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Automated monitoring system for assessment of the current state of groundwater

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Abstract. The article discusses the issues of control, accounting for the rational use of groundwater and methods for measuring the water level in the well. It is proposed to measure the water level using radio waves. This method can be used in difficult conditions, in particular at high pressure, at high temperatures without direct contact with the measured object. The problems of monitoring the groundwater level and analyzing the state of measurement are considered. Recommendations are given on instrumentation for level control, creating and implementing an automated observation system, and an integrated analysis system using a remote data transmission module via GSM. A program for monitoring the water level in a well has been developed on the Arduino platform. A functional and structural diagram of an automated system for monitoring the state of groundwater has been developed, and technical means of automation have been selected. The selected radio module type MX-RM-5V (433MNz), which transmits information in real-time.

INTRODUCTION

Under natural conditions, groundwater is characterized by a natural regime. The natural regime is formed mainly under the influence of meteorological, hydrological, and geological factors. Meteorological factors (precipitation, evaporation, air temperature, atmospheric pressure) are the main factors in forming the natural regime of groundwater. The rise in the level begins only some time after the precipitation falls. After precipitation, after a while, the groundwater level begins to rise. This period depends on the water permeability of the rocks and the depth of the groundwater.

The groundwater level changes not only seasonally but also in a multi-year cycle. Long-term fluctuations in the level are associated with climate changes and correspond to different cycles, among which the 11-year cycle is most clearly recorded. The amplitudes of long-term fluctuations can exceed the amplitudes of seasonal fluctuations and reach significant sizes (up to 8 m and more).

To predict groundwater level for the entire period of long-term operation of structures and other engineering calculations, it is necessary to study the long-term regime of groundwater [1]. As you know, the construction of reservoirs and other artificial reservoirs, irrigation, water leakage from underground networks of water-carrying communications, industrial pools, reservoirs, etc., contributes to an increase in groundwater level.

Groundwater levels can rise by 10-15 m or more under the influence of artificial (anthropogenic) factors. Large reservoirs have a particularly large impact. The regime and balance of groundwater are interrelated, and if the first reflects the change in the quantity and quality of groundwater over time, then the second is the result of this change. The groundwater balance is compiled for large areas or individual sections (irrigation and filtration fields, group water intakes, etc.). Measurements of the influx and discharge of groundwater are compiled in areas called balance. The water supply of the region and the possibility of annual replenishment of groundwater reserves, study of the causes of flooding of territories, forecasting changes in the groundwater level is determined using the balance [2].

An automated system for monitoring the level of groundwater in observation wells is used to measure the level and temperature of groundwater and store information offline during long periods of observation. The obtained information is used to replenish the database of long-term observations of the geographic information system.

Analysis of data from annual observation cycles allows predicting the state of groundwater in various modes and operating conditions and evaluating the effectiveness of measures for their protection [3-8].

MATERIALS AND METHODS

Modern level sensors

Consider modern level sensors that are used to measure the level of groundwater. The float level gauge provides an electrical discrete signal about the liquid level and the interface level of two immiscible liquids in devices and tanks of technological units. The disadvantage of this measurement method is mechanical instability [9].

The difference in electrical properties of liquids underlies the principle of operation of electric level meters. In this case, the liquids, measured level, can be both conductors and dielectrics. The disadvantage of this measurement method is the dependence of the electrical conductivity of water in the object [10].

The capacitive level gauge allows you to measure the current level and signaling of two limit levels of water. The operation of a capacitive level transmitter is based on the difference in the dielectric constant of liquids and air. The electrical capacitance of the sensing element of the level gauge changes in proportion to the level of immersion in the controlled environment (when filling or emptying the reservoir). This change in capacitance is electronically converted into a DC signal, then used for local readings, signaling, and transmission to other devices [11]. A conductometric level gauge operates based on measuring the resistance between electrodes placed in the measured medium (one of the electrodes can be the tank wall).

Conductivity level gauges (resistance level gauges) are designed to measure the level of conductive liquids. The accuracy of conductometric level gauges also depends on changes in the electrical conductivity of the working fluid and the polarization of the medium around the electrodes. For this reason, the errors of conductometric methods for measuring the level (even when using various compensation schemes) are quite high (5-10%). They are most often used as level indicators for conductive liquids [12].

