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AUTOMATED SYSTEM FOR REMOTE MONITORING OF THE SPRINKLING MACHINES STATUS

One of the most effective irrigation methods for main crops is sprinkling. This process is carried out by specialized irrigation machines, which have long been widely used in agriculture throughout the world. In Ukraine, due to its agro-climatic conditions and the predominant cultivation of grains and oilseeds, the advantage of sprinkling is even greater, which, in turn, led to the spread of "Frigate"-type sprinkler machines and their active use. Currently in Ukraine there are several ways to support and develop irrigation systems. The least expensive of them is the acquisition and restoration of used sprinklers and their accessories. Unfortunately, many of them are stolen. The relatively small size of i-Wob sprinklers (made in the USA) and their high cost makes them most vulnerable of the "Frigate" design elements. Given the frequent cases of theft of sprinkling machines and their parts, farms need to be protected from intruders. The aim of the study is to develop a system for remote monitoring of the state of the sprinkler, which would ensure the safety of not only the installation itself, but also its components. The article describes the system of remote monitoring of sprinkling machines. The description of the construction of such units and the difficulties of their full operation in the agricultural of Ukraine are given. The possibility of using microwave and vibration sensors to prevent invasions with the operation of sprinkler machines has been researched. The structure of the monitoring system is proposed. The main components of the systems are selected.

Keywords: sprinkler machine, monitoring system, microwave sensor, i-Wob.

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АВТОМАТИЗОВАНА СИСТЕМА ВІДДАЛЕНОГО МОНІТОРІНГУ СТАНУ ДОЩУВАЛЬНИХ МАШИН

Одним з найбільш ефективних методів поливу основних культур є дощування. Цей процес здійснюється спеціалізованими іригаційними машинами, які широко використовуються в сільському господарстві в усьому світі. В Україні, через її агрокліматичні умови і переважаюче вирощування зернових і олійних культур, перевага такої технології ще більше, що, в свою чергу, призводить до поширення спринклерних машин типу "Фрегат" і їх активного використання.

У даний час в Україні існує кілька способів підтримки і розвитку іригаційних систем. Найменш дорогим з них є придбання та реставрація використаних спринклерів і їх комплектуючих. На жаль, багато з них є крадеными, тому що відносно невеликий розмір розбризкувачів i-Wob (виробництва США) та їх висока вартість роблять їх найбільш уразливими з елементів конструкції "Фрагата".

З огляду на часті випадки крадіжки дощувальних машин та їх частин, ферми повинні бути захищені від вторгнень.

Метою дослідження є розробка системи дистанційного контролю стану дощувальної машини, яка забезпечувала б безпеку не тільки самої установки, а й її окремих чисельних компонентів.

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У статті описується система віддаленого моніторингу дощувальних машин. Надано опис конструкції таких агрегатів і труднощі їх повноцінної роботи в аграрній сфері України. Досліджено можливість використання мікрохвильових датчиків для запобігання втручання у роботу дощувальних машин.

Розглянуто питання ослаблення радіохвиль в навколишньому середовищі. Різні атмосферні утворення у вигляді конденсованої водяної пари викликають зменшення напруженості поля радіохвиль. Ослаблення викликається, по-перше, нерезонансним поглинанням в частинках і, по-друге, розсіюванням енергії на частинках.

Запропоновано структуру системи дистанційного моніторингу стану машини. Досліджено можливість розпізнавання руху людини і відділення його від інших рухів в контрольованій зоні.

Ключові слова: дощувальна машина, система моніторингу, мікрохвильовий сенсор, i-Wob.

