Multifunctional complex of environmental monitoring with optical communication channel

D Isaenko, B Reznikov and S Rodin

The Bonch-Bruevich Saint-Petersburg State University of Telecommunications, Saint-Petersburg 191186, Russia

E-mail: isaenko-d@mail.ru

Abstract. The research is focused on the development of a multifunctional complex for continuous monitoring of the environmental situation with an optical communication channel. The principle of the complex operation and its hardware are considered. Possible modifications of the complex are offered. The developed complex is absolutely modular, which allows making changes in the complex to adapt to any requirements.

1. Introduction

Some news publications call 2020 the year of environmental disasters in Russia. Of course, these accidents could have been avoided or the consequences minimized. To do this, it is necessary to conduct monitoring on a continuous basis. Not only technogenic-hazardous enterprises and territories need such monitoring, but also residential areas, transport arteries (highways, sea trade routes, railways, oil and gas pipelines). In other words, the whole ecosystem: volcanoes, fires, flood zones and other natural disasters.

2. Requirements to the complex

The following requirements were set forth while designing the complex:

2.1 Autonomy and vandal-proof. Complex has to work autonomously without human's participation, and also to be sufficiently durable or to be located in the place which is inaccessible for a common person;

2.2 Small dimensions;

2.3 Low power consumption;

2.4 Possibility to install a wide range of sensors. Since the specifics of environmental monitoring involves measuring a huge number of parameters, it does not make economic sense to measure all the parameters. It is necessary to select the specific measured parameters for the specific location of the complex;

2.5 The speed of data exchange with the data center;

2.6 Possibility to change the data transfer method depending on the complex location.

The scheme of the complex consists of power supply, optical signal transceiver, sensors, microcontroller board converting data from sensors and transmitting them to the transceiver.

