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Full Length Research Paper

Design of wireless underground sensor network nodes for field information acquisition

Zenglin Zhang[1,3], Pute Wu[1,2,3]*, Wenting Han[1,2,3] and Xiaoqing Yu[1,3]

[1]Northwest Agriculture and Forestry University, Shaanxi, Yangling, 712100, China.
[2]National Engineering Research Center for Water Saving Irrigation at Yangling, Institute of Soil and Water Conservation of Chinese Academy of Sciences, Shaanxi, Yangling, 712100, China.
[3]Research Institute of Water-saving Agriculture of Arid Regions of China, Shaanxi, Yangling, 712100, China.

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With the research of the wireless sensor network technology, some wireless underground sensor network nodes and a sink node based on embedded technology and RF technology were designed innovatively. Wireless underground sensor network node consists of sensor, the processor, wireless RF module and power module; here, processor using MSP430 microcontroller, RF modules adopting nRF905 communication module and having 433/868/915 MHz 3 ISM channel. Moreover, the sink node is made up of RF transceiver module, the core control circuit, information processing, data storage, Liquid Crystal Displays (LCD) module and power supply. The nodes which acquired soil parameters information were regularly distributed in the monitoring area. The sink node collected the information of nodes that were sent in way of a single jumping or multiple hops and implemented fusion, analysis, processing, storage and display of information. For 50% sands, 35%silt, and 15% clay, a bulk density of 1.5 g/cm^3 and a specific density of 2.6 /cm^3, test is conducted for different soil moisture (5, 10, 15, 20 and 25%) in three different frequencies 433/868/915 MHz, result shows that radio signal path loss is the minimum in the low frequency and low moisture. Furthermore, the changes of node deployed depth (0.2, 0.4, 0.6, 0.8, 1, 1.2, 1.4, 1.6, 1.8 and 2 m) affected signal attenuation under 433 MHz, it is concluded as the best wireless underground sensor networks (WUSN) node buried depth for effective transmission.

Key words: Wireless underground sensor networks (WUSN), sink node, MSP430, soil moisture, depth, information acquisition.

INTRODUCTION

Field information is the important and the deciding factor in agricultural production. Acquisition method is one of the primary technical problems in field information research and realization in modern agricultural production, which can collect variable information of crop growth environment in many-sides, accurately, rapidly and effectively. It is also the key and decisive factor of the modern efficient agricultural production (Sawant et al., 2004; Lyengar and Brooks, 2005). Perception, processsing, management decision-making and Information integration control of farmland information has become the focus in the field of contemporary international agricultural science and technology research. The wireless sensor network technology has been applied in agricultural information monitoring field (Boulis and Srivastava, 2002; Stojmenovic, 2005), and it has achieved good scientific research achievements. At the present application domain, underground sensing systems require data loggers or motes deployed at the surface with wiring leading to underground sensors in order to avoid the challenge of wireless communication in the underground. All of these existing solutions require sensor devices to

*Corresponding author. E-mail: zhangzenglin115@gmail.com or gjzwpt@vip.sina.com.

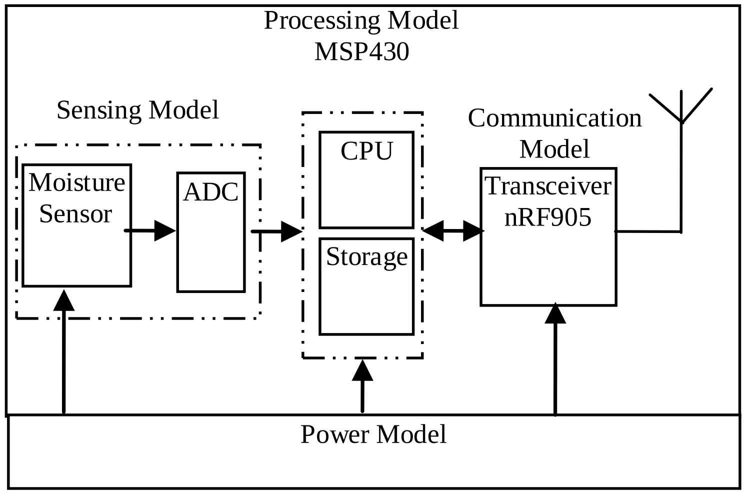

Figure 1. Architecture of wireless underground sensor network node.

be deployed at the surface and wired to a buried sensor. While the usefulness of these applications of sensor network technology is clear, there remain shortcomings that can impede new and more varied uses. These equipment exposed on the ground not only influence farming, wireless transmitting functions of wireless node also be affected because of geography, meteorology and natural factors.

