Screening Diagnostic System for Chronic Obstructive Pulmonary Diseases

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***Abstract* — Preventive screening examinations of the population are one of the most effective ways to prevent COPD today. In this paper the problem of technical support of chronic obstructive pulmonary disease diagnosis is described. Transmit channel data and testing of technical capabilities of NRF24L01-module for implementation in screening diagnostic system are analyzed. The present measurements agree with the following IEEE basic standards: IEEE 802.15 and IEEE 802.15g.**

Keywords* — *auscultation; spirometry, phonospirography complex, wireless data transmission.

I. Introduction

Breathing is the most important physiological function of the human body and it provides the normal course of metabolism through the exchange between the environment and the body which consumes oxygen and releases carbon dioxide.

With the integration and coordination of normal respiratory function human lungs are able to allocate an average of about 5–18 liters of carbon dioxide (CO2), and 50 grams of water per hour. There are about 400 other impurities of volatile compounds in one expiration. Diseases of lungs can selectively or totally affect the physiological processes and gas exchange.

At that moment, the increasing prevalence of bronchopulmonary diseases makes implementation of methods for monitoring respiratory an important scientific and practical problem.

According to the World Health Organization (WHO) 210 million people worldwide suffer from chronic obstructive pulmonary disease (COPD). Almost 90% deaths of COPD occur in low- and middle-income countries, including Ukraine, and the level of technical provision of health care institutions acts an important part here. Early detection of respiratory function disorders, dynamic monitoring of patients and choice of the most relevant violations allow to provide more effective therapy.

The preventive screening examinations of the population are one of the most effective ways to prevent COPD today. Usually such examinations were taken at the workplace or in specialized mobile unit. The specificity of screening examinations imposes special hardware requirements – portability, efficiency, accessibility. The most efficient solution for this purpose is using a variety of mobile devices with wireless communication technologies.

Spirometry is the most common of the pulmonary function tests, measuring lung function, specifically the amount (volume) and speed (flow) of air that can be inhaled and exhaled. Spirometry is an important tool used for obtaining pheumotachographs, which are helpful in assessing conditions such as asthma, pulmonary fibrosis and COPD.

The aim of the work is verification proposed screening diagnostic system based on the radio module NRF24L01 to IEEE basic standards [1, 2].

II. Results and Discussion

The present stage of development of the spirometry technique composed in that the patient performs specific breathing exercises such as calm breathing, forced expiration, maximum ventilation, etc. During the test, the volumetric air flow rate and air volume are determined at different stages of the procedure. Analysis of expiratory maneuver (exhaling) is clinically relevant information.

Important parameters, which obtained as a result of respiratory tests for diagnosis, are:

- vital capacity (VC);
- forced inhaled vital capacity (FVC);
- peak expiratory flow (PEF);
- maximum expiratory flow after exhaling 25% of FVC (MEF 25);

• maximum expiratory flow after exhaling 50% of FVC (MEF 50);
• maximum expiratory flow after exhaling 75% of FVC (MEF 75);
• forced expiratory flow rate of between 25% and 75% FVC (FEF 25-75);
• forced expiratory vital capacity in 1 second (FEV1);
• Tiffno index (FEV1 / VC);
• Gensler index (FEV1 / FVC).

Loop "flow-volume" builds according to obtaining information (Fig. 1). This loop is object of the procedures.

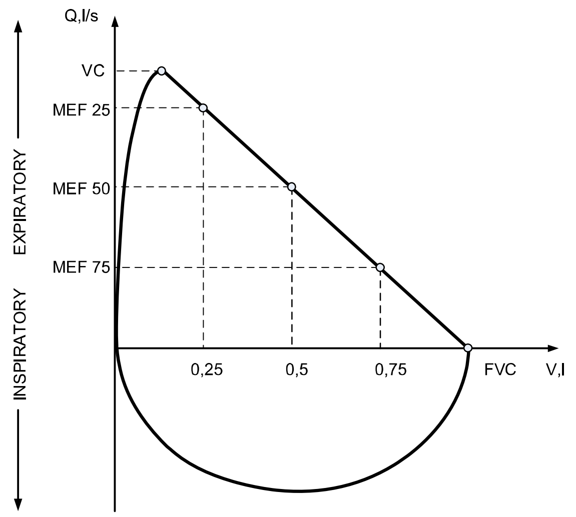

Fig. 1. Loop "flow-volume".