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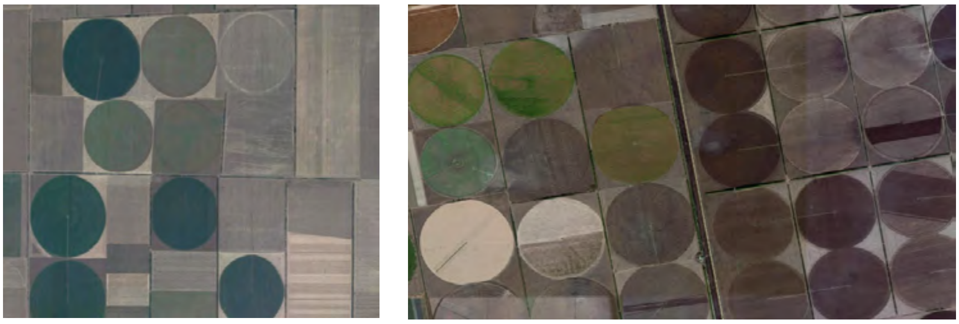
АВТОМАТИЗИРОВАННАЯ СИСТЕМА УДАЛЕННОГО МОНИТОРИНГА СОСТОЯНИЯ ДОЖДЕВАЛЬНЫХ МАШИН

В статье рассмотрена система удаленного мониторинга дождевальных машин. Приведено описание конструкции таких агрегатов и трудности их полноценной эксплуатации в сельских хозяйствах Украины. Исследована возможность использования микроволновых сенсоров для предотвращения вмешательства в работу дождевальных машин. Предлагается структура системы удаленного мониторинга состояния машины. Исследуется возможность распознавания движения человека и отделения его от других движений в контролируемой области.

Ключевые слова: дождевальная машина, система мониторинга, микроволновый сенсор, i-Wob.

Problem Statement

One of the most effective irrigation methods for main crops is sprinkling. This process is carried out by specialized irrigation machines, which have long been widely used in agriculture throughout the world. In Ukraine, due to its agro-climatic conditions and the predominant cultivation of grains and oilseeds, the advantage of sprinkling is even greater, which, in turn, led to the spread of sprinkling machines (SM) of the "Frigate" type and their active use (Fig. 1).



a) b)

Fig. 1. Satellite images of the fields (Google Maps) on which the sprinkling machine "Frigate" type is used: a) Crimea region, b) Kherson region.

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The sprinkler (Fig. 2) rotates around a central point (fixed pillar) on carts, the distance between which is up to 60 m. The energy source for the movement of carts is the water pressure in the pipeline (or electric power), which is supplied to the machine. Water through the valves is supplied to the hydraulic cylinders, which drive the wheels using a system of levers and pushers. The operator of the sprinkler sets a certain speed of movement corresponding to a given rate of irrigation.

Water can be supplied to the machine from stationary or mobile pumping stations. On the pipeline installed on the carts, there are sprayer of circular action i-Wob, which, when moving the machine in a circle, ensure uniformity of irrigation of the site.

a) b)

Fig. 2. Sprinkler machine [1]: a) general appearance; b) i-Wob type sprayer.

To prevent pipeline deformation in the vertical and horizontal planes, as well as to increase rigidity, the machine is equipped with a system of vertical and horizontal cable stretch marks. When one or several carts outpace or lag along the common pipeline line during movement, the amount of water supplied to the cylinders of movement of these carts automatically changes, as a result of which their speed changes until the pipeline is level [2].

In the case when the bend of the pipeline exceeds the permissible limits, the mechanical or hydraulic protection system is activated. When the mechanical protection is triggered, the machine stops completely. Hydraulic protection system by triggering a pulse valve through a pulse tube reduces the pressure in the hydraulic protection system, which ensures that the valve is closed and the water supply to the machine is stopped [3].

Wired systems with cables or wires are also used to ensure the security of the system. In case of damage to the conductor, covering the entire sprinkler and its aggregates, an alarm is triggered. Such systems are relatively simple, but require a lot of time to deploy and install.

Analysis of Recent Researches and Publications

Motion sensors are devices that are widely used in security systems, at enterprises and in everyday life in order to ensure the comfort of visitors and energy saving. They work at the expense of built-in sensors (for example, PIR detectors or microwave sensors, that working on the Doppler Effect), which monitor certain environmental parameters and transmit information about them to the user.