Based on these disadvantages, the wireless underground sensor networks (WUSN) provide a new method for underground monitoring. WUSN has also become a new research direction in the agricultural industry. Sensor equipments with wireless receiving and send module have been completely deployed in certain depth of soil, induction module sending data in the way of wireless when it perceives data. Many sensor nodes were formed into sensor networks, which complete automatically the whole process of perception and collection of data. WUSN have several remarkable merits, such as concealment, ease of deployment, timeliness of data, reliability and coverage density (Chen et al., 2010; Akyildiz et al., 2002). Besides monitoring soil ingredients in underground, a wireless underground sensor network can also be used for monitoring soil motion, forecasting landslide, debris, underground ice motion and volcanic eruptions (Akyildiz and Stuntebeck, 2006; Akyildiz et al., 2009) and it has higher value for study. WSN relevant theoretical research and practical application has existed internationally. J.A.Lopez has applied wireless sensor network in precise viticulture (Allen et al., 2006), O. Green has used a wireless sensor network to monitor temperature change of feed storehouse (Lopez et al., 2009), Lili applied wireless sensor network in greenhouse environment monitoring (Green et al., 2009), Zhang Rongbiao realized greenhouse wireless communications of wireless sensor network based on ZigBee (Li et al., 2009), Cai yihua designed farmland information acquisition node based on WSN (Zhang et al., 2008), Feng Youbing has applied wireless sensor network in water-saving irrigation (Cai et al., 2009).

Reality application or imagination about the various sensor monitor systems in the underground environment has a part of this writing. A. Sheth proposed that tension induction module attached to wireless sensor may forecast landslide (Feng et al., 2007), K. Martinez introduces a sensor that test ice parameter system (Sheth et al., 2005), G.W.Allen proposes the use of sensor network in monitoring volcanic activity (Akyildiz et al., 2009), these systems do not really construct wireless underground sensor network. This paper introduces the design of wireless sensor nodes and sink node of agricultural application based on a wireless underground network.

Furthermore, Signal attenuation experiment is conducted under different frequency and different moisture content. This work will lead to characteristics relationship among frequency, burial depth and path loss in farmland environment.

Design of WUSN node

Wireless sensor node is designed through the modularizing design method. The entire node system structure consists of sensor module, processor module, wireless communication module, and energy supply module. In farmland information monitoring applications, soil parameter information is the major factor. According to the application requirements, wireless underground sensor node for soil moisture acquisition is designed. The block diagram is shown in Figure 1.

Table 1. Sensor voltage and measurement.

Sensor category	Sensor type	Output voltage/V	Measuring range
Soil moisture	XR61-TDR2	0~2.5	0~100%(m^3/m^3)
Soil temperature	DS18B20	0~5	-55~125°C
Soil salt	NT18-TYC-2	--	0.02~0.15N; 0.15~0.3N