Clinical evaluation of pulmonary function of ventilation is based on a comparison of the results of the breath test performed by the patient correctly with the proper values. Proper values characterize for the individual normal parameters, with considering to sex, age and height.

So diagnostically valuable signal in spirometry is a volumetric flow rate. It should be noted that this signal has a number of features that lodge to spirometer increased as compared with other metering requirements: firstly, the wide range of input signal changes the order of 1:150; second, the composition of complex harmonic frequencies up to 20 Hz.

Auscultation is a physical medicine diagnostic method, which means listening to the sounds generated by the functioning organs. Auscultation of the lungs is one of the leading methods of patients' examination and is based on listening to the sound effects caused by fluctuations of some elements of the body. The sounds originated in the body by themselves due to the changes in tension of organs' tissues while functioning are auscultated. Therefore these sounds are rather weak and can be detected only by putting the ear on the body surface (direct auscultation) or by special sound-conducting devices, known as stethoscopes or phonendoscopes (indirect auscultation). The latter has a number of advantages over direct auscultation. Such as the possibility of sound amplification, filtering, recording, and digital processing [3].

Currently the one of the most promising sector of medical technology is development and production of spirometric devices (SD), therefore it put higher requirements of technical support.

There are several types of sensors SD in modern medicine:

• the narrowing type of sensor;
• turbine-type sensors;
• thermoconductometric sensors;
• ultrasound sensors.

Analysis of the advantages and disadvantages of these sensors showed that portable spirometric equipment most appropriate to use tachometric method, which used in turbine-type sensors. This sensor has a transfer characteristic is close to linear in the operating range, low air resistance, low weight, size and cost parameters.

Spirometer is a portable digital device designed for the study human respiratory function. It consists two main blocks: a measuring channel and the processing and the transmission of information block.

The working principle of the measurement channel is based on the transformation of the air flow, which supplied through the turbine flow transducer, to a sequence of the electrical pulses. This conversion is performed by the modulation of electromagnetic infrared radiation, coming from the source to the receiver by measuring turbine rotor lobes. Block diagram of measuring channel is shown in Fig. 2.

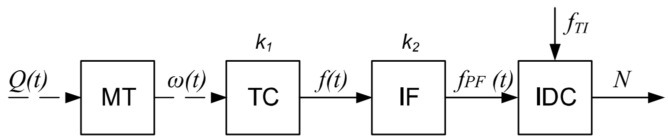

Fig. 2. Block diagram of measuring channel:
MT – measuring turbine; TC – tachometric converter;
IF – impulse former; IDC – impulse-to-digital converter.

TC converts the rotation of plate into an electrical signal with frequency f(t) which proportional to the w(t)

$$f(t) = w(t)\, k_1 / (2\pi),$$

where k_1 – transfer coefficient of TC.

IF converts the output electrical signal from MT to the series of short rectangular impulses with frequency f_{IF}(t) which equal

$$f_{IF}(t) = f(t)\, k_2,$$

where k_2 – transfer coefficient of IF.

IDC converts the frequency $f_{IF}(t)$ of impulses series into digital code N according to the method of sequential account.

Timing diagrams of the change process are presented in Fig. 3.

Structural scheme of processing and transmission information block is shown on Fig. 4.