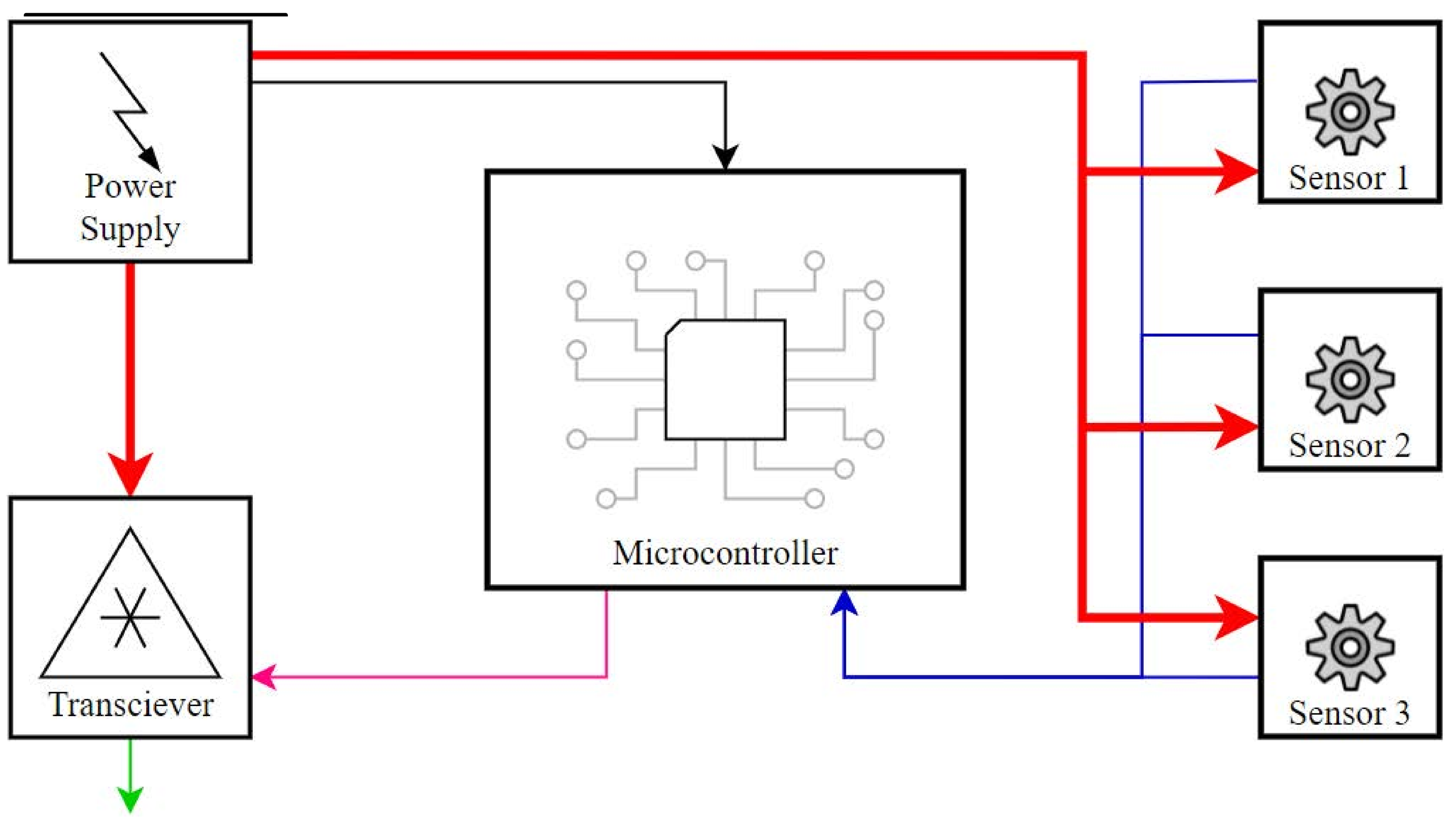

Figure 1. Scheme of the environmental monitoring complex

3. Components of the complex

Figure 1 shows a diagram of a multifunctional complex for environmental monitoring with optical communication channel, where:

PS - power supply;

T - optical signal transceiver;

S1-S3 - sensors;

MC - microcontroller that converts data from the sensors and transmits them to the transmitter.

3.1 Power supply circuit. It assumes the use of a low-power DC power supply with 220 V (50 Hz). As an example we chose the ESP-15-5 network converter, which has the necessary parameters.

This model is chosen with a significant power reserve, since there is no data on the exact power consumption of the whole monitoring complex, and, if necessary or if accurate data is available, it can be replaced.

However, when placing the monitoring complex in close proximity to the poles of power lines or on the poles themselves, it is possible to organize the power supply from a strong electromagnetic field. In this case, inductor coil and equalizing circuit voltage to the required operation of 5 V is used. In this case, the parameters of the inductor coil are determined individually, depending on the strength of the electromagnetic field and the power consumption of the sensors used.

3.2 Microcontroller. The Arduino Nano microcontroller board is the device that takes over the functions of signal conversion from the sensors and its transmission to the transceiver. The choice of this microcontroller is due to its small size and power consumption, as well as a large amount of documentation.

3.3 Fiber-optical communication line

In the environmental monitoring complex, an important component is a fiber-optic communication channel. This is necessary if the multifunctional complex is located on high-voltage power lines, in which case there will be no problems with electrical energy. The block diagram of the fiber-optic communication channel is shown in figure 2.