PIR detectors can detect the movement of body heat, and are ideally suited where a defined detection pattern is required, such as down a walkway. However they require movement across the infrared beams, meaning they must be installed in the right position to provide effective coverage and can be easily fooled by an intruder [4].

Microwave sensors are ideal for large spaces and areas that have an awkward shape or where fine motion is detected, such as a garden or driveway due to it providing greater coverage and security. These detectors sense motion in terms of speed and size, as opposed to a PIR sensor which senses in terms of heat and light.

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Most PIR sensors affected by the climate, mostly high temperatures and are only rated to IP44. Microwave sensors also offer a more stable performance and will operate in temperatures as low as −20°C and as high as 45°C.

The Doppler modulations due to human activity vary in time according to the dynamics of human movement. Non-stationary models for Doppler due to walking human targets were proposed in [5, 6]. However, walking induces high Doppler shifts in the waveform that can be observed over short time durations. The Doppler shifts due to walking also display regular repetitive frequency modulations, by virtue of the regularity of human gait. The finite non-zero dimensions of the human arm and other parts of the body result in a Doppler return that consists of multiple frequency components at each time instant [5]. In this paper, we are interested in modeling Doppler signatures due to movements that are characteristic of stationary humans. We conjecture that a human whose torso is not moving can be identified from the Doppler signatures due to activity such as breathing and movements of the arm [7].

Another way to monitor the safety of the sprinkler is to use accelerometers. The MEMS accelerometers family includes high-performance, high-reliability 3-axis, linear accelerometers [8]. Such sensors are used for anti-theft car alarm systems to detect real time status/position of a parked car, even slow moving attitude changes such as the vehicle being pulled onto a flat bed or being raised by a car jack.

One of the most important structural responses employed by SHM systems is acceleration, and as a result, nearly all wireless smart sensors include accelerometers. Because WSSs traditionally rely on battery power, low-power MEMS-based accelerometers are typically employed. Many of these accelerometers were initially developed for automobile airbag and mobile phone applications, and as a result, have relatively low resolution compared to wired accelerometers used in SHM applications.

The demands of monitoring of civil infrastructure are severe. Most wireless sensors are unable to measure these low-level structural vibration responses, undermining efforts to achieve successful SHM with WSSs [9].

The wireless surveillance sensor network with acoustic and seismic vibration sensors to detect objects and/or events for area security in real time already exist. The system includes an appropriate hardware as a part of multimedia surveillance sensor node and use proper classification technique to classify acoustic and vibration data that are collected by sensors in real-time. According to the type of acoustic data, the system triggers a camera as an action for detecting intruder (human or vehicle). Mel Frequency Cepstral Coefficients feature extraction method for acoustic sounds and, is used. Support Vector Machines as classification method for both acoustic and vibration data, is used [10].

Purpose of the Study

Currently in Ukraine there are several ways to support and develop irrigation capacity. The least expensive of them is the acquisition and restoration of used sprinkling machines and their components, which are many in the market, but, unfortunately, many of them are stolen.

The relatively small size of i-Wob type sprinklers (made in the USA) and their high cost makes them more vulnerable among the other parts of "Frigate" construction. Despite the frequent cases of theft machines and their parts, farms need to be protected from intruders. The purpose of the study is to develop a system of remote monitoring of the state of a sprinkling machine, which would ensure the safety of not only the installation itself, but also its components, in particular, sprinkler aggregates.

Description of Main Material of Research

Microwave sensors, also known as Radar, RF or Doppler sensors, detect walking, running or crawling human targets in an outdoor environment.

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Advantages of microwave sensors: detect objects through obstacles; high sensitivity and response to objects regardless of their temperature; built-in ability to automatically monitor and control electrical appliances; adjusting the sensitivity, off time and range of the sensor.

The work of the microwave motion sensor is based on the generation of high-frequency electromagnetic waves, which are reflected from objects around and return back to the radiation source. Thus, the sensor registers the movements or other changes occurring nearby in a certain radius and provides a quick response to them. Such devices are very accurate and sensitive, as they instantly react to even the slightest movements behind walls, windows, partitions or other obstacles.