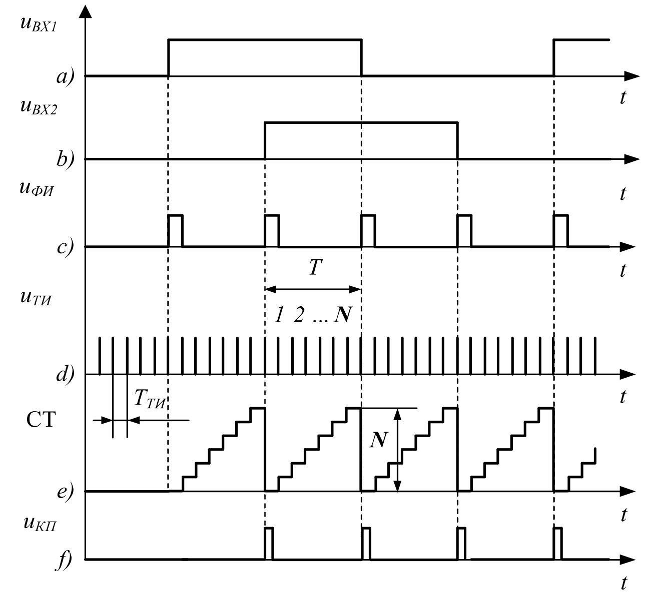

Fig. 3. Timing diagram of the change process

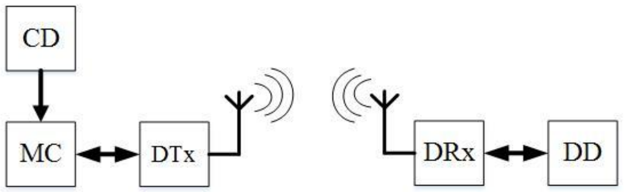

Fig. 4. Structural scheme of processing and transmission information block: MC – microcontroller; CD – control device; DD – digital device; DTx – device of information transmit; DRx – device of information received.

Digital code N supplied to the microcontroller (MC), where determined the instantaneous and average values speed of the airflow.

The device is controlled with control device (CD), which included four buttons A, B, C, D. The transmition of information is realized with device of information transmit (DTx). The received information is realized with device of information received (DRx). The information about the testing process serves is displayed with digital device (DD) [4].

Computer phonospirography complex KoRA is designed for digital auscultation. The environmentally friendly non-invasive electronic registration of the human respiratory noise, computer processing, visualization and storage of their acoustic characteristics is provided by KoRA. Fig. 5 shows the block diagram of the computer phonospirography complex KoRA.

Respiratory noises generated in the human broncho-pulmonary system are recorded by the two sensors 1, which convert the vibrations of the body surface to an alternating voltage, which is amplified by low-noise amplifier 2, filtered by low-pass filters (LPF) 3 and high-pass filters (HPF) 4, then proceed to ADC 5, where the signal digitizing is held. The signals from the ADC are fed to the computer 6, where they are processed and visualized (visualization is available either on a computer monitor or on A4 paper from the printer). Also, respiratory sounds are stored on the computer where they can be processed by different diagnostic methods for obtaining data.

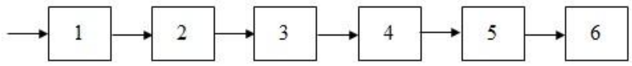

Fig. 5. The block diagram of the computer phonospirography complex KoRA

Portable devices of obtaining of rate and data signals do not always allow to use the appropriate processing software and data analysis, so it should be organized the transmission of data to more powerful devices.

The portable radio module NRF24L01 shown in Fig. 6 should be tested according to the standards IEEE [1, 2].

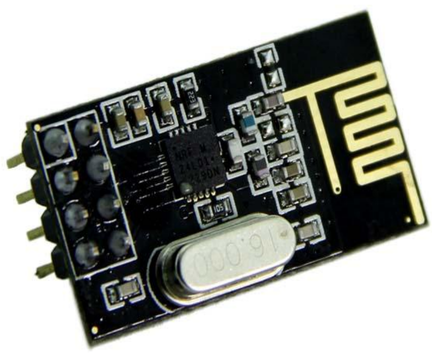

Fig. 6. Portable radio module NRF24L01.

