DESIGN AND IMPLEMENTATION OF SENSOR NODE FOR WIRELESS SENSORS NETWORK TO MONITOR HUMIDITY OF HIGH-TECH POLYHOUSE ENVIRONMENT

B. P. Ladgaonkar and A. M. Pawar
Embedded Technology and Instrumentation Laboratory
Post Graduate Department of Electronics, Shankarrao Mohite Mahavidyalaya,
Akluj Dist. Solapur – 413 101 (M.S.)

ABSTRACT

Wireless Sensors Network is a novel field shows tremendous application potential. To monitor the environmental parameters of high-tech polyhouse the Wireless Sensors Network (WSN) is developed. The heart of this ubiquitous field is the Wireless Sensor Node. Moreover, the field of microcontroller based embedded technology is innovative and more reliable. Therefore, based on an embedded technology and the RF module Zigbee a wireless senor node is designed about highly promising AVR ATmega8L microcontroller and implemented for WSN development. Recently, the modern agriculturists are demanding sophisticated instrumentation for measurement and control of environmental parameters of the polyhouse. To enhance crop yield one has to provide controlled environment to the crop. The humidity is important parameter, which plays vital role on the crop yield. Therefore, a Wireless Sensors Network (WSN) is designed and implemented for monitoring of humidity of polyhouse and the results of implementation are interpreted in this paper.

KEYWORDS

Wireless Sensors Network, Embedded Systems, Zigbee, Humidity, Polyhouse environment.

1. INTRODUCTION

Wireless Sensors Network (WSN) is the ubiquitous field showing wide spectrum of applications in various sectors [1]. It combines sensing, computation and communication also [2]. It consists of the sensor nodes, which are networked, by deploying network topologies, with each other and also with the based station. Majority of the applications of the WSN lies in information sensing, real time tracking, monitoring of the various physical parameters of industrial, environmental, health, automobile etc sectors [3]. This technology also helps to record the meteorological parameters. The architecture of the WSN is deployed by Chintalapudi [4] for monitoring the health parameters and suggested new architecture, NETSHM, wherein the constraints of network programming are minimized. Focusing on the investigation of the application potential Das et al [5] have reviewed this new domain of research, extensively. Wireless Sensor Network (WSN) is an emerging field of electronics ensuring the research of applied nature. Therefore, many researchers show interest in development of Wireless Sensor Network for various applications. Zhu et al [6] have designed Wireless Sensor Network system based on Zigbee compliant RF module CC2420. Moreover, they deployed the 8051 microcontroller for each node. A distributed control system based on Wireless Sensor Network is developed and presented by Pereira and Cugnasca [7] in 2005. In order to monitor the concentration of hydrocarbons particularly, in chemical industries a Wireless Sensor Network based system is designed by Kane et al[8] and interpreted the results, which could support the optimization of production. Mahfuz and Ahmed reviewed the field of Wireless Sensor Network and suggested its suitability for environmental protection [9, 11]. They reported features of both Zigbee as well as Bluetooth technologies. Erdongan et al [10] have developed Wireless sensor to monitor a pressure inside a tyre of automobiles. Zigbee technology supports IEEE 802.15.4 protocol and operates in the frequency of 2.4 $GH_{Z,}$ ISM band [11]. Emphasizing the low power requirement of Wireless Sensor Network, Francisco et al have employed WSN for medical applications [12]. Li and

Yuan have reported a waste water monitoring system based on Wireless Sensor Network [13]. Merrett et al have attempted to overcome the limitations on designing sensor nodes and reported an algorithm 'Information manageD awarE ALgorithm for sensor network (IDEALS) Systems' for WSN [14]. Moreover, the researches have also reported different protocols suitable for establishment of Wireless Sensor Network [15-17]. In short, one can say that a Wireless Sensor Network technology is a new and emerging field of research. Thus, many researchers investigated the Wireless Sensor Network and reported its suitability for environmental monitoring and control [18-20]. The sensor senses environmental parameters and sends the sensed data to a distant base station through which one can access the information for further use. Each sensor node powers with separate battery and it consumes very low power. Therefore, it helps to overcome the drawback of high power requirement of wired sensor network. Presently, there are two types of technologies used for the nodes of Wireless Sensor Network *viz* Zigbee and Bluetooth. On extensive study of characteristics of Zigbee and Bluetooth technology, it is found that Zigbee technology is mostly reliable and suitable for indoor as well as outdoor sensor network. It provides a transmission speed typically 250 kbps over a range of 10 to 100 m and can be configured in star, mesh or peer-to-peer topologies. In short, the field of development of Wireless Sensor Network is a novel and ubiquitous. On literature survey, it is found that, the reports on development of WSN for high-tech agricultural applications are rather rare. Therefore, the work of development of microcontroller based wireless sensor node for Wireless Sensor Network, based on Zigbee technology for precision agriculture is undertaken and results of the design as well as implementation are reported.