Serial low-cost microwave sensors can use power sources of both alternating current (110–220 V) and direct current (12–30 V). They have a radius of detection of objects from 2 to 10 m with an installation height of up to 3.5 m, and in addition, have a high ingress protection rating. Typical sensor wiring diagrams are shown in Fig. 3.

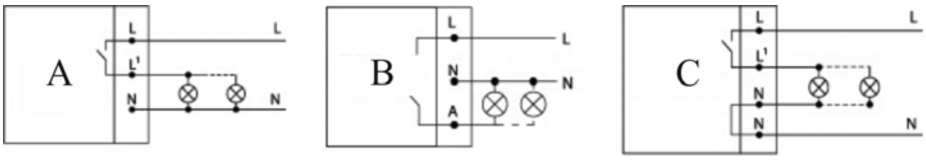

Fig. 3. Microwave sensor wiring diagrams.

Microwave motion sensors work on the principle of microwave radiation location - reflection. Sensors produce high-frequency electromagnetic waves with a frequency of 5.8 GHz and receive an echo, reflected from objects.

It should be noted that when working with sprinkling machines, such a fact as the attenuation of radio waves in the environment should be taken into account. Various atmospheric formations in the form of condensed water vapor – rain, fog, clouds, hail, snow, consisting of individual particles – droplets, ice, cause a decrease in the strength of the radio-wave field. Attenuation is caused, firstly, by non-resonant absorption in the particles and, secondly, by the scattering of energy on the particles. Attenuation may also occur due to reflection from a sharply defined strip of precipitation (which is typical of sprinkling machines). Attenuation in precipitation begins to affect frequencies $f > 6$ GHz ($\lambda < 5$ cm) and is particularly significant at frequencies above 10 GHz. The main importance is attenuation in the rain, as well as in fog and clouds, which depends on the amount of water per unit of volume, as well as on air temperature and wave frequency.

It is proposed to place the sensors and other modules of the monitoring system according to the diagram shown in Fig. 4

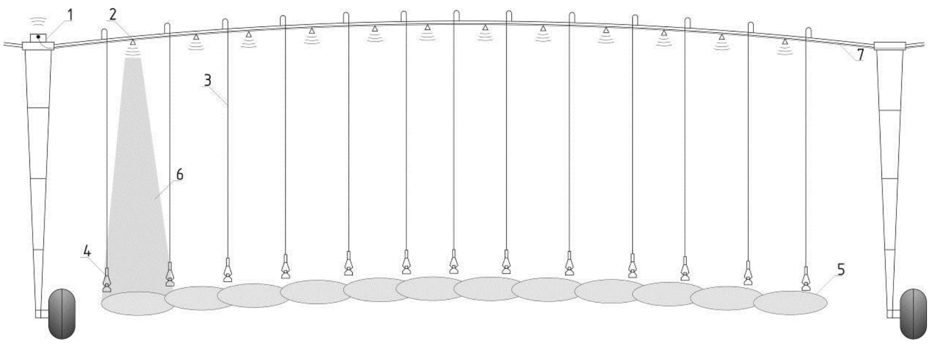

Fig. 4. The structure of the monitoring system: 1 – GSM module; 2 – microwave displacement sensor; 3 – sprinkler hose; 4 – i-Wob type sprayer; 5 – sensor control zone; 6 – "cone" of radiation of the sensor; 7 – main pipeline.

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Thus, the functional scheme of the system should consist of the sensors, the router to which they are connected, and the GSM module, through which information about the state of the system will be redirected to the operator (Fig. 5).

