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Wireless Sensor Network Based Soil Moisture Monitoring System Design

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Abstract—**Soil moisture is the amount of water in the soil. It plays a crucial role for efficient photosynthesis, respiration, transpiration and transportation of minerals and other nutrients through the plant. Proper irrigation schedule is very critical to plant growth. This paper presents a soil moisture monitoring system which comprises of commercially available soil moisture sensor Decagon EC-5, low power nRF24L01 wireless transceiver, and MPC82G516A microcontroller. The sensed soil moisture content from the EC-5 sensor node will be transmitted to the coordinator via 2.5GHZ wireless signal. The coordinator will transmit the data to the computer using RS232 interface. The key components used in the proposed system are low cost and more flexible. The locally developed MPC82G516A microcontroller consumes low power due to its 1-T instruction time. In addition, the EC-5 sensing electrode also has advantages of easy installation and replacement in the farm. The developed system provides a better data transmitted and processed wirelessly and it can serve as a basis for efficient irrigation scheduling.**

I. Introduction

WIRELESS sensor network (WSN) is now used in broad area of applications such as industrial monitoring, healthcare application, home automation and traffic control. The implementation of wireless sensor network does not only concentrate on the applications mentioned. Farmers can take advantage of the advancement of technology. Intelligent farming is now implemented to monitor the status of the field environment. The parameters that are monitored in the greenhouse are temperature, relative humidity, light intensity and others that have effect on the quality of produce.

One factor that affects the quality of crops is the content of water in the soil, also called soil moisture. It is a major component of the soil relative to plant growth. If the soil moisture is optimum for plant growth, plants can readily absorb water. Irrigation schedule is needed to meet the increasing demand of food. Soil moisture can be categorized based on the volumetric water content. This will determine the saturation level of the soil [1]. Modern intelligent agriculture uses wireless transmission to monitor other parameters in the greenhouse such as temperature, humidity and other environmental information [2].

One primary concern on wireless transmission is the power consumption [3]. The problem with other wireless transceiver like Zigbee and Bluetooth is the power consumption. As the range of the transmission becomes longer, the module needs more power to transmit the data. Another consideration also is the cost of the system. In this paper, our group implements a low power 2.4 GHz wireless transceiver for soil moisture monitoring and irrigation scheduling in agricultural greenhouse. The wireless sensor network module was developed in our lab was low cost because our group used locally commercial components and design our own sensor and coordinator node circuit board.

II. System Overview

The WSN soil moisture monitoring system is composed of sensor node and coordinator. Fig. 1 shows the system's block diagram. The sensor node is comprises of the EC-5 sensor, MPC82G81GA microcontroller, and nRF24L01 transceiver. The EC-5 sensing electrode gives voltage input to the MPC82G516A microcontroller. The analog to digital converter (ADC) of the microcontroller will process the voltage input into digital forms and send it to nRF24L01. The sensor node transmits the data to the receiver node. The receiver node is connected to the computer via RS232 as shown in right side of Fig. 1. The transmitted data will be stored in the database to categorize the soil moisture content. This will also be the basis for water irrigation scheduling

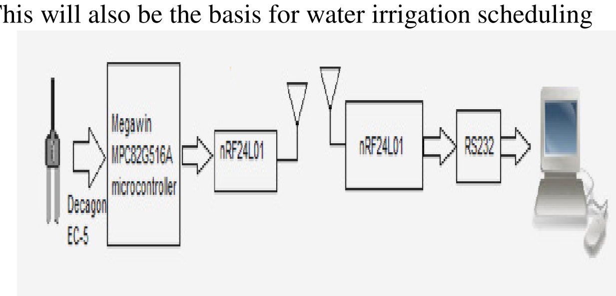

Fig. 1 WSN Soil Moisture System's Block Diagram

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III. HARDWARE DESIGN

A. Decagon EC-5 Soil Moisture Sensor

The EC-5 is a commercially available soil moisture sensor provided by Decagon Devices. It measures the dielectric constant of the soil in a frequency domain technology. It uses 70 MHz frequency to make it insensitive to soil texture [4]. It measure volumetric water content from 0 to 100% in determining the soil moisture. The volumetric water content of saturated soil range from 40% to 60%. The range varies on the different type of soil. Fig. 2 shows the EC-5 sensing electrode and enclosed circuitry.

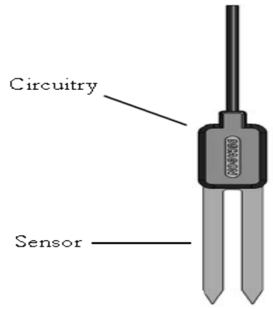

Fig. 2 EC-5 Physical Diagram [4]

The circuitry of the sensor readout comprises of three components namely: the phase detector, oscillator and the buffer [5]. The phase detector is connected to the transmission line of the sensor and the output of the buffer circuit. A low pass filter is included to give an output voltage that is constant and proportional to the difference in phase between the inputs of the phase detector. Oscillator circuit provides an output with the desired frequency. It also includes an astable multivibrator the gives continuous state to the oscillator.

