African Journal of Agricultural Research Vol. 6(21), pp. 4947-4953, 5 October, 2011
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR11.1231
ISSN 1991-637X ©2011 Academic Journals

Full Length Research Paper

Development of a remote sensing and control system for greenhouse applications

C. A. Olvera-Olvera[1]*, D. Duarte-Correa[2], S. R. Ramírez-Rodriguez[3], P. D. Alaniz-Lumbreras[1], A. Lara-Herrera[4], D. Gómez-Meléndez[5], J. I. Aguilera-Soto[6], M. A. Araiza-Esquivel[1], J. J. Villa-Hernández[1], E. Gonzalez-Ramirez[1] and G. Herrera-Ruiz[2]

[1]Doctorado en Ciencias de la Ingeniería, Unidad Académica de Ingeniería Eléctrica, Universidad Autónoma de Zacatecas, Jardín Juárez 147, Centro Histórico, Zacatecas, C. P. 98000, México.
[2]Investigación y Posgrado de la Facultad de Ingeniería, Universidad Autónoma de Querétaro, Cerro de las Campanas S/N, Col. Centro, Querétaro, C. P. 76010, México.
[3]Tlachia Systems S.A. de C.V., Calle 13 de septiembre No.1, Niños Héroes, C. P. 76010, Querétaro, México.
[4]Unidad Académica de Agronomía, Universidad Autónoma de Zacatecas. Jardín Juárez 147, Centro Histórico. Zacatecas, Zacatecas, C. P. 98000, México.
[5]Universidad Politécnica de Querétaro, Carretera Estatal 420 S/N, El Rosario, C.P. 76240, El Marqués, Querétaro, México.
[6]Unidad Académica de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Zacatecas, Carretera Panamericana Zacatecas-Fresnillo Km 31.5, El Cordovel Enrique Estrada, Zacatecas, 98500, México.

Accepted 3 September, 2011

Real-time monitoring provides reliable, timely information of crop and soil status, important in taking decisions for crop production improvement. This work presents a real-time monitoring and control system for climatological variables in greenhouse. The system has wireless communication capabilities, which allow it to cover extensive surfaces in real-time, without extra resources. The system implementation is based on the micro controllers "PIC18F4550" and "DSPIC 30F5011", user interface was programmed under LINUX. The proposed system performance was compared with commercial Data Loggers, readings present a linear adjustment with R^2=0.9656.

Key words: Zig bee, micro controllers, remote monitoring.

INTRODUCTION

Currently in Mexico, 6,000 greenhouses operate (Hernández, 2008), while in 1990 there were approximately 50 ha, with some sort of vegetable production in a greenhouse, increasing this surface in 2001 to 950 ha. The growth has been to the proportion of 814 ha per year according to the Mexican Greenhouse Vegetable Growers Association (AMPHI for its acronym in Spanish, 2003). According to data collected among the growers, tomato represents 70% of the volume produced in greenhouses, cucumber 10%, pepper 5%, and other crops correspond to 15% (Mejía, 2007). The production of greenhouse crops is one of the most modern techniques for agricultural production. The main advantage of the greenhouse before the traditional method in the open air is their capacity to establish a barrier between the external environment and the crop. This barrier, based on the permeability of its borders, protects the plants from drastic external fluctuations by generating a microclimate with characteristics that tend to be optimal, ensuring the sustainable growth of each crop. This barrier protects the crop from wind, rain, plagues, diseases, herbs, and animals.