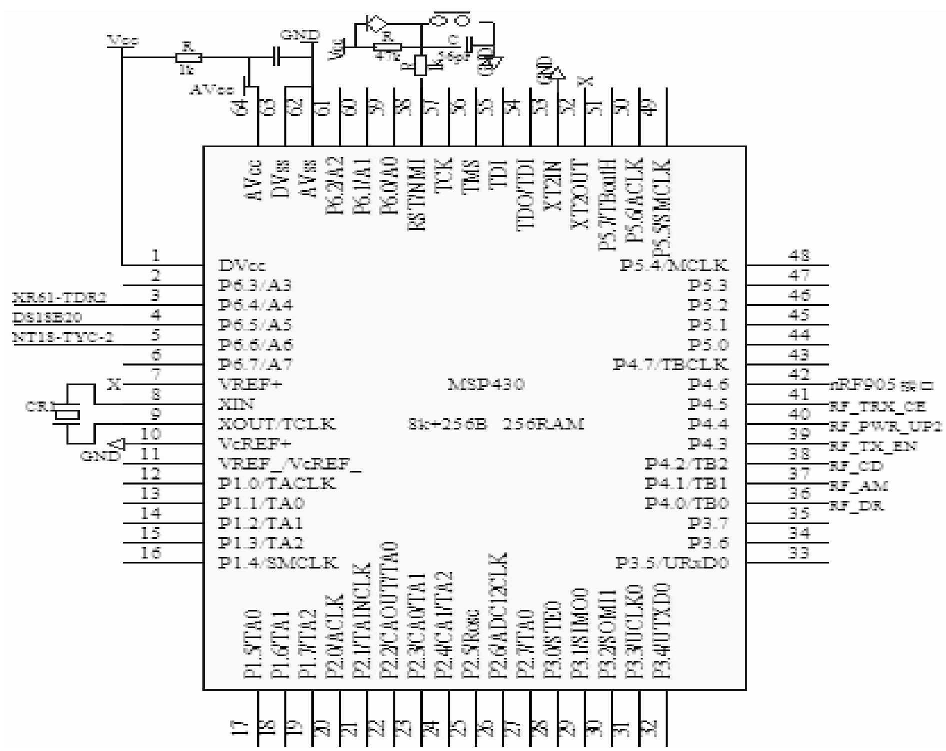

Figure 2. Diagram of processor block.

Design of sensor model

Node collects farmland necessary information through the sensor module. Processor module retained interfaces for various sensors. Here, it takes moisture sensor XR61-TDR2 for example. XR61-TDR2 has some advantages, such as high stability, high sealing, strong resistance to squeeze ability, good shielding effect and anti-interference, long transmission distance, less influence on soil qualities, volume miniaturization and low price. It can obtain the precise soil moisture content information for processor processing. Table 1 shows sensor voltage signal and measurement for the system.

Design of processing model

The 16 bit series MSP430 microcontroller is launched by TI Company and adopted as the main control chip. It has a unique advantage in low power applications. MSP430 has very high levels of integration, a single chip usually integrated 12 bit A/D comparator, multiple timer, USART, watch dog, oscillator, a large number of I/O port and high-capacity memory. This microcontroller is cost-effective, has many functions such as strong anti-interference ability, serial programming and is very convenient. Circuit principle diagram is shown in Figure 2.

Design of communication rf model

Wireless communication RF module implements the communication between the nodes. The Norway Nordic company nRF905 monolithic RF transceiver chip is adopted. It has two kinds of working mode and energy saving mode, they are power lost pattern, the standby mode, Shock Burst TM receiving mode and Shock Burst TM send mode separately. The chip can work freely in

