

ULTRA-WIDEBAND COMMUNICATION SYSTEM WITH HIGH DATA RATE

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The ultra-wideband communication system with high data rate is considered. Information in the system is transmitted by train of short pulses, which have duration about 1.0 ns. The hardware realization of the system is offered. The simulation of the system operation is presented.

1. Introduction

In modern communication systems, the problem concerning the transmission of large information flows is of vital importance. An increase in information volume can be achieved by widening the radio channel's frequency band. Therefore, the communication systems using the ultra-wideband (UWB) signals for their operation make rapid steps forward both in theory and practice the last years. For example, Multispectral Solutions, Inc. (USA) has developed several UWB communication systems. One of them provides data transmission with the rate up to 25.0 Mbps at the distance up to 10.0 km [2].

It must be noted that the implementation of UWB signals in communication systems leads to the need for solving some scientific and technical problems.

In this paper, we discuss the ways to design the UWB communication system to transmit video data from mechanical robots operating in destroyed buildings and industrial constructions; these operation conditions result in multipath signal propagation caused by signal rescattering. The operational range is 2.5–3.0 km; video data transmission rate is about 2.0 Mbps.

2. Ultra-Wideband Signals

Ultra-wideband signals are the signals with the value η :

$$\eta = \frac{f_{up} - f_{low}}{f_{up} + f_{low}},$$

(where f_{up} is the upper frequency of the frequency band; f_{low} is the lowest frequency in the frequency band) which lies within the limits $0.25 < \eta \leq 1.0$.

The implementation of such signals for data transmission through radio channel has the following advantages compared to narrow-band signals:

- Low average radiated power which is usually no more than units-tens milliwatt, it depends on the distance and data communication rate;
- Secure operation of communication systems thanks to low spectral power per a frequency band unit, electromagnetic compatibility with the narrow band systems operating within the same frequency band;
- High data transmission rate;
- Efficient resistance to multipath signal propagation due to time selection of direct and re-scattered signals and correlation reception;
- Minimum radio frequency circuits in receiver/transmitter schemes (the absence of high frequency generators, mixers, and others);
- Simplicity of the construction.

3. Description of the System

The specialists in Moscow Aviation Institute (“Analog and digital radio engineering systems” Department) have been working for several years on the development of UWB communication systems intended for transmitting various types of data.

The basis for these works is the conception of the use of UWB signals. The use of UWB short dura-