2. THE HARDWARE

With the view to develop sophisticated electronic instrument for agricultural applications, it is proposed design the Wireless Sensors Network. The hardware of the typical sensor node, at a glance, is depicted in Figure 1. Moreover, the schematic of the circuit is presented in the figure 2. As shown in figures 2.a & 2.b, broadly the system may be classified into following two sections.

- Wireless Sensor Nodes
- Base Station

Typically, the hardware of one sensor node is described in this paper.

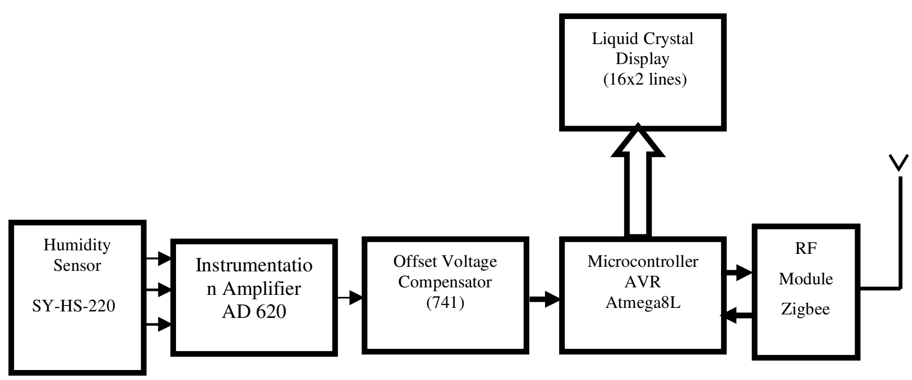

Figure 1 Block diagram of the Wireless Sensor Node for WSN for Polyhouse applications

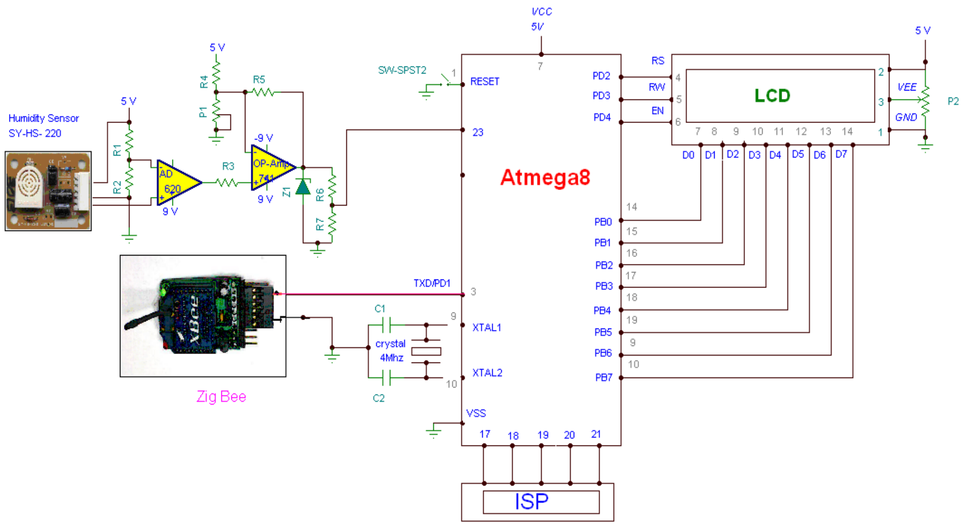

Figure 2.a: The schematics of the circuit of the wireless sensor node.