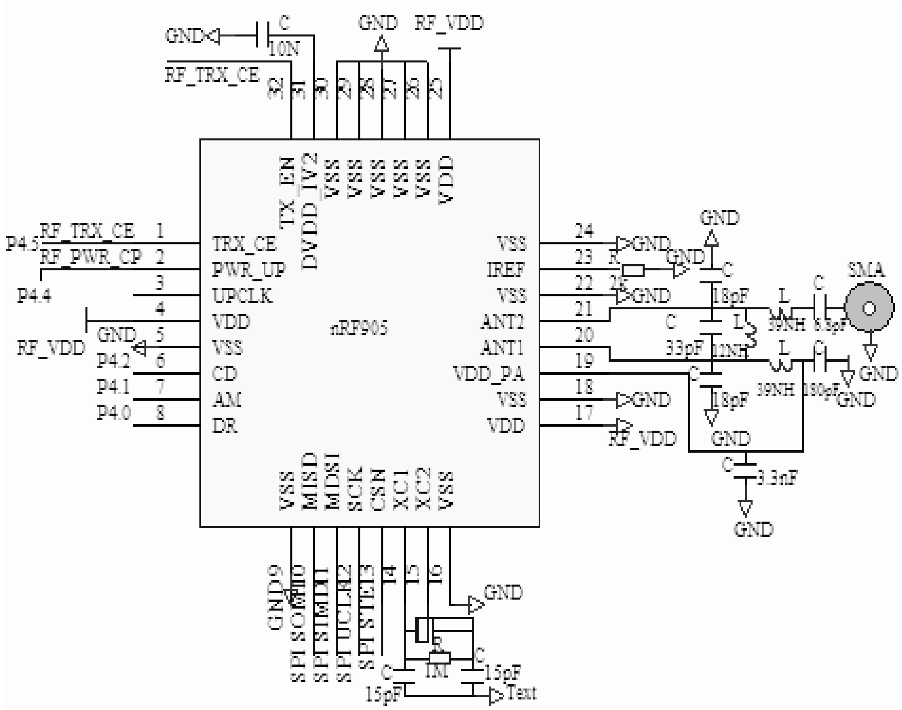

Figure 3. Control diagram of nRF905 block.

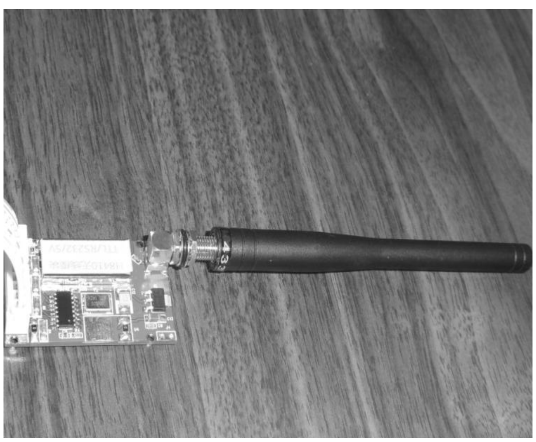

Figure 4. Picture of the WUSN node.

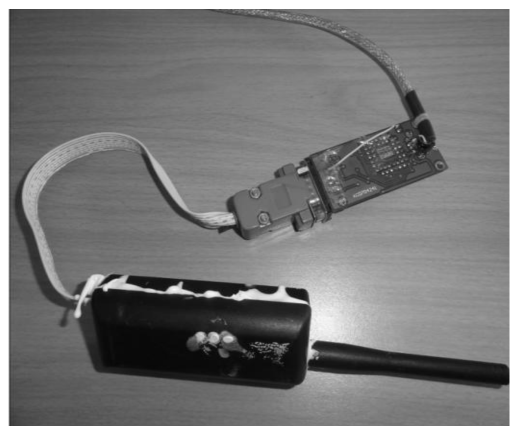

Figure 5. Picture of the sealed WUSN node.

433/868/915 MHz 3 ISM channel, communication with micro-controller by using SPI interfaces, configuration is very convenient, power consumption is very low. Figure 3 illustrates communication with the processor.

WUSN node

As we saw in the previous description, the chief requirements that were considered when designing node devices were robust radio technology and low cost, low-consumption electronic devices, etc. Figures 4 and 5 show the picture of the WUSN node and sealed WUSN node, respectively.

Design of sink node

Hardware design

Wireless underground sensor network node collect data, sink node is responsible for data gathering, analysis,

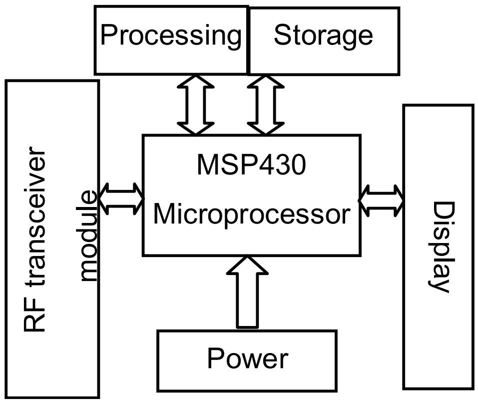

Figure 6. Structure of sink node.

