

DEVELOPMENT OF AN AUTOMATED SYSTEM FOR MONITORING 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, the creation and implementation of 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. Certificate (patent) No. DGU 117 24 dated May 19, 2021 was received for the development of the software "Groundwater level measurement method"

Key words: groundwater monitoring, radar level gauge, data transmission via GSM, spectral analysis.

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 the formation of 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 of time 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 the level of groundwater 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. contribute to an increase in the level of groundwater.

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 for individual sections (irrigation and filtration fields, group water intakes, etc.). Measurements of the influx and discharge of groundwater are compiled in areas called balance. 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 level of groundwater 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, store information in an offline mode 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.

2.1. 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, the level of which is measured, 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 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, which is then used for local readings, signaling and for transmission to other devices [11]. A conductometric level gauge operates on the basis of 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: 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.

2.2. Solution methods.

All of the above methods for measuring the level of groundwater in a well have drawbacks for the technological process. Measuring the water level using radio waves is possible in difficult technological conditions, in particular, at high pressure, high temperatures without direct contact with the measured object. Compared to ultrasonic level gauges, radio waves are capable of providing 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. Functions like a radar. This allows you to minimize the influence of various interferences, including interferences, which are caused by irregularities (waves) of the surface of the measured object [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 an output in the form of two combined pins (Figure 1).

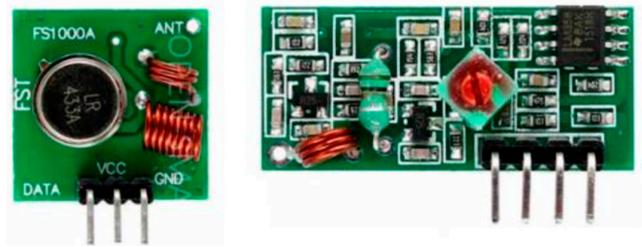


Fig.1. Radio modules MX-RM-5V for 433 MHz – transmitter and receiver (from left to right)

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 (Figure 2).

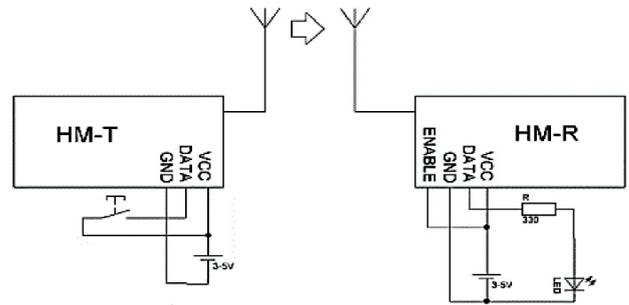


Fig. 2. Schematic diagram of the radio module

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. Part of the signal, after a certain time depending on the speed of light, returns back to the antenna.

The emitted and reflected signal 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 (Figure 3).

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 due to the fact that 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".

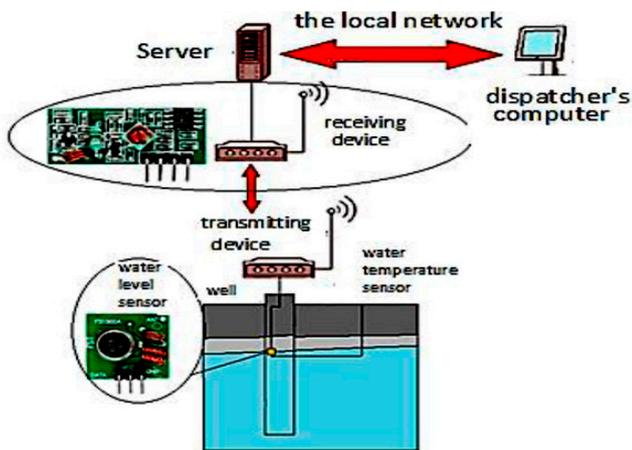


Fig.3. Functional block diagram of the automated monitoring system

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

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

3.1. 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); }
```

3.2. 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 output signal of the sensor over time. Figure 4 shows the sensor output signal on the oscilloscope screen in 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.

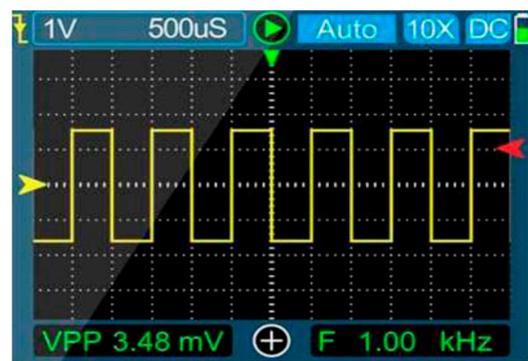


Fig. 4. The sensor output signal on the oscilloscope screen in in steady state

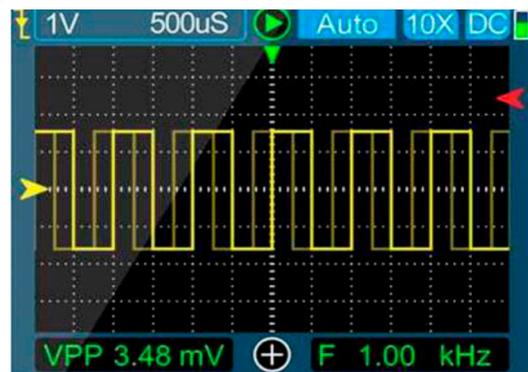


Fig.5. The sensor output signal on the oscilloscope screen in dynamic mode

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 are capable of operating 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. On the basis of 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.

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