Vibrating level switches are used to measure the limit values of liquids. The design of these devices is modular. This allows them to be used in containers, tanks, and pipelines. Thanks to the universal and simple measuring system, the functioning of the level switch is practically independent of the chemical and physical properties of the liquid. The vibration alarm works under unfavorable conditions (turbulence, air bubbles).

Vibrating level switches can be used to measure levels of almost all liquids. The vibrating element is driven (piezoelectric) and vibrates at a mechanical resonance frequency of approximately 1200 Hz. Piezo elements are not subject to thermal shock.

When a piezoelectric element is immersed in a liquid, its vibration frequency changes, this frequency change is transmitted to the built-in generator and converted into a changeover command. Vibrating level gauges are the best solution for sticky liquids [13].

The next type of level gauges is acoustic or ultrasonic. These level gauges use the phenomenon of ultrasonic waves reflection from the liquid-gas interface plane. Measuring the transit time of an ultrasonic wave from the transmitter to the surface of the liquid and back is the basis of the operation of these level gauges.

The emitter becomes a sensor upon receiving the reflected ultrasonic wave pulse. If the transmitter is inside the liquid, then the level gauge is called ultrasonic. If the transmitter is above the liquid, the level gauge is called acoustic.

The electronic unit performs the following functions: the creation of emitted ultrasonic pulses, amplification of reflected ultrasonic pulses, measurement of the transit time of a double path pulse (in air or liquid), and conversion of this time into a unified electrical signal [14]. Ultrasonic level gauges are used to control one level, two levels, or to control two levels in one technological process.

Solution methods

All of the above methods for measuring groundwater level in a well have drawbacks for the technological process. Measuring the water level using radio waves is possible in difficult technological conditions, particularly at high pressure, high temperatures without direct contact with the measured object. Compared to ultrasonic level gauges, radio waves can provide greater measurement accuracy, have a smaller dead zone, and are capable of operating at high pressures in the tank [15-16].

A radio wave sensor is an "intelligent" device that has a measuring part and processes the received signal. There is an interface for data exchange with a computer. It functions like a radar. This allows you to minimize the influence of various interferences, including interferences caused by irregularities (waves) of the measured object's surface [17].

The RF module of the RF transmitter operates in the VHF range. The standard frequencies used are 433MHz, 868MHz, or 2.4GHz. RF modules work with UART (RS-232) or SPI data protocols. The data transfer rate depends on the carrier frequency. Our proposed transmitter (model FS1000A) consists of two transistors, amplitude modulation of the signal, carrier frequency equal to 433 MHz, stabilized by a resonator of surface acoustic waves. The transmitter board has three pins: VCC, GND for power supply (3.5-12 V), the DATA pin is an input for modulating data, a high logic level on this pin turns on the transmitter. A carrier signal is generated [18-19].

The receiver (model XY-MK-5V) is a super-generator with a comparator at the output. Receivers of this type consist of a small number of parts and are therefore very simple. They have high sensitivity and automatic gain control. The receiver board has four pins: VCC, GND - 5V supply, and output in the form of two combined pins (Fig. 1).

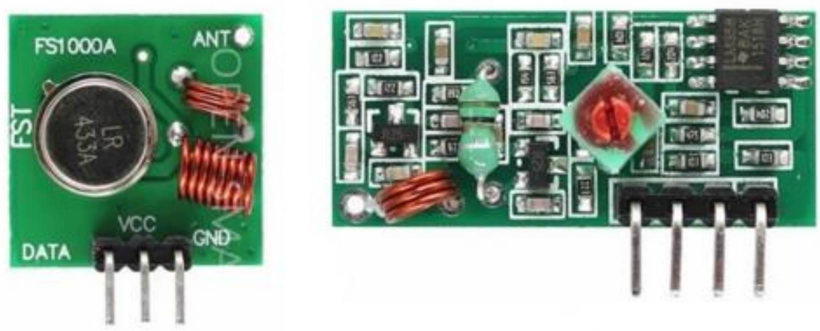

FIGURE 1. Radio modules MX-RM-5V for 433 MHz – transmitter and receiver (from left to right)

After assembling the 433MHZ Receiver + Transmitter kit, it may be necessary to adjust the receiver. For this, a trimming coil is provided. To configure, turn on the transmitter in the mode of sending signals with a carrier modulation frequency of 2-5 Hz and check for the presence of a signal at the output of the receiver (Fig. 2).