Moreover, this protection ensures the grower the control of temperature, the amount of light, and the possibility to effectively apply chemical and biological

*Corresponding author. E-mail: colvera@uaz.edu.mx. Tel: +52 (492) 9242 243, 9229 699.

control of the crop. Under greenhouse conditions, higher crop performance can be achieved, and a lower environmental impact derived from reduction of water use, as well as of fertilizers, is generated (Rodriguez, 2000), apart from the possibility of keeping production stable in any season, which ensures the constant supply of fruits or vegetables in seasons where it is not possible to harvest them with the traditional method (Fajardo, 2007). The greenhouse production includes several technologies. Some of them are applied to force the natural cycle of plants, starting with hybrid or genetically modified seeds (transgenic crops) resistant to the most common pathogens and which produce fast-growing vegetables with long lives. These systems let us keep the plan in ideal conditions to produce 24 h a day, 365 days a year. Greenhouses also generate an advance in regards of quality, given the control of plagues, the reduction in fertilizer consumption, and maximum use of irrigation water (Diaz, 2008). The existing technology in Mexico in the greenhouse area is mainly transferred from Israel, Spain, France, Holland, and Canada (Ocaña, 2007). It is used in different processes like climate control systems, irrigation and fertilizer injection, heating, CO_2 injection, etc.

Given the complexity of the greenhouse as a system integrating the crop, weather, mechanical structures, etc.; as well as the complex dynamics of the weather inside of it (Bennis et al., 2008; Frausto et al., 2003; Yürekli et al., 2007), it is necessary for growers to have the necessary knowledge and the proper technology to increase their production. The climate control in a greenhouse is one of the common tools to stimulate production. To control the climate, it is useful knowing how meteorological factors affect the crop, as well as the physical and chemical variables inside the greenhouse. Wired acquisition and control systems for greenhouses are impractical because greenhouses can be big enough to cover many acres, so the cost of installation and maintenance is too high (Blacke, 2002). This document shows the development of a remote sensing and control system for the intensive production of protected environments. The system monitors the critical variables in the horticultural production in greenhouses such as temperature and relative humidity inside and outside. This system shows the use and application of commercially available wireless technology applied to the measure of physical-chemical parameters. Finally, the comparison of the performace of this system against existing equipment on the market is presented.

MATERIALS AND METHODS

Tests were carried out between June 18 and July 9, 2010 in the community of Ojocaliente in the state of Zacatecas, México. The system was installed in macrotunnels covered with “milky white” plastic, where chile ancho was planted, with “Birch” in the soil and plastic mulch. Each macrotunnel is 50 m long, 6 m wide, giving a total surface of 3,600 m^2 (12 tunnels). They are 5.6 m high in their highest peak and 2.2 m in the base of the arch. Two field stations and a control stations were installed. The first greenhouse module monitored temperature and relative humidity. In the second greenhouse module, the second field station was installed, which monitored the temperature in the plastic cover.

Both field stations were connected to a central station 150 m apart. In order to validate the system, the greenhouses installed commercial monitoring systems. A Data Logger with built-in temperature and a relative humidity sensor were installed for the first module, and an external temperature and relative humidity sensor were installed for the second module. Both Data Loggers are Watch Dogg, models 150 and 125 respectively. Temperature and relative humidity sensors of the first module were installed 1.5 m apart from the plastic mulch system. The temperature sensor of the second module was installed in direct contact with the greenhouse cover. The system and Data Loggers were configured to obtain data every 5 min.

Monitoring and remote control system

The developed system is a monitoring and control station network named field stations. These stations communicate wirelessly with a main station called control station, forming a communication network (Figure 1). This system is focused on measuring the different analog signals, which represent atmosphere or physical variables of the protected agriculture environment, like temperature, relative humidity, etc. This communication network allows the control station to handle from 1 up to 50 field stations. Each station has a response time with the control station of 20 ms.

Control station

The control station depends on a communication module with USB protocol, a personal computer (PC), a power source, and a wireless module (Figure 2). The purpose of the control station is to be the concentrating device to make communication happen between the user’s interface (PC) and the field stations, forming a data network. Such network operates with star topology, where the data flow from the sender to the master concentrator (control station).