The EC-5 sensor was designed to install easily in the soil. There is no need to dig the soil. To place the EC-5 in the soil, just push it until the desired depth as shown in Fig 3.

Fig. 3 EC-5 Sample Installation [4]

B. Megawin MPC82G516A

The MPC82G516A is compatible with the instruction set of 8051 microcontroller. Idle mode and Power-Down Mode are the two power saving modes of MPC82G516A that reduce the power consumption. Another feature of this microcontroller to lessen the power consumption is that it can operate in a lower speed by using the 8-bit system clock [6]. There is no need for external analog to digital converter (ADC) circuit because it has its own 10-bit ADC.

C. nRF24L01

The nRF24L01 is a 2.4GHz transceiver for low power wireless application. It has power mode and standby mode as part of the power management feature of the chip [7]. Because it has a built in state machine, it can switch to four modes of operations. In the power down mode the chip consume less current because the nRF24L01 is disabled but all the registers from the Serial Peripheral Interface (SPI) are present and can be activated anytime. In the Rx mode, the nRF24L01 act as a receiver. This is the active mode of the chip where it consumes power. The Tx mode transmit the packet. This is in the active mode when the packet is ready to transmit. It remains in the Tx mode until it finished to transmit all the packet. The standby mode minimizes the current consumption but the crystal oscillator is still active. It will enter in the standby mode if there the Rx mode or Tx mode is not active. The mode of operation is based on the single direction relaying transmission method [8] as shown in Fig 4.

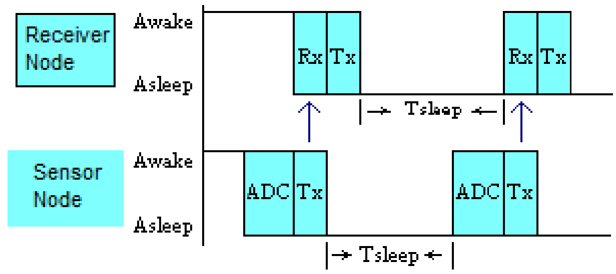

Fig. 4 Relaying Transmission

IV. METHODOLOGY

The sensed soil moisture values in this paper used volumetric water content. Volumetric water content is the ratio of the volume of water and the total sample volume of dry soil. The soil sample used to get the calibration curve of the EC-5 sensor came from Dai-Yun Organic Farm [9]. In getting the calibration curve of the EC-5 soil moisture sensor our group used the standard direct method of determining the soil moisture [10].

The analog data obtained from the characteristic curve served as the voltage input of the analog to digital converter of the MPC82G516A microcontroller. The microcontroller is programmed using Keil uVision4 IDE based on the obtained calibration curve of the EC-5 sensor. The wireless transceiver nRF24L01 is connected to the MPC82G51A microcontroller to transmit the data to the receiver node. Using Tera Term terminal emulator, the transmitted data can be viewed to the computer monitor and store in the database. The stored values will be used in making the irrigation schedule of the greenhouse. These values determined the volumetric water content of the soil. The volumetric water content will be the basis of the condition of the soil. There are four classifications that will be considered in the irrigation scheduling namely: dry soil, slightly moist soil, moist soil and wet soil. With this regards, the farmer can decide how frequent water is needed in the farm.

A low cost wireless sensor network node is illustrated in Fig 5. The network module can be integrated into different sensors. The components are locally available making it less costly with the other sensor nodes available in the market.

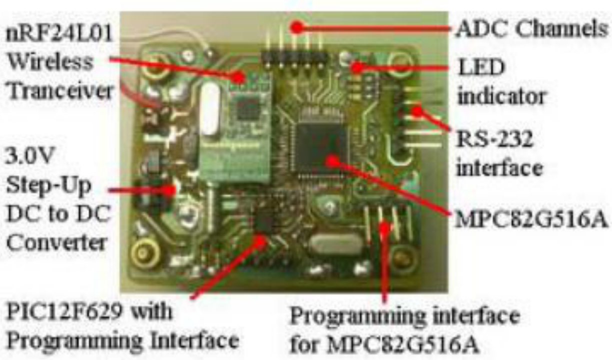

Fig. 5 Wireless Receiver Node Board [8]

A repeater node is also integrated in this wireless sensor network to extend the range of transmission distance and to resolve the line of sight problem occurring in the WSN. In order to maintain the low power consumption of the system a sleep mode and active mode is established in the repeater node. The repeater node will enter the sleep mode after the last packet is transmitted to the main coordinator.