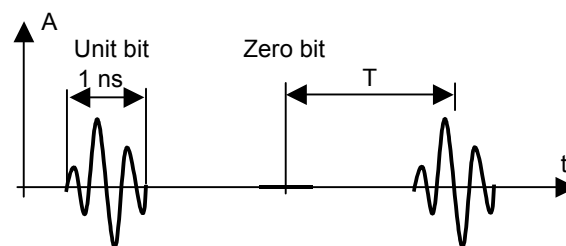


Fig. 1. ON-OFF Pulse Keying

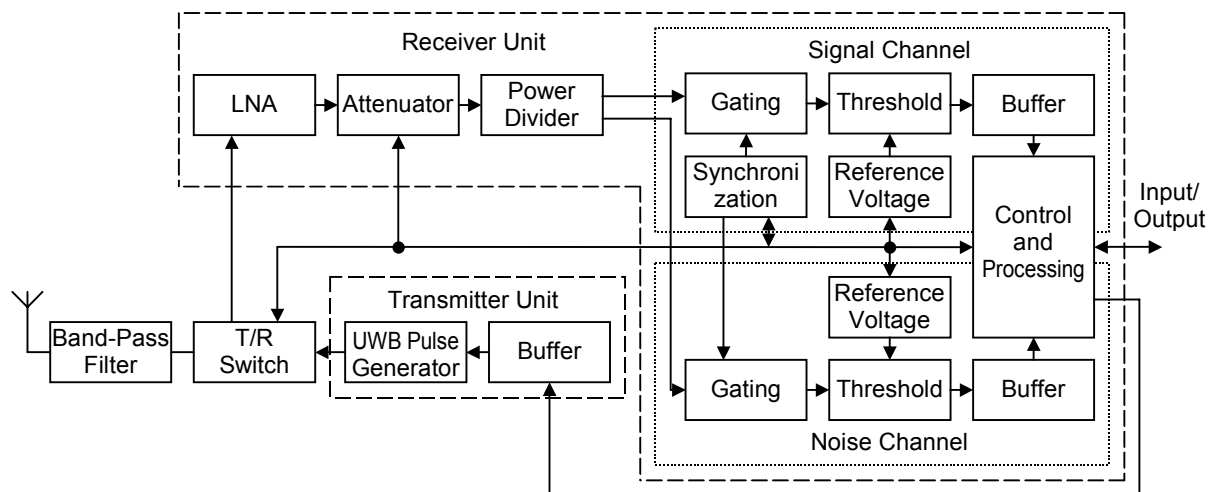


Fig. 2. Block diagram of UWB transceiver

tion signals helps to keep the high quality of the data transmitted. Thanks to reduction in radiated pulse duration a possibility appears for efficient resistance to multipath signal propagation caused by signal rescattering from objects located near the communication system antenna and the line-of-sight between the signal source and the receiver. If a signal duration is 1.0 ns and the objects which cause signal rescattering are located at the distance more than 30 cm from the line-of-sight, we will have undistorted signal detection.

In the developed system, the communication is realized by using the pulses, the duration is 1.0 ns, the repetition frequency is 2.0 MHz. The information is coded by ON-OFF Pulse Keying. (See Fig. 1). This type of modulation provides easy in data processing on retention of all advantages of UWB systems.

The block diagram of the developed system is shown in Fig. 2. The signal transmitting the information represents a sequence of zeroes and nulls; it arrives at a Buffer in the Transmitter Unit. The buffer performs the transformation of the data sequence into

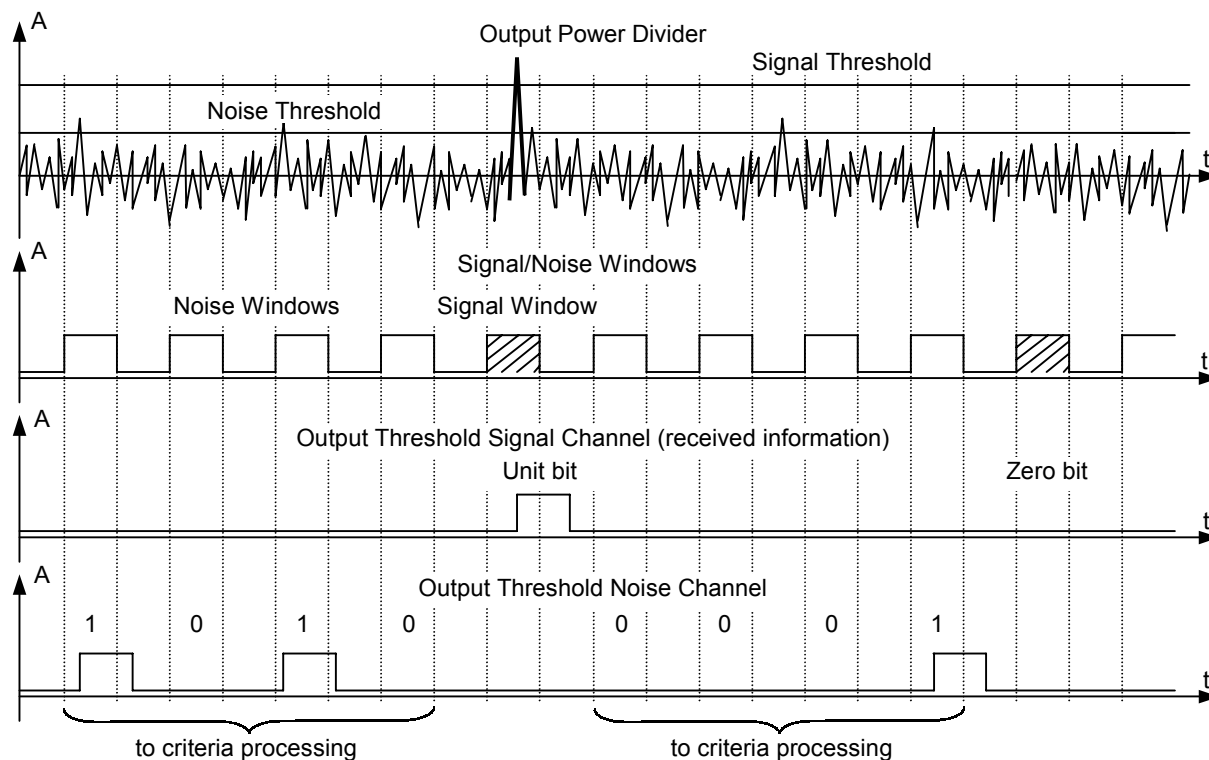


Fig. 3. Timing diagrams of operation of signal channel and noise channel

a signal, which drives UWB Pulse Generator with a “free” cut. The UWB Pulse Generator is made using diodes with quick restoration of a back resistance; it is loaded by the antenna with 50 Ohm wave resistance. Pulse power is fed from the Generator to the load with a pulse period-to-pulse duration ratio about 500. Information symbol repetition frequency is 2 MHz.