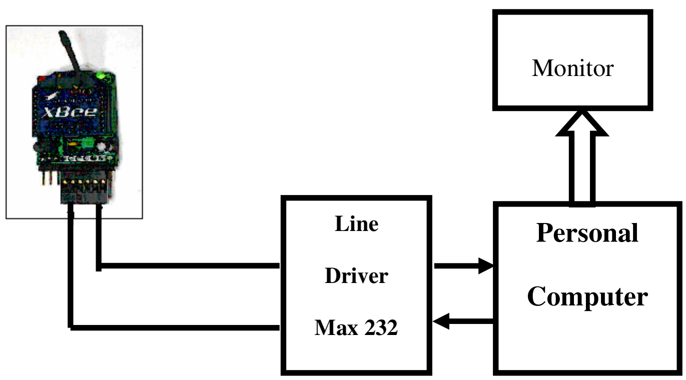

Figure 2.b: The schematics of the circuit of Base Station.

2.A Wireless Sensor Node :

The heart of Wireless Sensor Network (WSN) is the Sensor Node. Deploying embedded philosophy, a wireless sensor node is designed about advanced microcontroller, AVR Atmega8L and the details of this design are described. As depicted in the figure 2.a, the wireless sensor node is microcontroller based embedded system. It is designed to detect and compute the values of the physical parameters in engineering units. It comprises smart sensor, signal conditioner, data acquisition system, the microcontroller, display unit and power supply section. Moreover, to ensure the wireless communication the RF module Zigbee is employed.

The system is designed to monitor the humidity of polyhouse environment. Therefore, both analog as well as digital part of the hardware reflects the detection and measurement of humidity in RH%

2.A.a) The Humidity sensor module [SY-HS-220]:

To measure humidity, amount of water molecules dissolved in the air of polyhouse environments, a smart humidity sensor module SY-HS-220 is opted for the system under design. The photograph of humidity sensor SY-HS-220 is shown in the figure 3. On close inspection of figure 3, it is found that, the board consists of humidity sensor along with signal conditioning stages.

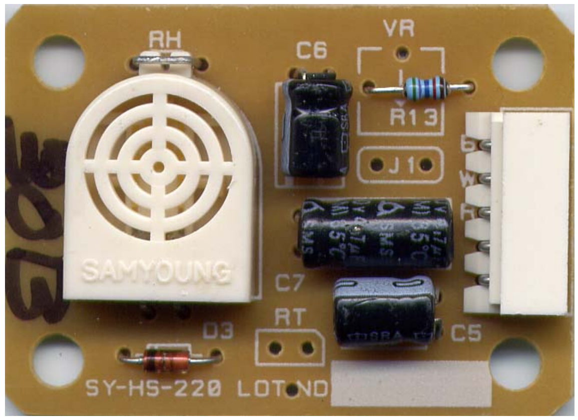

Figure 3: Humidity Sensor SY-HS-220

The humidity sensor is of capacitive type, comprising on chip signal conditioner. However, it is mounted on the PCB, which also consists of other stages employed to make sensor rather more smart [21]. The PCB consists of CMOS timers to pulse the sensor to provide output voltage [22]. Moreover, it also consists of oscillator, AC amplifier, frequency to voltage converter and precision rectifiers. Incorporation of such stages on the board significantly helps to enhance the performance of the sensor. Moreover, it also helps to provide impediment to the noise.

The humidity sensor used in this system is highly precise and reliable. It provides DC voltage depending upon humidity of the surrounding in RH%. This work with +5 Volt power supply and the typical current consumption is less than 3 mA. The operating humidity range is 30% RH to 90% RH. The standard DC output voltage provided at 25^0C is 1980 mV . The accuracy is ± 5% RH at 25^0C. As shown in the fig 3, it provides three pins recognized as B, W and R. The pin labeled W provides the DC output voltage, where as the pin labeled B is ground. The VCC of +5V is applied at the pin R. The humidity dependent voltage is obtained and subjected for further processing.

2.A.b) Signal Conditioner:

As stated earlier, a smart humidity sensor SY-HS-220 provides the D.C. output voltage (mV) linearly proportional to the humidity in RH%. To pick up this signal and to amplify the same, an instrumentation amplifier AD 620 is employed. Fig. 2 (a) depicts the circuit designed about AD 620. This is programmable instrumentation amplifier exhibiting very high input impedance, which could really help to isolate the sensor from remaining analog part of the hardware.