USB communication module

On the card a microcontroller is in charge of managing the USB communication with the computer and the RS-232 communication protocol with the transceiver. The microcontroller used was the PIC18F4550 (Microchip Technology Inc., 2009), since it has good processing speed with a clock of up to 48 MHz and USB interface. The communication card needs voltage levels conditioning, for which an LM7805 voltage regulator (Semtech Electronics LTD., 2002) was used for the microcontroller to work and a MAX 232 circuit (Texas Instruments Inc., 2002) for serial communication. The USB communication module is separate from the wireless module in order to locate the transmission and reception antenna in a better place, that is, in a place higher than the control room. To cover the distance between the modules, it was necessary to place an RS-232 communication channel. For microcontroller programming, a PCWH Compiler (Custom Computer Services Incorporated, 2008) was used. The microcontroller hardware was configured to work at 48 MHz with a prescaler, the serial communication speed is 57,600 bps (bauds per second), without parity, without one stop bit,

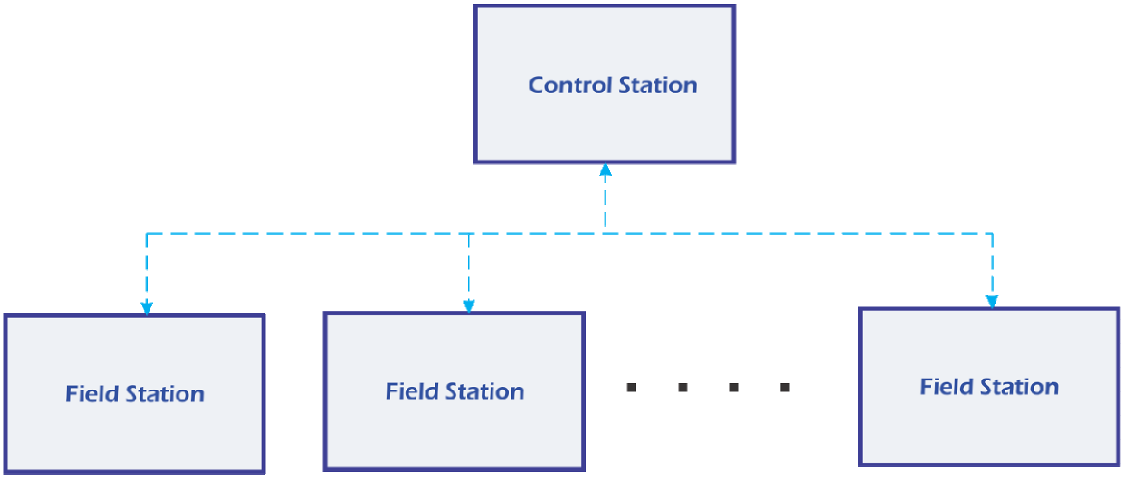

Figure 1. Communication network of the developed system.

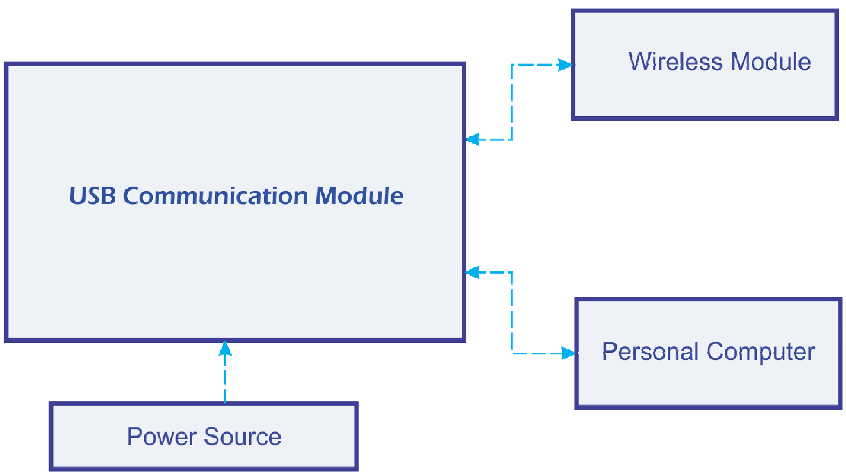

Figure 2. Block diagram of the control station.

without "watch dog."

