through microcontrollers and then these digital signals were sent to a master microcontroller. Master microcontroller was used for management and data saving.

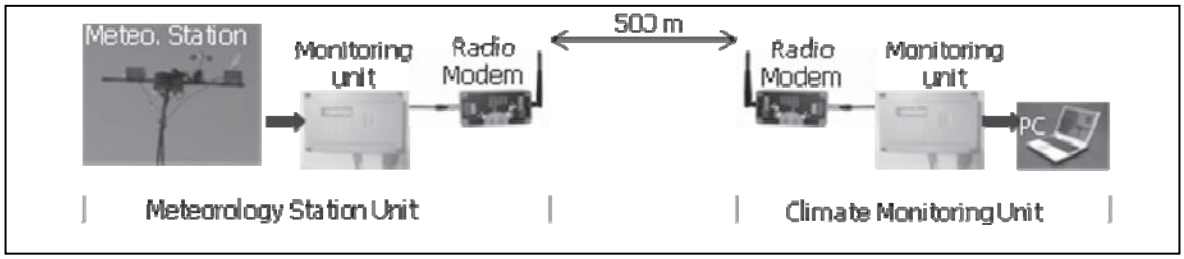


Figure 1. General scheme of wireless climate monitoring system

PIC (Peripheral Interface Controller) microcontrollers, which were manufactured by Microchip Technology, Inc., were used in the system. PIC microcontrollers are RISC (Reduced Instruction Set Computer) processors (Altınbaşak, 2000). RISC represents a CPU design strategy emphasizing the insight that simplified instructions, which "do less", may still provide for higher performance if this simplicity was utilized to make instructions to be executed very quickly. Four microcontroller units were utilized. Three of four units were located on the meteorological station to process data from sensors. Analogue signals, which were obtained from sensors, were converted to digital signals by PIC16F876 and PIC18F442 microcontroller units. All of data were sent to a master microcontroller, which is a PIC18F452. Data received were saved into EEPROM (Electrically Erasable Programmable Read-Only Memory) in PIC18F452 and were displayed on a 4X20 LCD. In addition, data were sent to climate monitoring unit in which was placed five hundred meters away, through a radio modem.

The climate-monitoring unit was located in a control room (Fig. 2). As soon as all of data have been received from meteorological station, they were saved and sent to a PC via RS232 interface. Data, transferred to PC, were observed as visual and saved in HDD (Fig. 2). A PIC16F877 microcontroller performed all of these processes. The climatic data were saved as minimum, maximum and average to EEPROM of PIC16F877 and saved data occupy 256 bytes in memory's space. The data, which were written to memory's space, were saved during two weekly periods. At the end of two weeks, all of data saved were erased from memory. Features of the microcontrollers, which were used in the study, are presented in Table 1.



Figure 2. The climate-monitoring unit

Radio modem is a frequency hopping spread spectrum modem operating in the worldwide ISM band of 2.4 GHz. The modems have over the air speed of 19200 bps while the serial interface can handle up to 57600 bps. The modems can accommodate both RS 232 and RS 485 signalling, transparent of the protocol. Standard modem with the integrated antenna can reach distances more than 2 km in outdoor, line of sight conditions. With external antennas, link distances of over 20 km are easily possible under line of sight conditions. Radio output power is 100 mW.

The SHT11 is a single chip relative humidity and temperature multi sensor module comprising a calibrated digital output. The device includes a capacitive polymer sensing element for relative humidity and a band gap temperature sensors. Both are seamlessly coupled to a 14-bit analogue to digital converter and a serial interface circuit on the same chip. The 2-wire serial interface and internal voltage regulation allows easy and fast system integration. Absolute Rh accuracy is ± 3% and temperature accuracy is ± 0.4 °C at 25 °C (Fig. 3).

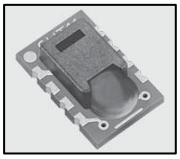


Figure 3. Temperature and humidity sensor (SHT11, Sensirion Inc.)