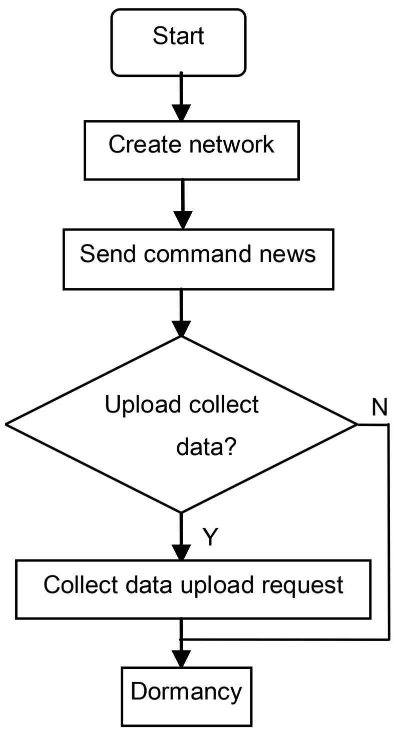

Figure 7. Flow chart of sink.

processing, storage and display. Hardware structure of sink node can be divided into RF transceiver module, the core control circuit, information processing, data storage, LCD module and power module, the structure is shown in Figure 6. After the RF transceiver module receiving signal, the signal is processed and converted by a regulator circuit, then it is stored into MSP430 microprocessor. In addition, the wireless underground sensor node composed nets. Sink node send data queries, WUSN node can will query data sent to sink node. Specially, relevant information can be displayed in LCD screen according to the demand of customers.

Software design

For ease of management and scheduling, the function achieved by node is defined as the events of processing, every event completes corresponding function. The events are string connected in a certain relationship, which can achieve function. Sink node workflow is shown in Figure 7.

MATERIALS AND METHODS

Test method of experiments

When wireless underground sensor network nodes get soil information, reflection, scattering and diffraction may exist simultaneously in the process of wireless electromagnetic wave transmission in soil and interface between soil and air. RF frequency is the core of electromagnetic signals that are influenced. In addition, agricultural environment dynamic changes constantly as seasonal variation, soil water content will cause great path loss to the radio signal propagation. In order to path loss minimum when underground sensor nodes are deployed, it is necessary to find a proper depth, which guarantee deployment of sensor nodes is the most economic, signal paths loss is minimum, and can transmit effectively. In the trial, we assume the clay percent as 15%,the silt percent as 35%, the sand particle percent as 50%, the bulk density as 1.5 g/cm^3, and the solid soil particle density as 2.6 /cm^3 unless otherwise noted.

According to three different frequencies of RF modules nRF905, the attenuation of signal strength and bit error rate are measured in different soil volumetric water content VWC (VWC were taken as 5, 10, 15, 20 and 25%). Meanwhile, the path loss is measured in different depth h WUSN node deployed (h were taken as 0.2, 0.4, 0.6, 0.8, 1, 1.2, 1.4, 1.6, 1.8 and 2 m) is under the same frequency.

RESULTS

Test analysis

Path loss is the difference in value between real received signal strength and source signal strength level, namely the signal attenuation extent, it reflects direct efficiency of wireless electromagnetic signal transmission. Figures 8 and 9 describe the path loss and bit error rate of the wireless signals which are caused by soil volumetric water content change in different frequencies, respectively. Figure 10 reflects the relationship between WUSN nodes deployed depth and the path loss under433 MHz RF frequencies.