This radio module is a highly integrated with ultra-low-power transceiver with a frequency of 2,4 GHz and the transmission rate with microcontroller reaches up to 2 Mbit/s.

The supply voltage range is from 1.9 V to 3.6 V, low cost and high speed SPI interface with the controller allows using it in medical technology.

There are next advantages of this module: low cost, accuracy, reliability, energy efficiency, energy security.

III. TESTING

For the testing the radio module NRF24L01 was created working model, presented in Fig. 7 and Fig. 8.

This working model included two microcontrollers STM32F411RE and two radio modules NRF24L01 and it simulates the transfer data from spirometer via wireless.

Fig. 7. Testing model (left – transmitter, on right – receiver).

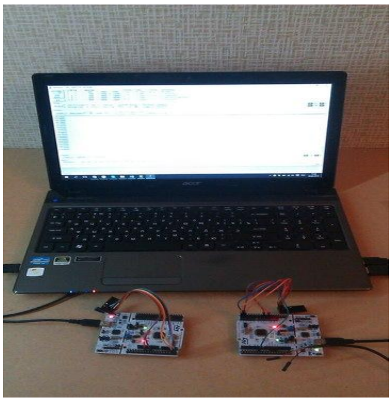

Fig. 8. Process of testing.

The following parameters were changed during the test:

• The data size transferred (8 kBit, 16 kBit, 32 kBit);
• Transmission and receive signal power (0 dBm, –6 dBm, –12 dBm, –18 dBm);
• Data transfer speed (250 Kbit/s, 1 Mbit/s, 2 Mbit/s);
• Distance.

At the end of the test were obtained diagrams of transmission, which presented in Fig. 9 – 8 byte, Fig. 10 – 16 byte, Fig. 11 – 32 byte.

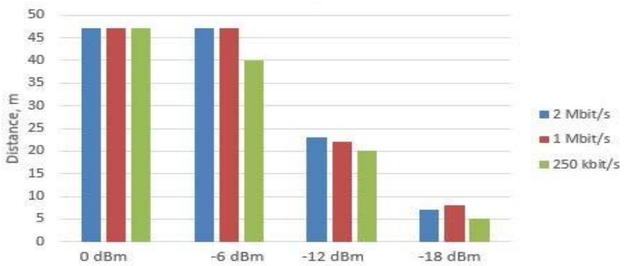

Fig. 9. Diagram transmission 8 byte.

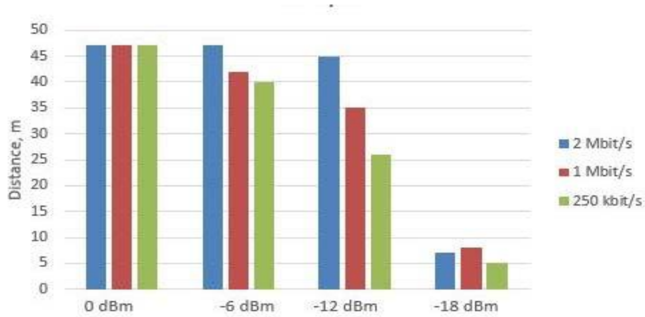

Fig. 10. Diagram transmission 16 byte.

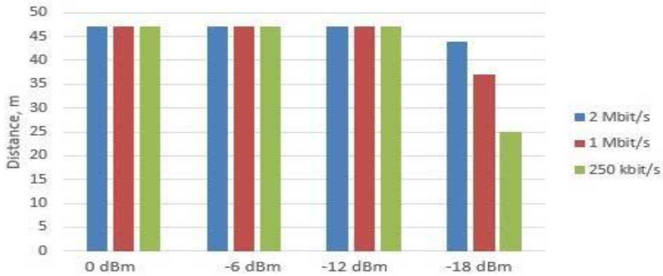

Fig. 11. Diagram transmission 32 byte.

The analyzis of results showed that radio module NRF24L01 satisfies to the standards of IEEE 802.15 and IEEE 802.15g and can be used in portable spirometers as module of transmission data by wireless communication.

