Research of data transmission system based on UWB technology

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Abstract. The paper analyzes the data transmission system based on UWB technology for unmanned surface vehicles. The main advantages of using ultra-wideband signals are presented. It is shown that such a communication system allows for a transmission speed of several tens of Mbps with a radio path length of not more than 10 m.

1. Introduction
To date, work performed by machines under human control is transferred under the control of automated systems. Technical systems operated by people, at the current level of development of electronics, in most cases are more expensive and this is due to the fact that it is necessary to spend resources on management and supervisory organs.

Thus, the use of unmanned aerial vehicles has already been mass-produced, they are used everywhere, especially for solving military and monitoring tasks. At the same time, there is growing interest in unmanned surface vehicles (USVs), which may be useful for solving the problem of monitoring the coastal and surface zones and analyzing the movement of ships during patrols. Such continuous monitoring helps to prevent threats of man-made or natural emergencies.

The amount of data collected during such patrols can reach up to 10-100 gigabytes. To ensure the autonomy and increase the speed of information extraction from USVs data recorders, it is proposed the use of a high-speed and wireless data transmission system.

This system is based on UWB (UltraWideBand) technology, which provides high-speed transmission of information at distances of up to 100 m. This technology can be considered optimal due to the fact that the ultra-wideband signal has a wide radio frequency range from 3100 to 10600 MHz, due to which it can transmit over wireless channels with impressive data volume for a short period of time [1]. In this operating range, the power spectral density of the signal is limited to 41.5 dBm/MHz. At the same time, such a signal almost merges with the noise level, which means UWB signals do not need to be licensed. The combination of low power consumption and the impulse character of the information transmission can achieve a high data transfer rate without negative electromagnetic effects from other radio systems. That makes it possible to consider UWB technology as an ideal option for transmitting video data.

Digital information can be transmitted using amplitude manipulation with a passive pause, in this method of transmitting information, each pulse transmits one bit. The number of pulses transmitting one bit per unit time is determined by the average radiation power. This type of modulation is not energetically beneficial. Nevertheless, it is easier to implement hardware, and therefore the most promising.

2. Data transmission system research
In accordance with the technical parameters of the equipment used in this work, the following parameters were selected: emitted pulse duration - 0.5 ns, bandwidth: 3100 ... 5100 MHz, the maximum allowed spectral density of the UWB signal in the bandwidth – $7.413 \cdot 10^{-14}$ W/Hz (in accordance with the standards of electromagnetic compatibility of the International Electrotechnical Commission).

The Shannon-Hartley theorem states that the amount of information transmitted per unit time is proportional to the signal bandwidth. In this regard, ultra-wideband signals can provide many communication channels, since it takes a short time to transmit short pulses, so at the same time there can be many such signals on the air “without collisions” [2]. Independence from fading due to the short pulse duration is ensured, which is especially important for mobile systems. Another advantage of UWB technology, in comparison with similar systems in terms of infrared exchange rate, is the ability to operate the system in conditions of indirect visibility.

To evaluate the features of receiving a UWB signal, simulation was carried out, the channel parameters were determined in accordance with the Saleh-Valenzuela model standardized in IEEE. The period of one signal symbol is taken to be 2 ns; the sampling period is 20 ps. The length of the radio channel was chosen less than 5 m and from 5 to 10 m. The simulation results are shown in the figures below, which show the impulse characteristics of the channel for cases of direct visibility (figure 1-2) and its absence (figure 3-4).

![Figure 1](image1.png)

**Figure 1.** Impulse response of the Saleh-Valenzuela model channel in the case of direct visibility at a range of less than 5m.

![Figure 2](image2.png)

**Figure 2.** Impulse response of the Saleh-Valenzuela model channel in the case of line-of-sight at a range of 5-10m.
Figure 3. Impulse response of the Saleh-Valenzuela model channel in the case of non-line-of-sight at a range of less than 5m.

Figure 4. Impulse response of the Saleh-Valenzuela model channel in the case of non-line-of-sight at a range of 5-10m.

When passing channels with a shorter transmission distance, a concentration of 2-3 clusters occurs with a small delay. As the distance increases, the clusters become larger and the delay increases due to different cluster reception rates. The gain in channels with a distance of 5 to 10 meters decreases faster due to the increased distance, in comparison with channels whose distance is less than 5 meters.

The pulse shape of the transmitted signals undergoes expansion and flattening of the final pulse while maintaining its shape. When using pulses up to 0.1 ns, the distortions become so significant that extracting information from the time dependence becomes impossible.

The following is an estimate of the possible amount of data for transmit-receive within 30 meters. The range of the communication system is determined by the expression:

\[
D = \frac{P_{TRpeak} G_{TB} G_{RV} (c \tau)^2}{16\pi^2 P_{RV}}
\]  

(1)

where \(P_{TRpeak}\) – the peak power of a transmitter; \(G_{TB}\) – the transmitting antenna gain; \(G_{RV}\) – the receiving antenna gain; \(c\) – the speed of light; \(\tau\) - duration of the emitted UWB pulse; \(P_{RV}\) - receiver sensitivity.

The peak power of a transmitter is defined as:
\[ P_{TR\text{peak}} = P_{TR\text{mean}} \frac{T}{\tau} = \frac{P_{TR\text{mean}}}{\tau \cdot V} \] (2)

where \( V \) - information transfer rate, bit/s; \( P_{TR\text{mean}} \) - ultimate average power, which is calculated as follows

\[ P_{TR\text{mean}} = N_{UWB} \cdot \Delta f_{UWB} \cdot N_{UWB} = 7.41 \cdot 10^{-14} \] - permissible power spectral density of the UWB signal, W/Hz; \( \Delta f_{UWB} = 2 \) - receiver bandwidth, GHz.

The sensitivity of the receiver is described by the formula:

\[ P_R = N_{RV} \cdot q \] (3)

where \( N_{RV} \) - noise level operating in the working band of the UWB receiver; \( q \) - the ratio of signal to noise at the input of the receiver, required to provide a given probability of error per bit.

The noise level \( N_{RV} \) is defined as:

\[ N_{RV} = k \cdot T_K \cdot \Delta f_{UWB} \cdot N \] (4)

where \( k = 1.38 \cdot 10^{-23} \) - Boltzmann constant, J/K; \( T_K = 293 \) - absolute temperature, K; \( N = 10 \) - receiver noise figure.

To achieve the error probabilities per bit \( BER=10^{-3} \), he signal-to-noise ratio \( q=30 \) and for \( BER=10^{-6} \) the signal-to-noise ratio \( q=70 \).

Based on the foregoing, the dependence of the range of the system on the data transfer rate will be determined by the following formula:

\[ D = \frac{N_{UWB} \cdot c^2 \cdot \tau}{16\pi^2 k \cdot T_K \cdot N \cdot q \cdot V} \] (5)

In accordance with the formula (5), a graph was constructed of the dependence of the coverage range of system on the data transfer rate (Figure 5).

**Figure 5.** The dependence of the coverage range of system on the data transfer rate.
The results enable to conclude that UWB technology is productive only for data transmission at a distance of less than 10 m. At the same time, the low spectral power density of the UWB signal, which can be considered noise at the input of the receivers of conventional radio systems, makes it possible to work in common frequency bands with other systems. This difference from other communication technologies guarantees a high degree of stealth and noise immunity.

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