Conclusion

We introduced the wireless underground sensor network

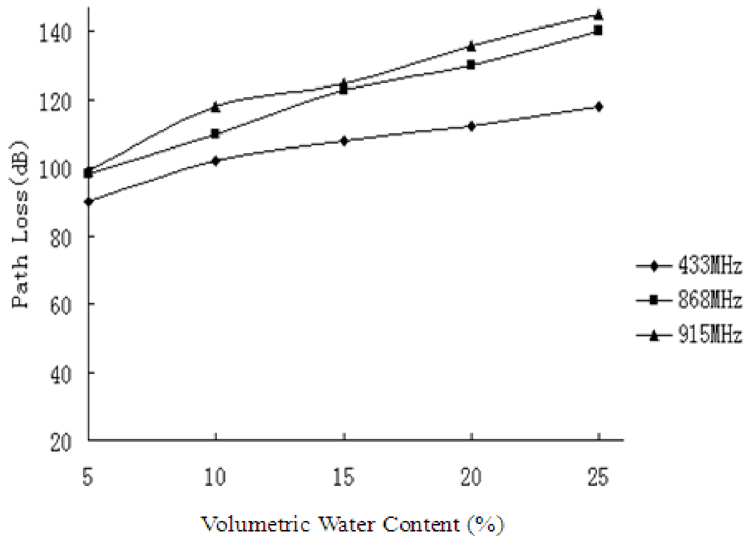

Figure 8. The relationship among path loss, operating frequency and volumetric water content.

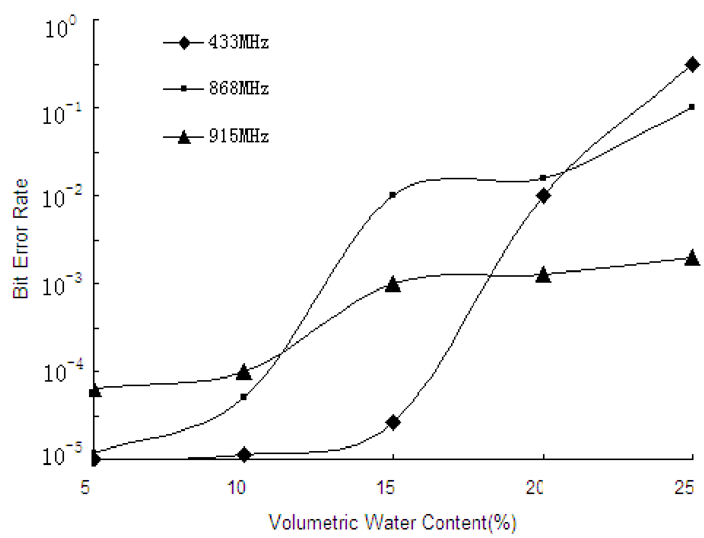

Figure 9. The relationship among bit error rate, operating frequency and volumetric water content.

in which sensor devices are deployed completely below ground. WUSN can be used to monitor a variety of conditions, such as soil properties for agricultural applications. We demonstrated the benefits of WUSN over current sensing solutions including: complete network concealment, ease of deployment, timeliness of data, reliability and coverage density. Through test and analysis of experiment, we conclude several important results as follows:

(1) According to the application requirement of soil environmental information, wireless underground sensor network technology is researched. Underground sensor node is developed combined with embedded processors, which realized real-time dynamic collection, transmission, store and display for the soil property parameter. Nodes satisfy requirements of low power consumption, low cost, high real-time, high reliability for soil property monitoring;

(2) For three different frequencies of wireless RF

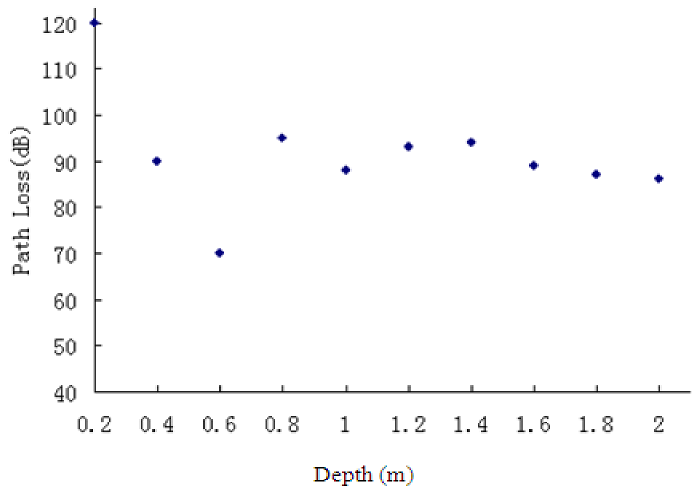

Figure 10. The relationship between path loss and depth.