Table 1. Devices features

Features	Devices		
	PIC18F452, PIC18F442	PIC16F876	PIC16F877
Operating Frequency	DC-40 MHz	DC-20 MHz	DC-20 MHz
Program Memory	16K (PIC18F442) 32K (PIC18F452)	8Kx14bit Flash ROM	8Kx14bit Flash ROM
Data EEPROM Memory (Bytes)	256	256	256
On-Chip RAM (Bytes)	1536 (PIC18F452) 768 (PIC18F442)	368	368
I/O Ports	Ports A,B,C,D,E	Ports A,B,C	Ports A,B,C,D,E
Timers	4	3	3
Interrupt Sources	18	13	14
10-bit Analogue to Digital Module	8 inputs channels	5 inputs channels	8 inputs channels
Serial Communications	MSSP, USART	MSSP, USART	MSSP, USART
Parallel Communications	PSP	-	PSP
Capture/Compare/PWM Modules	2	2	2
Instruction Set	35 instructions	35 instructions	35 instructions
Instruction Set	75 Instructions	35 Instructions	35 Instructions
Packages	40-pin DIP	40-pin DIP	40-pin DIP

The rain sensor consists of three parts, funnel, box and base plate, which can be easily assembled. The rain sensor registers the rainfall by the water running through the collectors funnel into a self-emptying spoon (Fig. 4).

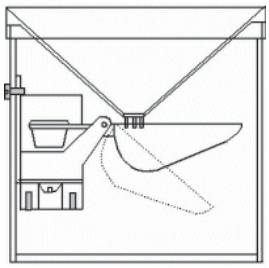


Figure 4. Rain sensor

The rain runs through the funnel of the rain collector into a self-emptying spoon, which automatically tips and is emptied as soon as there is a certain quantity of water in the rain collector for which it has been adjusted. The spoon is fitted with a magnet being kept in position by an anchor implying that the spoon is emptied by a quick tip returning immediately to collecting position for collection of a new portion of water. After one millimeter of rain, the spoon tips and empties, and the rainfall is shown on the device that is it connected to microprocessor.

A cup anemometer is used in order to measure of wind velocity. Anemometer using a range of operating principles, including mercury wetted reed switch, offer accurate and precise (1% ±0.01 m/s) methods for measuring average wind velocity, and can operate in temperatures as low as -30 °C. This sensor is very sensitive, with a threshold wind velocity of only 0.6 m/s (Fig. 5).



Figure 5. Wind velocity sensor (Delta-T, Inc.)

Wind direction sensor, which is another sensor located on meteorological station. It is notified about wind direction to system. Wind direction is measured the response of the aerodynamic body, which aligns itself with the direction of the horizontal wind. Eight opto-couples are used to perceive of wind direction. Four of eight opto-couples are indicated main paths (east, west, north and south) and other four opto-couples are indicated other paths, east north, east south, west north and west south (Fig. 6).

The sensor shaft is attached directly to the wind direction transducer, producing an output signal, which varies in binary format. Each path is represented by 3 bits address. With a number of bits next to each order, combinations of zeros and ones can be made.

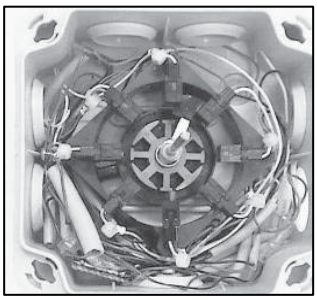


Figure 6. Internal structure of wind direction sensor

Climatic data are displayed by a general purpose alphanumeric LCD, with four lines of 20 characters. The circuits were designed in Proteus electronic circuit design program. Proteus Virtual System Modelling (VSM) combines mixed mode SPICE circuit simulation, animated components and microprocessor models to facilitate co-simulation of complete microcontroller based designs (Şahin, 2004). After the circuit schemes were drawn (Taşbaşı and Altınbaşak, 1995) and according to Çetin (1992), printed circuit boards (PCB) were prepared and circuit elements were soldered with a soldering iron on it. Microcontrollers were programmed in language C that is manufactured by CCS (Custom Computer Services Inc.).

Sensors' accuracy and precision are very important, because of obtaining data correctly. Although the accuracy of a sensor is guaranteed by design, thorough device characterization and stringent production testing, in order to achieve the best accuracy, the consideration of external factor is equally important. Optimal final system performance, however, depends on several external factors including the characteristics of the remote diode, PCB layout, external noise influence, or choice of sensor placement. Either the sensors follow a known standard response within a given tolerance, or they must be calibrated against known standards. Some of sensors used in this system such as wind velocity, wind direction and rain, were calibrated according to sensor characteristics that it published by sensor manufacturer. To measure of temperature and relative humidity is utilized SHT-11, which is calibrated by factory and therefore it does not need field calibration.