Personal computer

The computer system was the user's interface, which allows the visualization of all variables in each station. Data are updated each second and can be graphed. The system records up to each minute all input and output variables. Moreover, it keeps an incidence record that shows when the communication starts, when an alarm goes off, or if a relay is activated. The information history is used to predict the greenhouse behavior in displayable graphics per day or per week.

Power source

The power source in charge of making the control station and the Field Module work comes from a solar or alternative current Power Source. This depends on the connection possibilities in the field. The system operates with a supply voltage of 110 V and the Stations (Control and Field) operate with a voltage of 12 V.

Wireless module

The wireless modules have a radiofrequency transceiver linked to an asynchronous serial port. The module can communicate with any UART type compatible logic and voltage (Ali et al., 2004) or through a level converter to any serial device through this serial port. Devices with serial interface can communicate directly with the radiofrequency modules. Serial communications depend on two UART units that need to be configured with compatible features (parity, bauds, start bits, stop bits, data bits). The wireless module has a 5 V regulator that supplies a MAX232 circuit to adjust the voltage levels, and a 3.3 V regulator that supplies the wireless transceiver. A DB9 female connector was used given that it is a DCE (Data Communications Equipment) unit, according to the EIA (Electronics Industries Association) RS-232. The wireless transmission via radiofrequency is carried out through an Xbee Pro

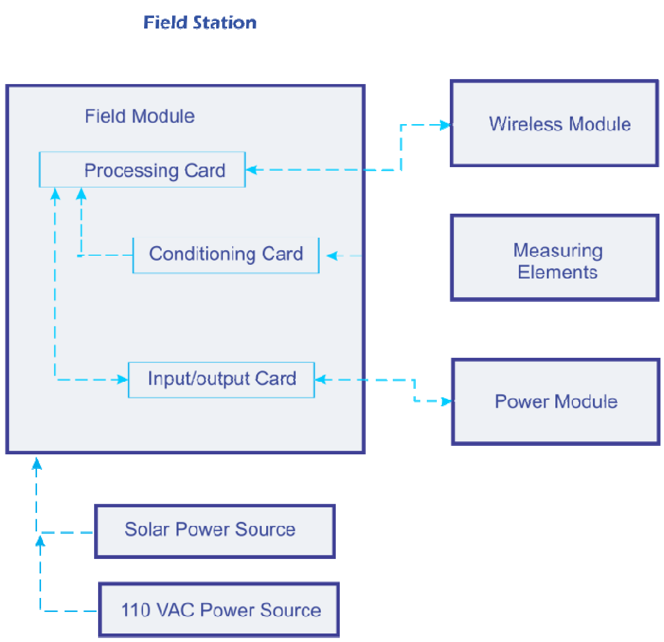

Figure 3. Block diagram of the field station.

802.15.4 Multipoint circuit, which allows us to handle distances of up to 150 m.

Field station

The purpose of the field station is to continuously obtain the voltage values of the analog channels. It includes a wireless module, measurement elements, a power module, a supply source (either alternate current or solar), and a field module, which stores the control and acquisition wiring (Figure 3). The wireless module has to be located in a place that is 2 m high to facilitate the wireless transmission and avoid obstacles. The wireless module of the field station is the same as that used in the control station. This way, we are looking for the system to be totally compatible and that it can be replaced between the field stations and the control station. The field station can have or not have the measuring elements (sensors) and work only as a remote control to activate the actuators like valves, engines, pumps, fans or engines for windows.

Field module

The field module is comprised of a processing card, one input/output card, a conditioning card, and an activation card (Figure 3).

Processing card

The processing card has a microcontroller that executes a program in charge of managing the wireless communication, the acquisition of data, diffuse control, the activation of digital outputs, and additional tailored functions. The microcontroller used is the DSPIC30F5011. For programming, the same methodology as the control station was used, following the requirements set out in the description. A PCWH compiler was also used.