2.A.c) Offset Voltage Compensator:

It is found that humidity sensor SY-HS-220 produces the Dc output voltage 1980 mV at 25^0C and 60% RH [21]. This voltage is the offset voltage (V_{offset}). Therefore, one has to compensate this offset voltage. The offset voltage compensator is designed about operational amplifier 741 and presented in Figure 2(a). The compensating voltage (V_C), equal in magnitude and opposite in sign to that of offset voltage (V_{offset}), is added so that the offset voltage will be compensated. The amplifier has unit gain. Hence, the output voltage (V_0) can be expressed as

$$V_0 = V_{RH} + V_{offset}$$

$$\therefore\ V_{RH} = V_0 - V_{offset} = V_0 - V_C. \qquad \ldots(1)$$

Where, V_{RH} is the humidity dependent voltage

At normal conditions the output voltage is equal to offset voltage. Therefore, the resulting voltage is zero. However, for all conditions other than normal the output voltage V_0 deviates from the offset voltage. Therefore, it results the humidity dependent DC voltage V_{RH}. This voltage is in mv range. This V_{RH} is then subjected to the microcontroller ATmega8L for digitization and further processing. However a care is taken, to limit this voltage below 2.5V for condensation of water. The circuit designed for this purpose is depicted in fig. 2(a).

2.A.d) Data Acquisition System:

Designing of DAS, is highly important and tedious job for instrumentation design. Generally, it consists of the blocks such as multiplexer, ADC etc. However, present embedded system is developed about the advanced microcontroller, AVR Atmega8L, which has promising on chip resources. The 6 channel ADC with 10-bit resolution is available in this microcontroller. Moreover, the microcontroller it self has the source of reference voltage of 2.56V [23]. Deploying this on-chip facility of ADC the digitization of the signal is carried out.

The AVR ATmega8L has six channels, multiplexed analog to digital Converters, each of ten bit in resolution. Deployment of such on chip facilities results in the reduction of not only in the hardware and software complexity, but also in the cost. Moreover, it enhances the reliability embedded system.

The port C has this alternate function. The pin number PC0 to PC5 respectively provide analog inputs ADC0 to ADC5. Internal multiplexer can be used for channel selection [23].

Here, in this hardware the channel ADC0 (PC0 Pin No. 23) is used as analog input. The SFR ADCMUX (ADC multiplexer selection) is configured. It is known that AVR microcontroller has internal reference voltage facility [23]. Therefore, by selecting REFS1:0 bits to 11, the internal source of reference voltage of 2.56 volt is enabled. By default digital data is right justified which gives preciseness in the result. The left justified data causes the reduction in the preciseness. The MUX bits of ADCMUX register are configured as 000 for analog input ADC0.

The ADC normally requires three handshaking signals, SC, EOC and OE, particularly for off-chip ADC. However, this microcontroller is having on-chip ADC, such control signal can be internally generated. The ADCSRA is employed for the handshaking of these signals, through proper software routine.

When an ADC conversion is completed, the result is found in the two ADC data registers ADCL and ADCH [Figure 4]. Two successive read operations will read the lower byte and higher byte data. The ADCL consist lower byte and ADCH consist higher bytes of converted digital data. These two unpacked byte are packed by using the relation.

$$ADC = (256 * ADCH) + ADCL \quad \text{…. (2)}$$

Bit	15	14	13	12	11	10	9	8	
	–	–	–	–	–	–	ADC9	ADC8	ADCH
	ADC7	ADC6	ADC5	ADC4	ADC3	ADC2	ADC1	ADC0	ADCL
	7	6	5	4	3	2	1	0	
Read/Write	R	R	R	R	R	R	R	R	
	R	R	R	R	R	R	R	R	
Initial Value	0	0	0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	

Figure 4. The 10 bit Data Register of AVR ATmega 8L

2.A.e) The AVR ATmega 8L Microcontroller:

As a need of an embedded system, the microcontroller AVR Atmega8L is used as the computing device. Therefore, the salient features of this microcontroller are mentioned. Figure 5 depicts the pin description of the AVR ATmega 8L microcontroller.