The PC software is written in Delphi 6.0 programming language (Yağımlı and Akar, 2002) and this software allows saving climate data over a longer period and display

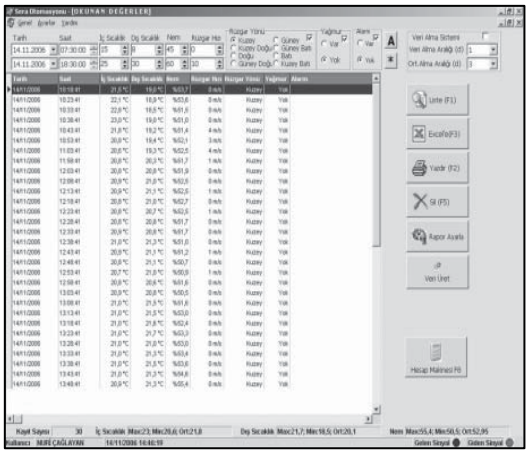


Figure 7. Data recording scene

data in graphs. The recording data can be filtering according as prefer date, time, temperature, humidity, wind velocity etc. Therefore, desired climatic data can be obtained which are from saved data in HDD (Fig. 8). In addition, graphs, which are obtaining data, can be displayed on screen as a real time (Fig. 8) and these data can be transmitted to MS Excel. Recorded data in computer can be printed, if computer is connected to a printer.

The system calculates if there is a risk for the crops' growth throughout the day. If the air conditions come too close to rigor point, an alarm is generated, such as strong wind velocity, heavy rain and high temperature. The following data are shown:

- Date & hour (local time)
- Wind speed at 3 m height (m/s)
- Wind direction at 3 m height (°)
- Air temperature at 1.5 m (°C)
- Relative humidity (%)
- Rainfall (mm/m^2)
- Alarm outputs (such as strong wind velocity, heavy rain, high temperature and relative humidity)

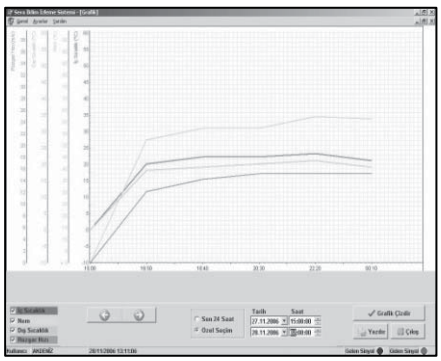


Figure 8. Graphic scene

RESEARCH RESULTS

In this study, the aim was to desing a relatively cheaper climate monitoring system for agricultural purposes. The design includes radio modems with integrated rubber duck antenna. The modems can transmit data about 500 m wide at around without any problem in suitable weather conditions by its own internal antennas. However, some problems in data transfer have been observed in extreme wheather conditions. Therefore, we can suggest that, high gain antennas should be used and then be located suitable position for effective data transmit. Modem manufacturer advices that 24 dBi antennas should be used for healthy data transmit instead of external antennas. Therefore, data transmit distance can be increase to 20 km wide. In addition, 25 channel and 65000 separated addresses can be defined. In this way, communication can be provided without any signal problem by station system. In the other hand, reliability and safety on data transmit are increased by encrypted data.

User-friendly interface was improved in designed software for simplify of using. Graphical outputs of data, transferring to MS Office software and storage of the data, which was transmitted, from climate monitoring system can be done without any problem. Statistic reports of the data, which was saved, can be obtained as daily, weekly and annual. The designed software can be developed and it can be used for different agricultural and industrial fields.

Circuit's elements are so cheap and they can be provided easily. In addition, there are wide technical supports for PIC Microcontrollers, which was used in circuits. It is important that selecting of the sensors as well as microcontrollers.

Accuracy and sensitivity are very important because of that sensors were selected according to these points. In additional, analogue to digital converters were designed special to system for wind direction, rain, temperature and relative humidity sensors.

DISCUSSION and CONCLUSIONS

Best way for data transmit is radio wave except internet connection. In the study, the success of data transmitting with wireless systems was investigated for these kind of systems. Data transmitting problems which are caused physical cable failures, can be prevented by using wireless systems. In addition, there are no cable installations in wireless, for this reason, cost and time losses are prevented.

If the system is used with photovoltaic, use of electric network is not necessary. Besides of all advantages of wireless systems there are some disadvantages like signal transmit problem because of rigors of the weather, physical barriers (trees, buildings, hills, etc.). If a high gain antenna is used, these negative cases can be omitted. Regional weathercast can be monitored using mobile phone or modem connection with GPRS. Sensors can observed be by standard internet browsers. Then the reports can be generated be automatically. Moreover, the reports can be sent be by e-mail. Optimum systems can be improved be for greenhouses using advanced systems like fuzzy logic and feed forward systems. In addition, photosynthetic active radiation (PAR) sensor, soil humidity sensor and solar radiation sensor can added be to existing system for increase to number of parameters.

Designed system is very suitable for remote control of pumping system, climate controlling of animal houses, greenhouse automation systems and controlling cold weather stores.

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