Conditioning card

For signal conditioning, two types were proposed: one is a passive filter and the other is an active filter. Both are low pass filters; that is, it will attenuate the high frequency components for our system, which tend to be responsible for unwanted readings. The conditioning card has six active filters that can be configured by changing the resistances and/or capacitor's values. Each processing card can have two conditioning cards connected, with their 10 pin ports.

Input/output Card

This card, through its two ports; an input and an output port, can manage different voltage values. The eight digital inputs are opto-isolated though the PS2501 circuit. The eight outputs include a relay that can manage up to 5 A or 110 V.

RESULTS

The developed system shows the following features: six 0 to 5 V analog inputs, six 4 to 20 mA analog inputs, eight 1 to 24 V digital inputs, eight outputs with 1 A to 250 V relays, a configurable RS-232 port, and wireless Zig bee communication of up to 150 m. The system records each minute all input and output variables, and it saves an incidence record that shows when the communication starts, an alarm goes off or a relay is activated. For this document, a sampling time of 5 min was programmed. The implementation of the prototype was carried out in different stages. The USB communication card where you can see different peripherals is shown in Figure 2. The system is based on the LINUX operating system, in which the user's interface allows the observation of the behavior of the variables measured with graphics on the same home screen. This screen lets you see the field stations' activities through a virtual visual indicator and a box where it marks the system's activity. You can configure alarms for high or low levels, modify sampling times, activate digital outputs and save an electronic log.

The results obtained in the comparison between the developed system and the commercial Data Loggers show that the differences found depend mainly on the difference in the resolution that both systems handled. The Data Logger has a 0.5℃ resolution, while the system has a 0.1℃ resolution. The relationship in the reading of both systems for the first installed field station, macrotunnel one, is as follows: For the room temperature sensor, the readings show a linear adjustment with R^2 = 0.9656 (Figure 4). For the relative humidity sensor, the readings show a linear adjustment with R^2 = 0.9912 (Figure 5). For field station two, installed in the adjoining macrotunnel, the readings of the cover's temperature show a linear adjustment with R^2 = 0.9837 (Figure 6). To