The AVR core combines RISC instruction set with 32 general-purpose working registers. All the 32 registers are directly connected to the

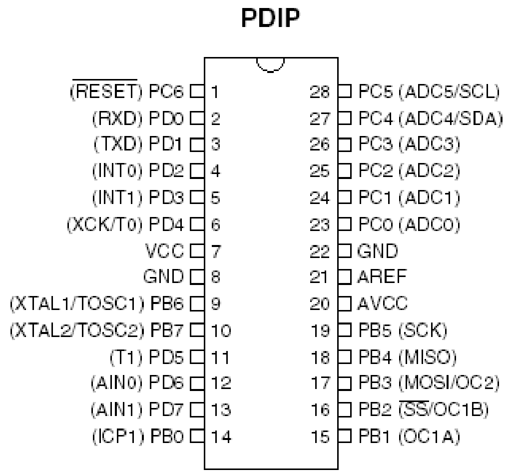

Fig.5: Pin description of AVR Atmega8L

Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting architecture is more code efficient. It is ten times faster than conventional CISC microcontrollers. The ATmega8L provides the following features: 8K bytes of In-System Programmable Flash with Read-While-Write capabilities, 512 bytes of EEPROM, 1K byte of SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible Timer/Counters with compare/capture modes, internal and external interrupts, a serial programmable USART, a byte oriented Two-wire Serial Interface, a 8-channel ADC with 10-bit accuracy, a programmable Watchdog Timer with Internal Oscillator, an SPI serial port, and five software selectable power saving modes. The Idle mode stops the CPU while allowing the SRAM, Timer/Counters, SPI port, and interrupt system to continue functioning. The Power-down mode saves the register contents but freezes the Oscillator, disabling all other chip functions until the next Interrupt or Hardware Reset. In Power-save mode, the asynchronous timer continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping.

The AVR ATmega 8L microcontroller reads analog signal and deploying on chip ADC, it digitizes the signal to 10 bit resolution. A proper firmware is developed for this dedicated applications, which computes the signal into RH% and displays the same on to LCD. The serial pins of TxD and RxD are used to interface the Zigbee module.

2.A.f) Power supply :

A separate power supply unit is employed for each sensor node. It obtained from DC Battery of 9V

2.A.g) The RF Module Zigbee:

The Zigbee, the RF module, is heart of the Wireless Sensor Node. The Zigbee , shown in figure 6, from Digi International, is a wireless transceiver supporting the IEEE 802.15.4 protocol. Low-Rate Wireless Personal Area Network protocol (LR-WPAN) for Wireless Sensor Networks (WSN) or for mesh networking use ZigBee or DigiMesh This allows addressable communications between nodes. Data may be sent to individual nodes (point-to-point), or to all nodes in range (point-to-multipoint) using a broadcast address.

Figure 6. RF Module The Zigbee Pro

By default, the modules are configured from the factory to be a wireless serial line replacement. It can be programmed to do other functions which behave as the "wireless wire" where a level transition on an input pin of one module is sent out as the same level transition on a different module output pin. The salient features of Zigbee are as follows.

- Power output:
- 63 mW (+18 dBm) North American version
- Indoor/Urban range: Up to 300 ft (90 m)
- Outdoor/RF line-of-sight range: Up to 1 mile (1.6 km) RF LOS
- RF data rate: 250 Kbps
- Interface data rate: Up to 115.2 Kbps
- Operating frequency: 2.4 GHz
- Receiver sensitivity: -100 dBm (all variants)
- Power output:
- 2mW (+3 dBm) boost mode

The architecture of the Zigbee module is presented in figure 7. Data enters the module UART through the DIN (pin 3) as an asynchronous serial signal. The signal should idle high when no data is being transmitted. Each data byte consists of a start bit (low), 8 data bits (least significant bit first) and a stop bit (high). The figure 8 illustrates the serial bit pattern a frame of data passing through the module.

Figure 7. The Architecture of Zigbee Pro module.

The module UART performs tasks, such as timing and parity checking, that are needed for data communications. Serial communications depend on the two UARTs to be configured with compatible settings (baud rate, parity, start bits, stop bits, data bits).