Testing of the NRF24L01 module for the suitability to its usage for data transmission from phonospirography complex. The transmission distance without packet loss, depending on the volume settings of transmitted packets and signal attenuation were tested. Fig. 12 shows the working model.

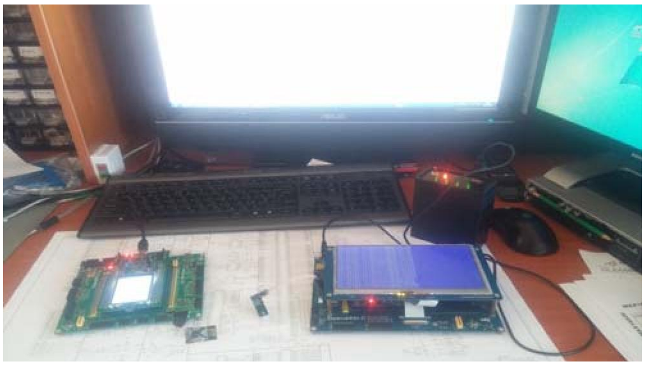

Fig. 12. Working model.

The test result are diagrams of transmission, which presented in Fig. 13 – 8 byte, Fig. 14 – 16 byte, Fig. 15 – 32 byte.

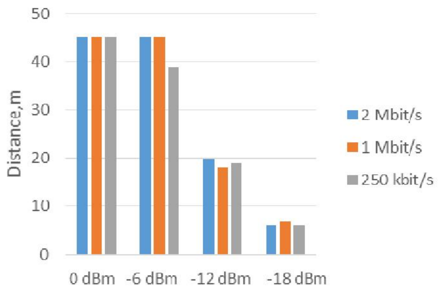

Fig. 13. Diagram transmission 8 byte.

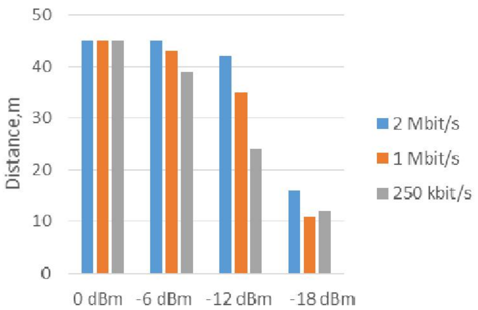

Fig. 14. Diagram transmission 16 byte.

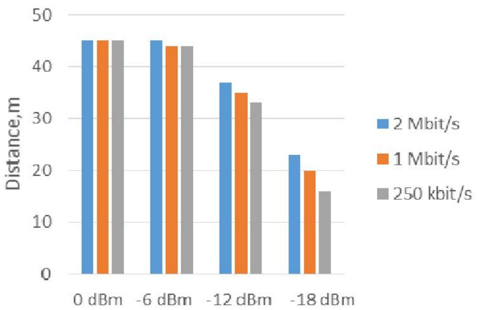

Fig. 15. Diagram transmission 32 byte.

The data that are shown in the diagram was obtained in a long straight passage, the 100% reception was even at the greater distances than at the ones presented in the table, but the packets were lost at intermediate values. The values, that are presented in the table, correspond to the distance over the entire length, where the broadcast was without packet loss. Besides, during the tests the fact of while a human is between the transmitter and the receiver closer to transmitter, the number of lost packets increases, was taken into consideration.

This module meets our requirements both in speed and in the transmission distance as the portable phonospirography complex, which data will be transmitted from, and the computer that will receive the data will be located in the same room.

IV. CONCLUSIONS

The analysis of test results showed that proposed screening diagnostic system based on the radio module NRF24L01 meets the IEEE 802.15 and IEEE 802.15g standards and module can be used in portable spirometers as a module of transmission data by wireless communication. Thereby the module NRF24L01 can be used in screening diagnostic systems for chronic obstructive pulmonary disease.

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