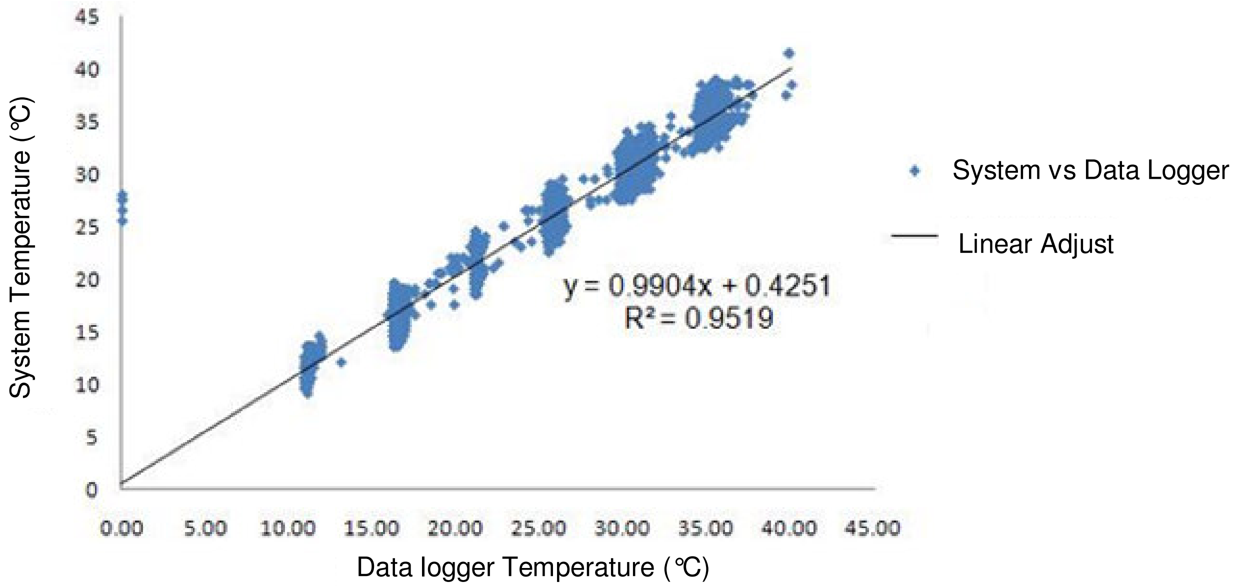

Figure 4. Relationship between the room temperature in a macrotunnel, determined with the proposed system and with a commercial data logger.

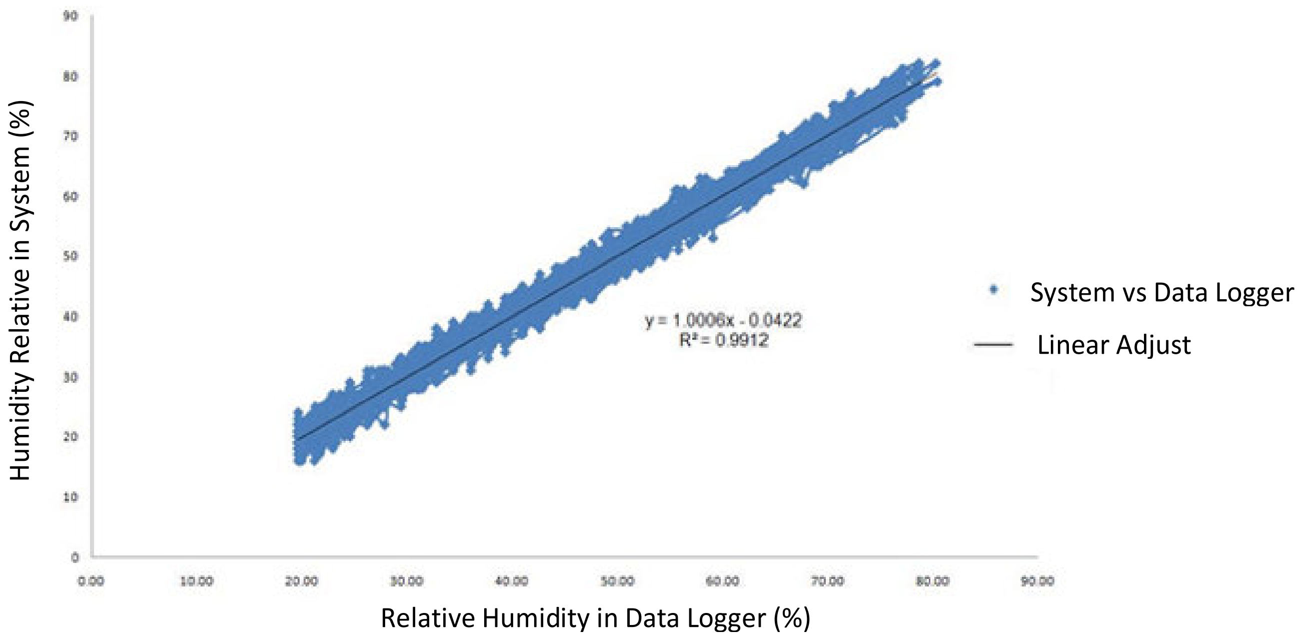

Figure 5. Relationship between the Relative Humidity of the environment in a macrotunnel determined with the proposed system and with a commercial data logger.

collect data of the commercial Data Loggers, a trip through both tunnels had to be made every 9 days. You had to take a laptop to download the data; the disadvantage is that only one external sensor could be connected (for the case of the second macrotunnel) per Data Logger. The collection of data from our system was carried out in real time, with graphic visualization of the variables, wireless, and only in one point for both macrotunnels.