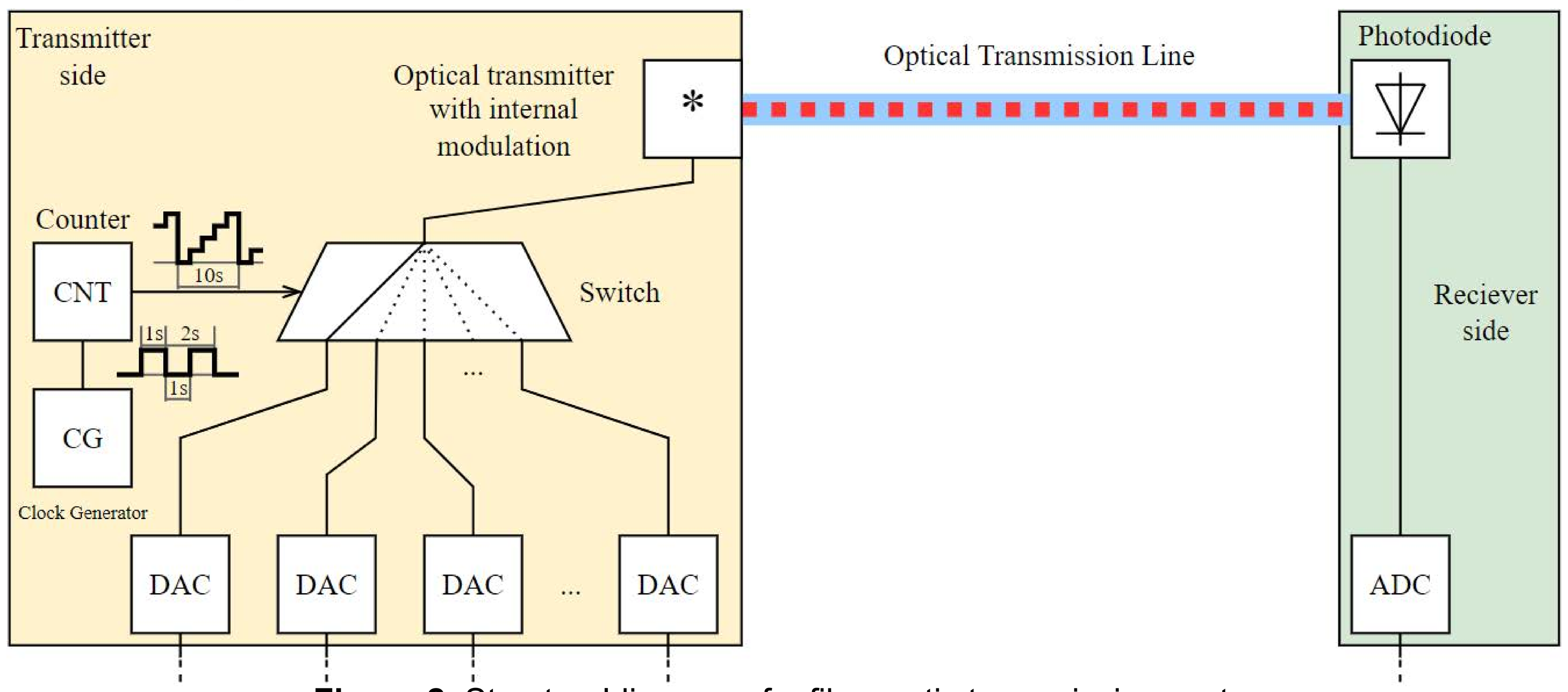

Figure 2. Structuraldiagram of a fiber-optic transmission system

3.4 Sensors. The market offers a wide range of different sensors for environmental monitoring, but it is worth noting that the design of the monitoring complex allows you to use almost any type of sensor not only for environmental monitoring, but also, for example, to conduct meteorological observations.

As an example, the following parameters will be monitored:

- air condition (carbon dioxide, formaldehyde, particulate matter suspensions);
- wind direction and speed;

If necessary, the list of parameters required for monitoring can be increased many times.

As CO2 sensor, WINSEN industrial infrared sensor MH-410D is used. This sensor operates based on the absorption of infrared light by the gas. Different gases have different infrared absorption peaks, therefore gas type and concentration can be determined by measuring and analyzing the absorption curve of the gas.

The electrochemical sensor WINSEN ME3-CH2O is used to detect a wide range of formaldehyde compounds. This sensor is based on an electrochemical process of oxidation of the target gas at the working electrode inside the electrolytic cell. The current produced in the electrochemical reaction of the target gas is directly proportional to its concentration. The concentration of the gas can then be obtained by measuring the value of the current.

WINSEN ZPH02 is the sensor for suspended solids. It is based on infrared detection technology that can detect particles from 1 μm in diameter.

There are many ways to measure wind velocity (anemometry), the main ones are the following:

- thermo-anemometric;
- mechanical - with a propeller (more precisely, an impeller) or a cup horizontal impeller (classical cup anemometer). Measuring speed in these cases is equivalent to measuring the rotation frequency of the axis on which the propeller or impeller is fixed;
- ultrasonic - combines measurements of speed and direction.

There are fewer ways to measure direction:

- ultrasonic;
- A mechanical vane with an electronic angle of rotation measurement. There are also many different ways to measure angle of rotation: optical, resistive, magnetic, inductive, mechanical.

In operation, for simplicity, two separate mechanical sensors are used to determine wind speed and direction.

A feature of the developed optical communicationchannel is the temporal division of the transmitted information about the state of the environment over one single-mode fiber. This allows, on the one hand, to optimize the design of the FOCL for information transmission. On the other hand, to provide a higherstability of the optical communication channel from various factors. For this, a clock generator is used. The signal from this generator is fed to the counter, which alternately closes and opens the electronic keys. Through these switches, the input of the transmitting laser module receives an analog signal from the measuring sensors, which modulates the laser radiation in amplitude.