Antenna switch performs the commutation of reception/transmission operational modes. We have examined several types of UWB transmitting/receiving antennas. All antennas were made on the base of the strip technology. Antennas’ frequency band is about 0.4–2.0 GHz. Antennas’ sizes are from 40 to 900 cm².

The receiver comprises a low-noise amplifier (LNA), attenuator, several high rate chips advanced CMOS logics. The digital signal processor controls transmitter/receiver operation. Programmable logic array is used in the synchronization and signal-tracking scheme.

The Receiver Unit is composed of two channels, which make simultaneous reception. One channel serves for signal detection; the other channel serves to estimate the level of external interference and the signals rescattered from the objects located at the signal propagation line.

The basic schemes in both channels are the highly sensitive threshold schemes made on the base of key tunnel diodes operating in frequencies up to 20 GHz. The diodes are manufactured in Russia.

Any received signal is amplified and fed to the power divider and then to the threshold schemes in the Signal and Noise Channels. The output signal from the threshold schemes goes through Buffers to Digital Signal Processor. The signal processor analyses both a received signal and noise. The analysis of external noise is based on the criteria processing of the signal received in Noise Channel. Digital Signal Processor performs the estimation of rescattered signals and noise level followed by criteria processing. Adjustment of receiver sensitivity is made by threshold regulation depending on the processing results. Adaptive adjustment of the receiver dynamic range is performed using the Attenuator. Synchronization scheme is also controlled using the results of the analysis.

In Signal and Noise Channels, the signals are detected in the time intervals (time windows). The signal detection within the time window, not far wider than the signal duration, provides high noise resistance of the receiver [3]. Timing diagrams of operation of signal channel and noise channel is shown in Fig. 3.

The detection of noise signals is also performed in windows with the width equal to signal window. Noise windows precede signal windows in time. The number and places of noise windows is variable, it

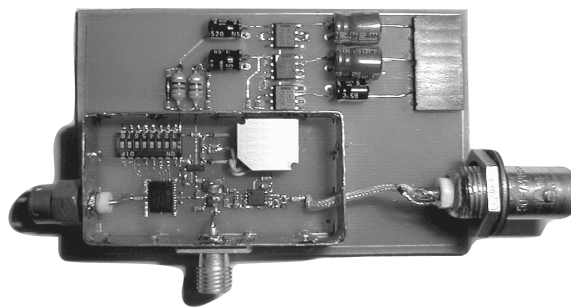


Fig. 4. *The design of signal (or noise) channel*

depends on external noise environment. Noise signals received in the windows are processed in Digital Signal Processor. The processing criteria can be different. The type of criteria selected depends on maximum signal-noise ratio.

The structure of signal channel and noise channel is identical. The design of one channel without the block of control and synchronization is shown in Fig. 4.

4. Operational Modes of Communication System

A. Calibration

Before operation, the receiver must be calibrated by external noise. The aim of calibration is to determine the reference voltage fed to threshold schemes in Signal and Noise Channels. While calibrating, the threshold level in Signal Channel is set higher than the threshold level in Noise Channel. The calibration is made after switching on the receiver power supply and when the signal is lost while operation. This also promotes high noise resistance of the receiver.

B. Signal Searching

After calibration, the receiver converts to the signal searching mode. Signal searching means the mode when the transmitter and receiver in the communication system are going to be synchronized. The transmitter emits a special signal, which serves to state the relation between the signal and the receiver. In this mode, the receiver signal window is searching the emitted signal. The signal detected is set in the middle of the window. Such signal searching process is performed by the synchronization system after receiver power supply is switched on and when the signal is lost during operation, just as for the calibration process.

C. Operational Mode

During the operational mode, a continuous estimation of the noise level in the noise windows is carried out. With variations of the noise level, the threshold values in Noise and Signal Channels change their values; and the input Attenuator regulates the signal level. Along with this process, the signal location in

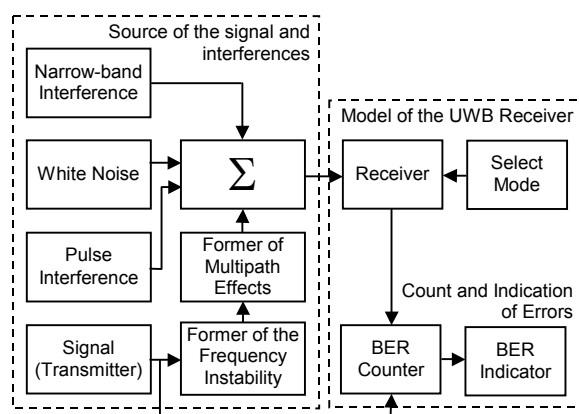


Fig. 5. Structure of model

the signal window is controlled. If the signal is displaced from the middle of the window at the given minimum time interval, then the synchronization system forms a command to move the signal window at the needed time interval.