DISCUSSION

The centralized control acts like a wiring concentrator,

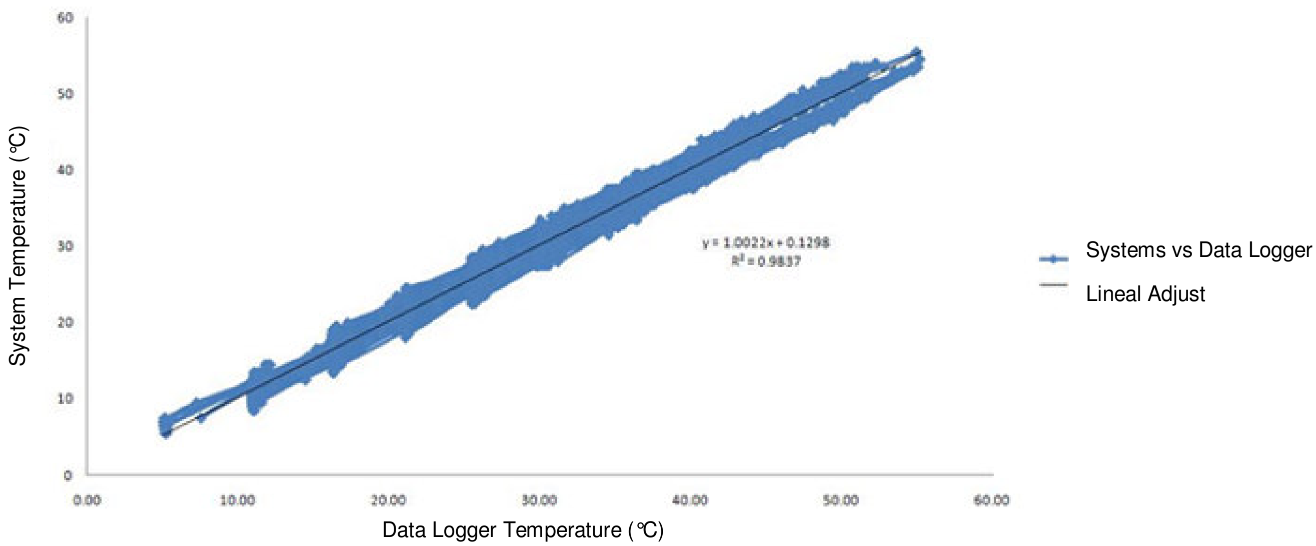

Figure 6. Relationship between the temperature of the plastic cover in a macrotunnel determined with the proposed system and with a commercial data logger.

where the information packages are directed through the master concentrator towards their destinations. This way, collisions are avoided and the interrupted connections do not affect the rest of the network. The communication of the control station to the field stations is carried out in a broadcast type wireless transmission (transmission of a data package that will be received by all devices in one network). The network's topology, as well as the data transmission, allows the software to manage the field stations necessary until a practical limit of 50 remote terminals. This, given the individual response time of each station of approximately 20 ms, it is hoped to have a sample of all field stations' variables in 1 s, in a way that they can be updated and shown in the user's interface screen.

For this case in particular, the proposed system allowed a saving of 376 m (US$80.00 each 100 m) of twisted pair cable for the two field stations wiring. In addition, the saving of four RS-232/RS485 (US65.00 each one) adapters for the data transmission to distances longer than 1200 m, generating savings for the user of US$300.0 in cable and US$260.00 in adapters excluding the cost of installation and maintenance.

Conclusions

The communication administration and control is carried out by a centralized unit with the help of a computer, which is the control module and communicates wirelessly with the field modules that record the information of its measuring elements, forming a communication network among these modules, which mainly include a micro-controller programmed in language C and a wireless transceiver. The measurements taken with the system show that it has a high signal quality with a 97% successful transfer of frames between the control station and the field stations. This system has configuration and versatility advantages, compared with the commercial wired systems. The system shown allows remote and safe monitoring, with information in real time. The versatility consists in connecting any type of sensor to the field stations, so that it is necessary only to condition the electric signal of the sensor outside the field station card.