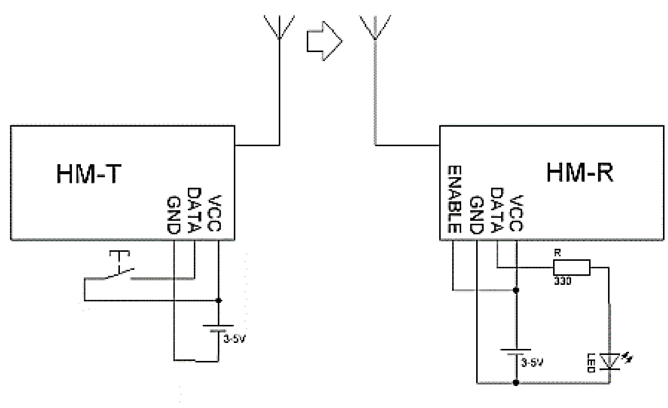

FIGURE 2. Schematic diagram of the radio module

The principle of operation of the device is as follows. The microwave generator of the level sensor generates a radio signal, the frequency of which changes in time according to a linear law. This signal is emitted in the direction of the measured object, reflected from it. After a certain time depending on the speed of light, part of the signal returns back to the antenna.

The emitted and reflected signals are mixed in the level sensor. As a result, a signal is formed, the frequency of which is equal to the difference between the frequencies of the received and emitted signals. This signal is proportional to the propagation time and accordingly to the distance from the antenna to the measured object (Fig. 3).

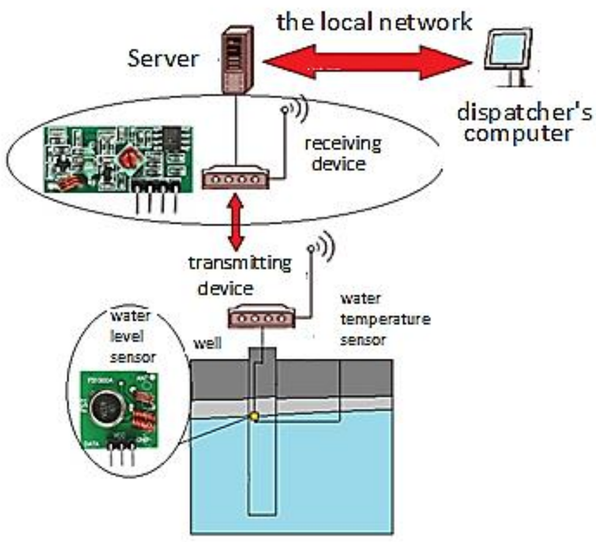

FIGURE 3. Functional block diagram of the automated monitoring system

The reflected, and hence the resulting signal, which carries information about the level of the measured object, also contains various noise and parasitic components. This is because the measurement is carried out under real conditions of possible disturbances of the object, incomplete reflections of the radio signal, and its partial absorption by the surface of the measured product.

Therefore, the resulting signal is subjected to spectral analysis. For this, the received signal inside the level sensor is digitized and converted into a "spectrum".

Further, using special algorithms of spectral analysis in real-time, the parasitic components of the signal are filtered. The frequency of the esulting signal is determined with high accuracy, which corresponds to the level of the measured object.

RESULTS AND DISCUSSION

On the Arduino platform, a program was developed for monitoring the water level in the well.

Code for 433 MHz transmitter

```
#include <VirtualWire.h>
 void setup(void)
{
  vw_set_ptt_inverted(true); // Necessary for DR3100
  vw_setup(2000); // Set the baud rate (bit / s)
}
 void loop(void)
{
  int number = 123;
  char symbol = 'c';
   String strMsg = "z ";
  strMsg += symbol;
  strMsg += " ";
  strMsg += number;
  strMsg += " ";
```

```
  char msg[255];
  strMsg.toCharArray(msg, 255);
  Serial.println(msg);
  vw_send((uint8_t *)msg, strlen(msg));
 vw_wait_tx(); // We are waiting for the transfer to be completed
 delay(200);
}
```