When the signal is lost (no pulses in the signal window) during some time interval, then the communication system gets out of the operational mode and goes into calibration and searching modes.

5. Simulation

The main goal of simulation was the testing of UWB receiver functioning when it is influenced with various types of interference. The model was development at MatLab 6.0 software. The model consists of two parts: the model of UWB receiver and the model of adequate interference sources.

The prototype of UWB receiver is correspondent with the structure given in Fig. 2. The work of the receiver can be estimated for any mode separately. The choice of operational mode is carried out by the switch "Selection mode" (Fig. 5). The automatic change of operational modes to monitor the receiver's work is envisaged.

The unit of count and indication of errors permits to fix the errors of signal transmission under installation of various types of interference in communication channel.

The model permits:

- To regulate amplitude and time parameters of all signals and interference;
- To connect as single so several interference sources to the receiver input.

With the help of this model the tests under various UWB receiver operational modes and different interference combinations are carried out. Time diagram of the work of UWB communication system in signal searching mode, obtained as simulation issue is given in Fig. 6 for example. There receiver transition from searching to operational mode is shown. The interference signals in four "noise windows", opening before "signal window" are visible.

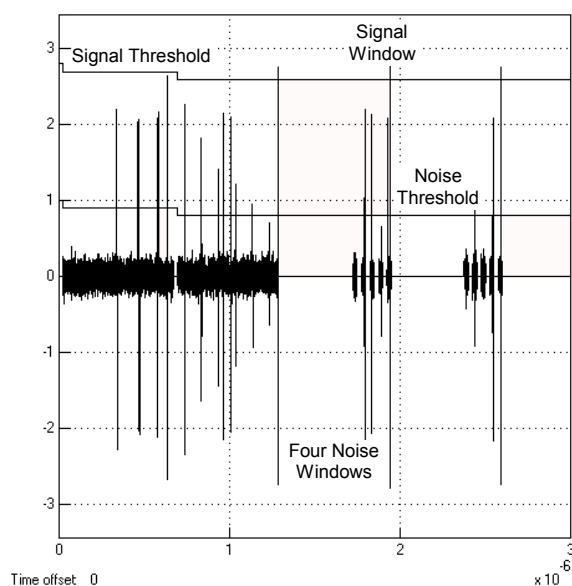


Fig. 6. Simulation of signal searching mode

6. Conclusion

The UWB Communication System discussed makes possible the transmission of large data flows in the presence of intensive interference of rescattered signals. The system is secure in operation and biologically safe for the operational personnel thanks to low average radiated power distributed over a wide frequency band. Adaptation of the operational mode to external conditions of multipath signal propagation, caused by rescattering of radiated signals, gives the opportunity of its implementation in various fields related with the transmission of large information flow; for example, telemetry, local computer networks located in buildings where cable-laying is difficult, general inter-building computer networks formation, and so on.

However, until recently the state permissions on operation UWB communication systems were absent. It was supposed that their use can create interference to existing radio systems. February 14, 2002 Federal Commissions of Communication (FCC), USA first time has received the decision permitting the use of the UWB systems. It is "First Report and Order" that permits the marketing and operation of certain types of new products incorporating ultra-wideband technology [4]. This document includes the standards designed to ensure that existing and planned radio services, particularly the safety services, are adequately protected.

Apparently, it is not a last pitch made in some direction of the use of the UWB systems in a separate country. We may hope that the taken decision will be an example for other advanced and developed countries.

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СВЕРХШИРОКОПОЛОСНАЯ СИСТЕМА СВЯЗИ С ВЫСОКОЙ СКОРОСТЬЮ ПЕРЕДАЧИ ДАННЫХ

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Рассматривается сверхширокополосная система связи с высокой скоростью передачи данных. Информация в системе передается посредством серии коротких импульсов, длительность которых около 1 нс. Предлагается аппаратная реализация системы. Представлена модель функционирования системы.

НАДШИРОКОСМУГОВА СИСТЕМА ЗВ'ЯЗКУ З ВЕЛИКОЮ ШВИДКІСТЮ ПЕРЕДАВАННЯ ДАНИХ

І.Я. Иммо́реєв, О.А. Судаков

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