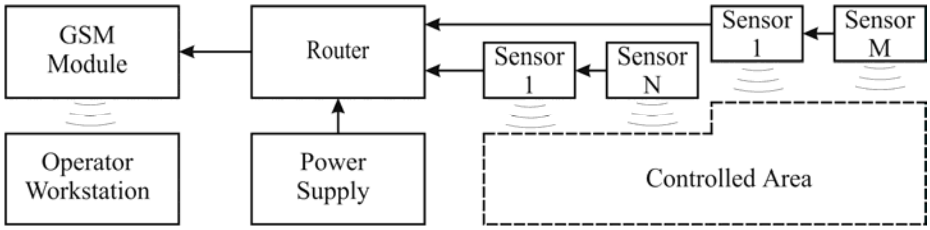

Fig. 5. Functional diagram of the monitoring system.

Registration of movement in the control zone will be carried out according to the Fig. 6

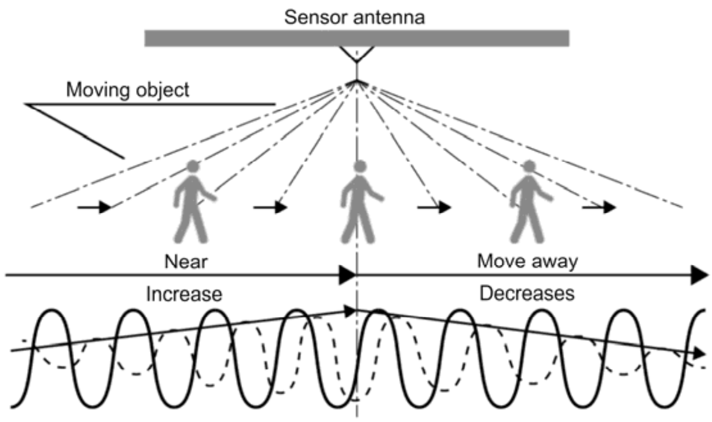

Fig. 6. Process of registration of motion by microwave sensor [11].

In Fig. 7 shows the response of the microwave sensor to motion: 00..03 - no movement; 03..05 - active movement on the spot (waving hands, turning the torso, one wide step) at a distance of 1 meter from the sensor; 05..10 - a slight movement at a distance of 2 meters; 10..16 - walk to the distance; 16..20 - no movement (the person stopped at a distance of 5 meters) 20..23 - active movement at a distance of 5 meters; 23..27 - no movement; 27 - the entrance to the room and the passage through the room to the far corner from the entrance and back. The effect of interference on the sensor operation is also shown [12].

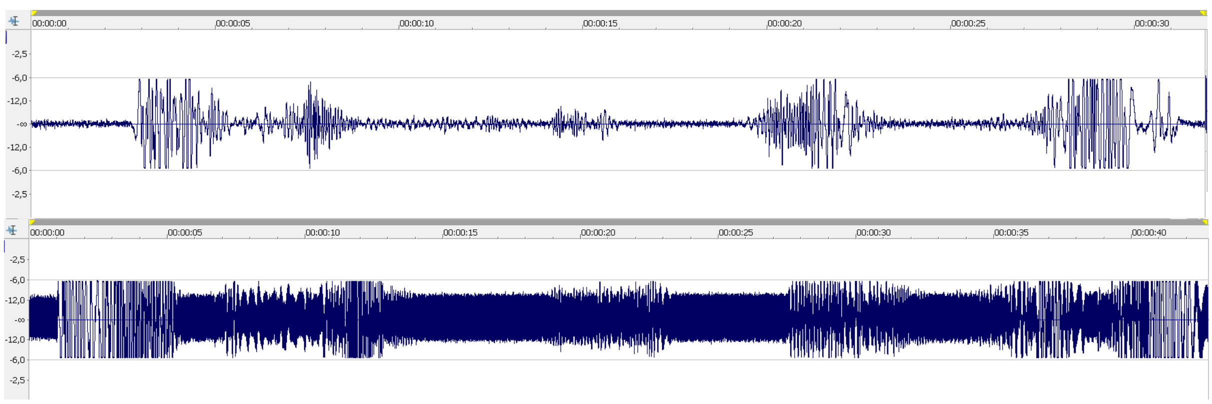

Fig. 7. Diagram of the sensor signal in the absence or presence of various movements.