Code for 433 MHz receiver

```
 #include <VirtualWire.h>
 void setup()
{
  Serial.begin(9600);
  vw_set_ptt_inverted(true); // Necessary for  DR3100
  vw_setup(2000); // We set the speed of reception
vw_rx_start(); // We start monitoring the broadcast
}
 void loop()
{
 uint8_t buf[VW_MAX_MESSAGE_LEN]; // Buffer for message
  uint8_t buflen = VW_MAX_MESSAGE_LEN; // Buffer length
   if (vw_get_message(buf, &buflen)) // If a message is received
{
    // We start parsing
    int i;
    // If the message is not addressed to us, exit
    if (buf[0] != 'z')
    {
      return;
    }
    char command = buf[2]; // The team is at index 2
    // Numeric parameter starts at index 4
    i = 4;
    int number = 0;
    // Since the transfer is character by character, you need
to convert the character set to a number
    while (buf[i] != ' ')
    {
      number *= 10;
      number += buf[i] - '0';
      i++;
    }
    Serial.print(command);
    Serial.print(" ");
    Serial.println(number);
  }
}
```

The program is loaded into the microcontroller of the sensor. With the help of an oscilloscope, we obtain the change in the sensor's output signal over time. Figure 4 shows the sensor output signal on the oscilloscope screen in a steady state. Figure 5 shows the sensor output signal on the oscilloscope screen in dynamic mode. As you can see, when the distance between the receiver and transmitter changes, the phase frequency of the radio signal changes.

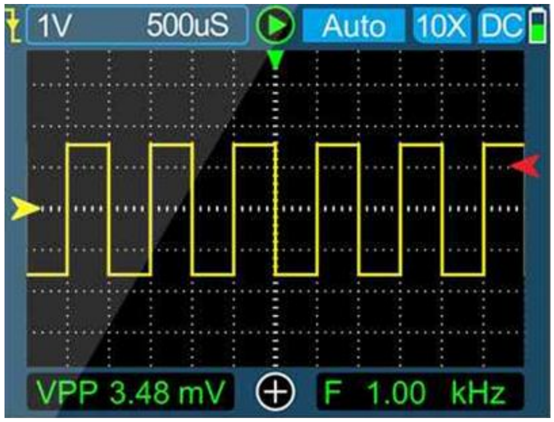

FIGURE 4. The sensor output signal on the oscilloscope screen in in steady state

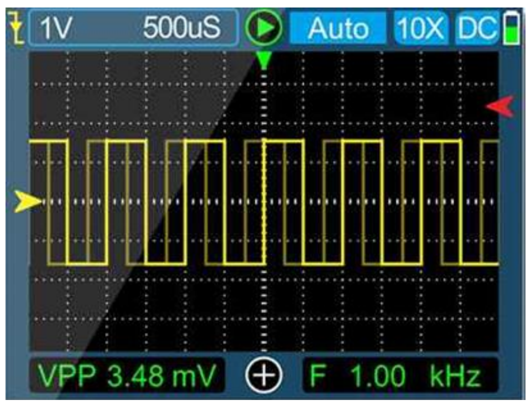

Figure 5. The sensor output signal on the oscilloscope screen in dynamic mode

CONCLUSIONS

The paper proposes measuring the water level using radio waves. Radar sensors can be used in difficult technological conditions, in particular, at high pressures, high temperatures without direct contact with the measured object. Radio waves are capable of providing greater measurement accuracy, have a smaller dead zone, and operate at high pressures in the tank. To improve the operation of the radar sensor, a transmitter-radio module of the MX-RM-5V type on 433MNz was chosen, which transmits information in real-time. We also chose a receiver (model XY-MK-5V), which is a super-generator with a comparator at the output. Receivers of this type are very simple. They have high sensitivity and automatic gain control.

Based on the system analysis associated with the development of automated monitoring of the groundwater level control, the issues of information transfer and the sustainability of the technological process were resolved [20-21].

The resulting sensor signal, which carries information about the level of the measured object, contains various noise and parasitic components. To filter them, the output signal is examined using spectral analysis based on special algorithms in real-time. The frequency of the signal corresponding to the level of the measured object is determined with high accuracy.