The modulated optical signal is recorded by a photodiode, which converts the received optical signal into an electrical voltage. This signal is then sent to an analog-to-digital converter. The most important characteristic in this case is the dynamic range of the developed optical communication channel. The results of measuring the dynamic range are presented in Figure 2.

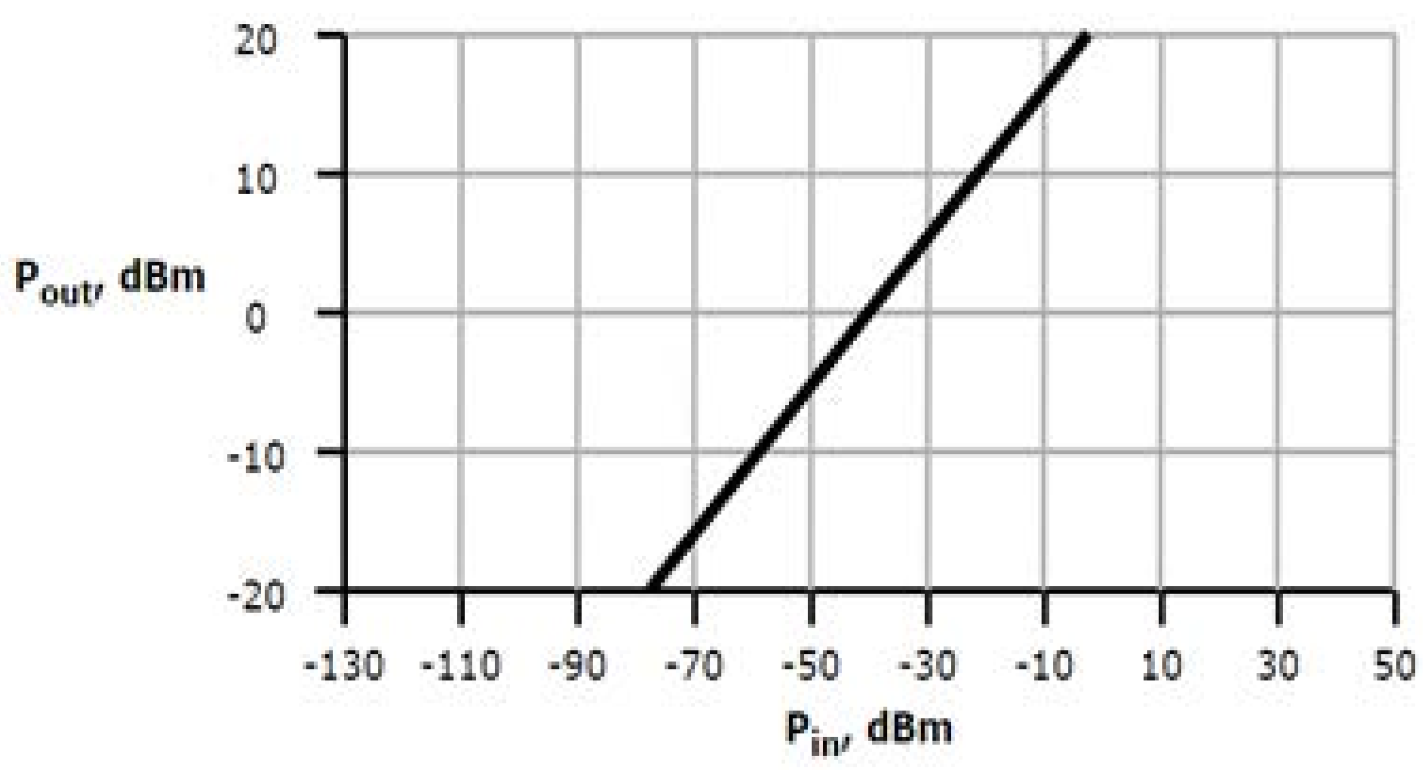

Figure 2. Dynamic range of the optical communication channel

4. Conclusion

The proposed monitoring complex differs from the existing options in small size, cost and, most importantly, modularity of design, which allows the complex to adapt to any conditions required by the customer. The optical communication channel provides the possibility of high-quality data transmission over long distances without the use of amplifiers, provides information exchange at high speeds between the monitoring complexes and the data processing center, which allows you to respond quickly to the situation.