In addition to controlling the perimeter around the sprinkler, it is possible to control the vibrations that occur as a result of unauthorized contact with the machine or its parts [13].

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Practice shows that sensitive sensors can detect the heartbeat of a person who has touched the main pipeline of the sprinkler. At the same time, the touch point is at a distance of about 100 meters from the sensor. However, such indicators can be achieved under the condition that the sprinkler is not working normally and there are no vibrations caused by operation. Also, this approach requires a very accurate system calibration. Reliable monitoring will be provided for the basic design of the sprinkler, but not for sprayers (i-Wob).

Placing the sensors directly on the sprayers eliminates the disadvantages described above. However, placing the sensor on each individual sprayer causes a significant increase in the cost of the monitoring system and complicates its installation. It is proposed to use a wireless connection of sensor nodes for easy installation. The design of the individual sensor has also been revised [14].

There are a large number of radio modules on the electronics market, for example, the ESP8266 has a very wide functionality that is redundant for the current task. In addition, this module has an average cost of five dollars, which, in the case of an increase in the number of nodes in the network, will require significant financial costs. The best option is nRF24L01. This radio module is not a full-fledged Wi-Fi adapter, but only a transmitter. However, it has the minimum necessary functionality, which allows you to exchange small messages between two or more modules. In addition, this module has low power consumption and compactness, but has a range of up to 100 m in open areas. This distance is acceptable for the status sprinkling machine monitoring.

In quality of the microcontroller is selected Arduino Pro Mini. The following libraries were used to connect and control the nRF24L01 radio module: RF24, which serves to connect and interact with the radio module with a microcontroller; RF24Network, which provides interfaces for simple and fast networking from nRF24L01 modules. These libraries are publicly available and distributed freely.

Each node must be assigned an 15-bit address by the administrator. This address exactly describes the position of the node within the tree. The address is an octal number. Each digit in the address represents a position in the tree further from the base. Node 00 is the base node. Nodes 01-05 are nodes whose parent is the base. Node 021 is the second child of node 01. Node 0321 is the third child of node 021, an so on (Table 1).

The largest node address is 05555, so up to 781 nodes are allowed on a single channel. An example topology is shown below, with 5 nodes in direct communication with the master node, and multiple leaf nodes spread out at a distance, using intermediate nodes to reach other nodes.

Table 1

Wireless sensor network topology

		0			0				Master Node (00)
		1			4				1st level children of master (00)
	11		21			14			2nd level children of master. Children of 1st level.
11			21	21			14		3rd level children of master. Children of 2nd level.
				221		114	114	114	4th level children of master. Children of 3rd level.

The data transmitted between the modules are the values obtained from the sensors.

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Thus, each individual node of the monitoring system consists of the communication module, the sensor (accelerometer) and the microcontroller. The power source is a compact large-capacity battery.

Each individual sprayer (i-Wob) is completed with a measuring network node. The nodes, using the algorithm that was described above, send the sensor data to the head module. In the head module, data are pre-processed and sent to the operator via GSM to the web interface. The data can be displayed on a personal computer, smartphone, or a specialized console of a security company.

As sensors are used inexpensive three-axis accelerometers. They allow to measure the deviation of the sprayer position from the normal working condition with high accuracy and the necessary frequency.

It is proposed to use artificial intelligence methods for decision making. This is because when working sprayers may come in contact with crops, birds or be exposed to wind. In such cases, accelerometers will also record some random deviations, which should be recognized by the monitoring system as safe.

Conclusions

The article analyzes the conditions and features of the operation of sprinkling machines in the farming enterprises of Ukraine. Based on the analysis, the choice of microwave motion sensors to ensure control of access to the sprinklers is justified. A structural and functional diagram of a system for monitoring the status of sprinkling machines has been developed.

The prospect of further research is to assess the possibility of accurately determining the source of movement in a controlled space in order to prevent false alarms of the monitoring system.

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