The versatility of the system compared with the commercial equipment allows the data to be kept in real time. A user who wants to obtain the Data Loggers' data would need to walk almost 50 m to download the data. Knowing the state of the variables at that time at least four times a day would require the user to walk almost 2 km per day. For intensive production systems, it is very important to visualize the behavior of the variables in real time to take prevention and/or control measures. The delay of information can cause problems for both the plant and the spreading of plague, or even the loss of the crop. The system could be applied to other types of intensive agricultural production systems like fish production or the monitoring of parcels in the open air, where the current humidity of the soil could be monitored (matric potential).

REFERENCES

Ali L, Sidek R, Aris I, Ali A, Suparjo BS (2004). Design of a micro-UART for SoC application. Comput. Electrical Eng., 30: 257-268.

Bennis N, Duplaix J, Enéa G, Haloua M, Youlal H (2008). Greenhouse climate modelling and robust control. Comput. Electron. Agric., 61: 96-107.

Blake R (2002). Introducción a los sistemas de comunicación. In: Sistemas Electrónicos de comunicaciones. Thomson, 2da. Edición. México.

Díaz ML (2008). La producción intensiva, futuro de Aguascalientes.

Fajardo D (2007).El gobierno del estado impulsa la agricultura bajo ambiente controlado.Notas del Gobierno de Zacatecas. Secretaría de Desarrollo Agropecuario (SEDAGRO).

Frausto HU, Pieters J, Deltour J (2003). Modelling greenhouse temperature bymeans of auto regressive models. Biosystems Engineering, 84: 147–157.

Gómez-Melendez D, López-Lambraño A, Herrera-Ruiz G, Fuentes C, Rico-García E, Olvera-Olvera C, Mercado-Fernández,T, Alaniz-Lumbreras D, Verlinden S (2011). Fuzzy irrigationgreenhouse control system based on a field programmable gate array. Afr. J. Agric. Res., 6(11): 2544-2557.

Hernández V (2008). Operan en México seis mil hectáreas de invernaderos. El Siglo deTorreón. Sección de Finanzas.

Mejía CD (2007). Órgano Informativo de la Secretaría de Fomento Agropecuario. La producción de cultivos en invernaderos. La mejor alternativa para invertir en México.

Microchip Technology Inc (2009). PIC18F2455/2550/4455/4550. Data Sheet. Chandler, Arizona. 426 p.

Ocaña IL (2007). Pros y contras de la agricultura protegida.Imagen Agropecuaria.

Rodriguez I (2000). Ahorro de agua y necesidades hídricas de los invernaderos. Agro Revista Industrial del Campo, p. 49.

Olvera-Olvera CA, Olvera-González JE, Mendoza-Jasso J, Peniche-Vera R, Castañeda-Miranda R, Herrera-Ruiz G (2009). Feed dosage and ammonium control device based on C/N ratio for a zero-discharge system. Int. J. Agric. Biol., 11: 173-177.

Semtech Electronics LTD (2002). LM7808. Hoja de datos. Hong Kong. p. 2

Soto-Zarazúa GM, Herrera-Ruiz G, Rico-García E, Toledano-Ayala M, Peniche-Vera R, Ocampo-Velázquez R, Guevara-González RG (2010). Development of efficient recirculation system for Tilapia (*Oreochromis niloticus*) culture using low cost materials. Afr. J. Biotechnol., 9(32): 5203-5211.

Texas Instruments Inc., (2002). MAX232. Data Sheet. Dallas, Texas, 17 pp.

Yürekli K, Simsek H, Cemek B, Karaman S (2007). Simulating climatic variables by using stochastic approach. Build. Environment, 42:3493–3499.