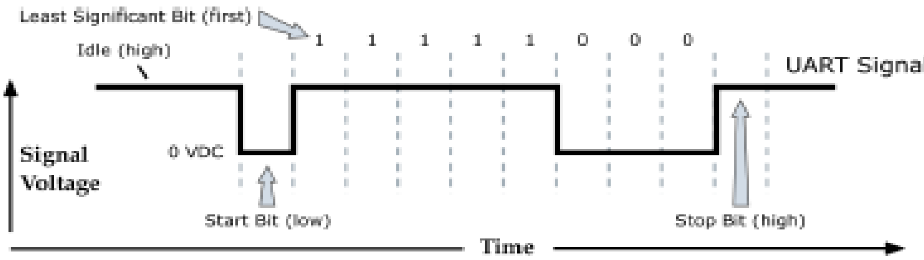

Figure 8. UART data packet 0x1F as transmitted through the RF module

Thus by this embedded system, Wireless Sensor Node, the humidity dependant signal is produced and transmitted towards the receiver installed at the base station.

2.B) The Base Station :

In order to monitor the values of humidity observed at various location of the polyhouse a PC based Base station is developed and presented in fig 2.b. As depicted in figure 2.b the base station consist of the RF module Zigbee as the wireless receiver. As discussed earlier, it is serial receiver and produces the serial data. The two lines TxD and RxD are interfaced to the PC via serial port RS 232. However, it is known that RS 232 is not following TTL Logic levels. Therefore, the Max 232 is incorporated as the line driver. The parameter values which are already calibrated at the sensor node is read serially into the PC and displayed on the monitor on specifically designed windows.

3. THE SOFTWARE

The work emphasizes the development of sensor node for wireless sensor network. It is an embedded system. Therefore, for the synchronization of operations, the firmware is required. The present embedded system is based AVR Atmega8L. Therefore, Code Vision AVR, is employed as the IDE and firmware is developed in embedded C environment. Along with the main programme the firmware comprises various modules developed for specific tasks. Following are the modules developed and used in the programme with proper sequence.

a) Reading of the Analog signal [Read data ()]
b) Analog to digital conversion [ADC (channel)]
c) Calibration to Humidity [calibration( )]
d) Initialization of LCD [lcd_init( )]
e) Character display [lcd_display]
f) Decimal to BCD and ASCII conversion [(dec-bcd)]
g) Serial communication [ser_trans_zigbee()]
h) Parameter value display [LCD( )]
i) Configuration of LCD[LCD cmd ( )]
j) Sending data to LCD[LCD data( )]
k) Delay Function [Msdelay( )]

4. EXPERIMENTAL

For calibration, in the beginning a humidity dependent voltage is measured for entire range from room temperature conditions to the condensation of water. The experimental arrangement is shown in photograph as shown in figure 9. The voltages are measured up to saturation point. For calibration, the humidity chamber, model Gayatri Scientific Ltd. Mumbai is used. The humidity from 30 RH% to 90 RH% with accuracy of 1 RH% is applied. The temperature range from 25^0C to 95^0C can be controlled. The temperature as well as humidity of the chamber is controlled by using PID techniques. Keeping temperature constant, the humidity applied to sensor is varied between 30 RH% to 90 RH%. The data regarding emf is collected and used for calibration.

Figure 9: Experimental arrangement for calibration of the system

Moreover, the system developed is implemented to carry out experiment of measurement of humidity of polyhouse environment. The measurements are carried out at polyhouse of "Lonkar Krushi Udyog Kendra, Lonkar Wasti, Sangramnagar. Akluj, District Solapur".

5. RESULTS AND DISCUSSION

The emf observed is plotted against humidity in %RH. The graph of emf against humidity in RH% is shown in figure 10. Using least square fitting process of data analyzed and fitted to the straight line. The coefficients are obtained for straight line expression. The expression resulted from curve fitting procedure is

$$\mathbf{H} \text{ (Humidity RH\%)} = \mathbf{(V_{RH}+7.52)/1.152} \qquad \ldots(3)$$