REFERENCES

1. M. Zakirov, I. Agzamova and N. Mavlyanova, Tech. Sci. Innov. 2019, 148 (2019)
2. M. Giuliani and A. Castelletti, Water Resour. Res. 49, 3912 (2013)
3. L. Gao, J. D. Connor and P. Dillon, Water (Switzerland) 6, 1662 (2014)

4. B. Liu, C. Xiao, Y. Zhou, X. Jiang and F. Zhang, in Second Int. Conf. Mech. Autom. Control Eng. (Institute of Electrical and Electronics Engineers, China, 2011), pp. 7591–7594
5. Cao Yang, Teng Yanguo, Zhai Yuanzheng, Wang Wei, Su Xiaosi and Liu Yang, in Int. Symp. Water Resour. Environ. Prot. (Institute of Electrical and Electronics Engineers, Xi'an, China, 2011), pp. 153–156
6. A. I. J. M. Van Dijk, R. S. Crosbie, J. L. Peña-Arancibia, P. Tregoning and S. McClusky, in Int. Geosci. Remote Sens. Symp. (2012), pp. 1318–1320
7. R. Agarwal and P. K. Garg, in 2016 IEEE Int. Geosci. Remote Sens. Symp. (Institute of Electrical and Electronics Engineers, Beijing, China, 2016), pp. 1808–1811
8. L. Oberkircher, Soc. Nat. Resour. 24, (12), pp. 1270–1285, (2011)
9. S. Wang, C. Chen, C. Wu and C. Huang, in 2018 IEEE Int. Conf. Appl. Syst. Invent. (Institute of Electrical and Electronics Engineers, Chiba, Japan, 2018), pp. 151–154
10. S. E. Woodard, IEEE Trans. Instrum. Meas. 59, 3206 (2010)
11. S. Kv and M. Gupta, in 2nd International Conference on Trends in Electronics and Informatics (ICOEI), 1421-1424, (2018) doi: 10.1109/ICOEI.2018.8553732.
12. A. L. Berezhetskyy, C. Durrieu, J. Chovelon, S. V. Dzyadevych and C. Tran-Minh, in International Solid-State Sensors, Actuators and Microsystems Conference, 1421-1424, (2007) doi: 10.1109/SENSOR.2007.4300410.
13. A. Jahn, F. Ehrle and C. Roppel, in 2014 6th European Embedded Design in Education and Research Conference (EDERC). (Institute of Electrical and Electronics Engineers, Milan, Italy, 2014). pp. 245-249.
14. A. Rocchi, E. Santecchia, F. Ciciulla, P. Mengucci and G. Barucca, IEEE Sens. J. 19, 3077 (2019)
15. E. Kim, Y. Yamada and S. Okamoto, in 2017 IEEE/SICE International Symposium on System Integration (SII). (Institute of Electrical and Electronics Engineers, Taipei, Taiwan, 2017), pp. 942-947, doi: 10.1109/SII.2017.8279344.
16. M. Vogt, in 2018 IEEE MTT-S International Conference on Microwaves for Intelligent Mobility (ICMIM). (Institute of Electrical and Electronics Engineers, Munich, Germany, 2018), pp. 1-4, doi: 10.1109/ICMIM.2018.8443505.
17. J. Wessel, R. K. Yadav, P. S. Zarrin, F. I. Jamal, D. Wang, G. Fischer, in 2020 IEEE International Symposium on Radio-Frequency Integration Technology (RFIT), (Institute of Electrical and Electronics Engineers, Hiroshima, Japan, 2020), pp. 241-243, doi: 10.1109/RFIT49453.2020.9226229.
18. H. Li, J. Ding, Z. Zhou and G. Liu, IEEE SENSORS, pp. 1-4, (2015), doi: 10.1109/ICSENS.2015.7370682.
19. F. Sidek, A. N. Nordin and M. E. Zaghloul, in 2011 54th International Midwest Symposium on Circuits and Systems (MWSCAS), (Institute of Electrical and Electronics Engineers, Seoul, Korea (South), 2011), pp. 1-4, doi: 10.1109/MWSCAS.2011.6026617.
20. S. R. Ubaydulayeva and A. M. Nigmatov, in 2020 International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM), (Institute of Electrical and Electronics Engineers, Sochi, Russia, 2020), pp. 1-6, doi: 10.1109/ICIEAM48468.2020.9111939.
21. S. R. Ubaydullayeva, D. R. Kadirova and D. R. Ubaydullayeva, 2020 International Russian Automation Conference (RusAutoCon), (Institute of Electrical and Electronics Engineers,Sochi, Russia, 2020), pp. 464-469, doi: 10.1109/RusAutoCon49822.2020.9208076.