modules, path loss and bit error rate of radio signal are analyzed in different volumetric water content through changing of soil volumetric water content. Experiment shows that soil attenuation and bit error rate are the minimum in the low frequency RF and low volumetric water content;

(3) In 433 MHz RF frequency, path loss is influenced by different depth WUSN node deployed in the soil. The results indicate that signal attenuation is the minimum when node is deployed in suitable depth; and

(4) In comparison with manual soil property monitoring, an advanced wireless sensor network improved the real-time of soil property collection and provide the basis for the application of water-saving agriculture.

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REFERENCES

Akyildiz IF, Stuntebeck EP (2006). Wireless underground sensor networks: Research challenges [J]. Ad Hoc Netw., 4: 669-686.
Akyildiz IF, Su W, Sankarasubramaniam Y, Cayirci E (2002). Wireless Sensor Networks: A Survey [J]. Comput. Netw., 38(4): 393-422.
Akyildiz IF, Vuran MC, Sun Z (2009). Channel modeling for Wireless Underground Communication in Soil[J]. Phys. Commun., 3: 245-254.
Allen GW, LorinczK, Welsh M, Marcillo O (2006). DePloying a Wireless Sensor Network on An Active Volcano [J].IEEE Internet Comput., 10(2): 18-25.
Boulis A, Srivastava MB (2002). A Framework for Effieient and Programmable Sensor Networks[C]//Proceedings of OPENARCHZ2002, New York, June, pp. 117-128.
Cai YH, Liu G, Li L (2009). Design and test of nodes for farmland data acquisition based on wireless sensor network [J]. Chinese Soc. Agric. Eng., 25(4): 176-178.
Chen JM, Cao XH, Cheng P, Yang X, Sun YX (2010). Distributed Collaborative Control for Industrial Automation with Wireless Sensor and Actuator Networks. IEEE Transactions on Industrial Electronics, 2010.
Feng YB, Zhang RB, Gu GD (2007). Application of Wireless Sensor Network in Water-Saving Irrigation [J].China Rural Water and Hydropower, 2: 24-26.
Green O, Nadimi ES, Blanes V (2009). Monitoring and modeling temperature variations inside silage stacks using novel wireless sensor networks [J]. Comput. Electron. Agric., 69(1): 149-157.
Li L, Li HX, Liu H (2009). Greenhouse Environment Monitoring System Based on Wireless Sensor Network [J]. Trans. Chinese Soc. Agric. Machinery, 9(40): 228-231.
Lopez JA, Soto F, Suardiaz J (2009). Wireless sensor networks for precision horticulture in Southern Spain [J]. Comput. Electron. Agric., 68(3): 25-35.
Lyengar SS, Brooks RR (2005). Distributed sensor networks [M]. Boca Lyengar Raton, Fla. Chapman & Hall/CRC.
Martinez K, Ong R, Har (2004). A Sensor Network for Hostile Environments [J].IEEE SECON, 1: 81-87.
Sawant H, Tan J, Yang QY, Wang QZ (2004). Using Bluetooth and Sensor Networks for Intelligent Transportation Systems[C] // Proceedings of IEEE Intelligent TransPortation Systems Conference, Washington.D.C., USA, pp. 767-772.
Sheth A, Tejaswi K, Mehta P (2005). Senslide: A Sensor Network Based Landslide Prediction System[C]//Proceedings of Sensys’05-The 3rd International Conference on Embedded Networked Sensor Systems, pp. 280-281.
Stojmenovic I (2005). Handbook of sensor networks [M]. CRC Press.
Zhang RB, Gu GD, Feng YB (2008). Realization of Communication in Wireless Monitoring System in Greenhouse Based on IEEE802.15.4 [J]. Trans. Chinese Soc. Agric. Machinery, 39(8): 119-122.