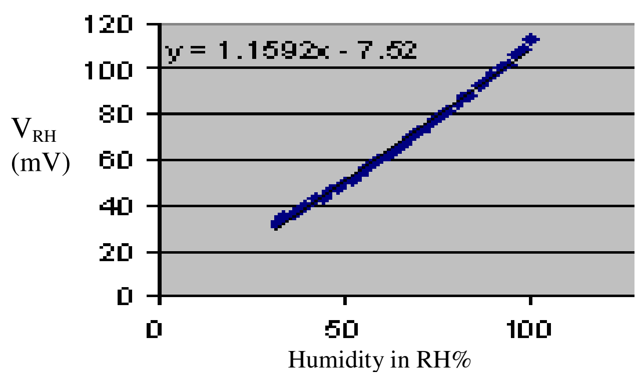

Figure 10: Graph of observed emf (mV) against applied humidity in RH%

This expression is used for further calculation. The expression is solved during firmware execution. It takes emf produced by the system and processes the same to give humidity in RH%. The system is precisely calibrated and it shows accurate reading of humidity in RH%.

An embedded system is developed, about AVR Atmega8L microcontroller, to measure humidity of polyhouse environment.

The measurements are carried out at "Lonkar Krushi Udyog Kendra, Lonkar Wasti, Sangramnagar. Akluj, District Solapur" for different times of the day and for the period of about 1 hour. The humidity data (RH%) is plotted against time and the graph of humidity against time is depicted in figure 11. From this graph, it is found that the humidity of the polyhouse environment satisfactorily remains constant.

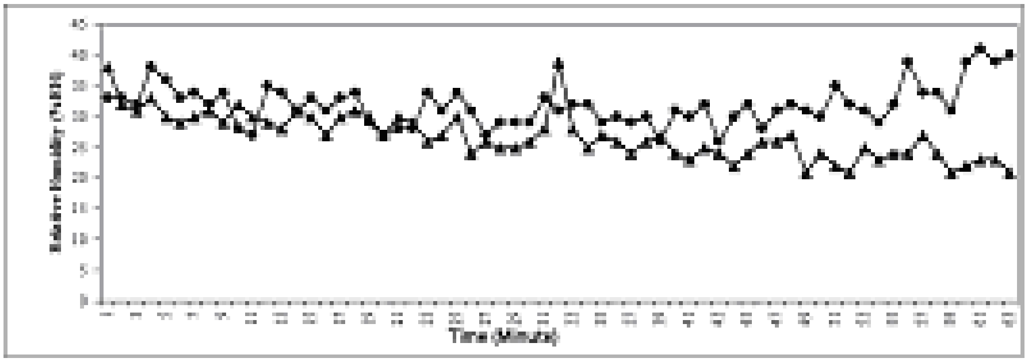

Figure 11. The Graph of Relative Humidity (RH%) Vs. Time (Min)

6. CONCLUSION

Employing embedded technology, based on AVR ATmega 8L microcontroller, the Wireless Sensor Node designed and implemented for development of WSN for polyhouse applications. Use of smart sensor module causes to enhance the accuracy and reliability as well. On inspection of the results, it is found that the humidity data given by the sensor node is accurate. The RF module Zigbee operated at 2.4GHz ISM band really help for secure data transmission. The humidity data in RH % is continuously observed on the monitor of the base station. Thus, the supervisor could get the humidity of different places of the polyhouse environment, which could be helpful to provide controlled environment to the crop to increase the yield. The system works with great reliability.

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Author's biography

Dr. Bhimrao Ladgaonkar is the Head of Post Graduate department of Electronics, Shankarrao Mohite College, Akluj Dist Solapur (India). He is recognized guide in Electronics and areas of research are Embedded technology, Instrumentation designing for high tech agriculture, Sensor materials, VLSI design and technology, Mixed signal SoC design. He guided 4 M. Phil. students. Presently, 4 students for Ph.D. and 5 students for M.phil. are working under his guidance. More than 20 international and 36 national level publications are in his credit. He organized 7 National level conferences and seminars funded by various institutes. He completed 3 research projects.

Aparna Pawar is research scholar working for Ph. D. degree in Electronics. She obtained master degree from Solapur University, Solapur. Her area of research is the development of Wireless Sensor Network for High-Tech agriculture. Presently, she is working as Assistant Professor at TC College, Baramati Dist Pune (India). She awarded with best paper presentation award at Research Festival "Avishkar-2010" organized by Solapur University, Solapur. She presented 4 research papers in National level seminars.