V. Results

The result of the calibration curve is depicted in Fig 6. The accuracy of the output values were compared to the output reading of the ECH20 utility software connected to the Em5R data logger. The output reading of the two devices showed that the output voltage is proportional to the water content of the soil. The saturation level of the soil starts from 35% and 40%. These values obtained from the sensor node will serve as the basis for irrigation scheduling. Fig 7 illustrated the sample output window of the ECH20 utility software.

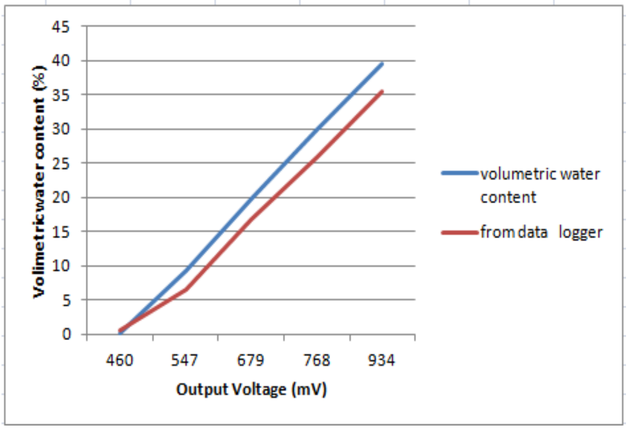

Fig. 6 Characteristic or calibration curve

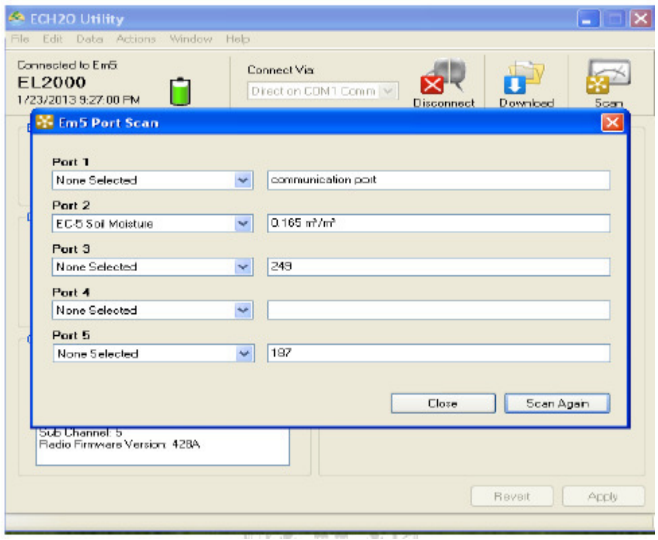

Fig. 7 Data logger Sample Output Window

The output of the wireless sensor network is shown in Fig 8. The transmitted data were displayed in the computer monitor. These values are stored in the database for developing a user interface design for irrigation schedule.

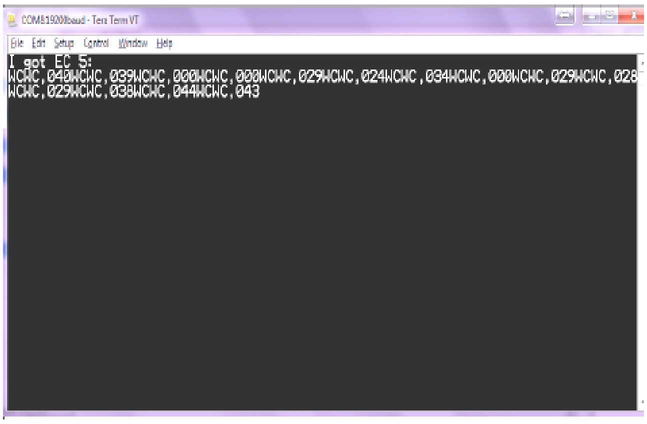

Fig. 8 Tera Term Wireless Transmission Output

VI. Conclusion

This paper implemented a low cost wireless sensor network system for soil moisture monitoring. The flexibility of the sensor node and transceiver node to integrate to other type of sensor was tested and implemented on this work. The characteristic curve proved the accuracy of the sensor in determining the soil moisture content. It also showed that volumetric water content can be used to monitor and schedule the irrigation in the agricultural greenhouses more efficiently.

VII. Future work

The volumetric water content of the soil moisture can be classified into four categories. Dry soil, slightly moist, moist, and wet are the possible classification of the soil moisture to better understand the values. Fuzzy logic approach will be use to determine the soil moisture characteristic. The design of the graphical user interface is also being considered. This system can also be integrate in a web design application or include in the parameters of the precision agriculture.

Acknowledgment

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