Types of modulation in IR ultra-wideband technology

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Abstract. One of the ways to implement the UWB system is the pulse radio IR method, which is based on the transmission of very short (on the order of several nanoseconds and picoseconds) and low – power pulses. The paper considers the types of modulation in short-pulse signals of ultra-wideband communication: binary pulse-position modulation Binary PPM, binary modulation format with two values of the signal amplitude, two-phase modulation Bi-Phase Modulation.

1. Introduction
The term Ultra Wideband (UWB) currently means a number of radio engineering concepts: a radio signal without a carrier, an ultra-wideband radio signal (UWB), a very short radio pulse, a time pulse (time domain, "chip"). This signal is broadband, since the ratio of its bandwidth to the value of the central frequency of the signal spectrum is greater than one (for traditionally used radio signals in radio communications, this ratio is significantly less) [1]. For SSHPS, the concept of a carrier oscillation is not defined (we can consider, and then only conditionally, the central frequency of the spectrum). Thus, the term UWB is rather a common name that was given to the physical process in the late 80's.

2. Methods
The definition of the term "ultra Wideband signals" — Ultra Wideband-was first introduced by the US Department of Defense's DARPA agency in 1990 and adjusted by the US Federal Communications Commission (FCC) in 2000. According to the FCC definition, UWB includes all signals with a spectral band of at least 1.5 GHz, as well as signals with a spectral band width of at least 25 % of the center frequency value. This definition is quite unambiguously related to the current level of development of UWB signals and systems.

The full name of the new technology is Ultra Wideband Pulse Technology-ultra-wideband pulse technology. The next stage in the development of this new technology came in February 2003, when the IEEE approved the wireless standard 802.16 a, based, in particular, on UWB and focused on the use in the construction of wireless networks of the city scale-Wireless Metropolitan Area Networks (WMAN) [2].

Ultra-wideband communication (UWB) is a method of transmitting information using high-frequency pulses with low energy [3].
3. Results and discussion

UWB wireless communication technology is fundamentally different from all other wireless communication systems. The main difference between UWB technology is that it does not use a radio frequency carrier, but instead uses short and ultrashort low-energy modulated pulses (IR-UWB technology) or multiband MB-OFDM technology (Multiband OFDM).

In the IR (Impulse Radio) technology of ultra-wideband communication, such types of modulation are applicable as binary pulse-position modulation (Binary Pulse Position Modulation), binary modulation format with two values of the signal amplitude OOK (On-Off Keying), two-phase modulation (biphase) BPSK (Bi-Phase Modulation) [4].

4. Technical features of the SSHPSTechnology

In practice, the pulse duration ranges from 200 picoseconds to one nanosecond, and the pulse repetition intervals range from 10 to 1000 ns. Usually (but not necessarily) UWB signals have the form of idealized Gaussian monocycles, the parameters of which are selected so that the main part of the radiation spectrum is concentrated in the frequency range from 1-2 to 6-7 GHz.

In principle, the modulation of such pulses with useful data can be carried out by any of the known methods based on changes in their amplitude, duration, repetition frequency, etc. However, in practice, TM-UWD technology is now most often used, in which signals are formed using Pulse-Position Modulation (Pulse-Position Modulation — PPM), that is, the information parameter is the time position of the leading edge of the pulse. At PPM, depending on the instantaneous value of the modulating signal, the position of each working pulse changes in the time domain with respect to the position of the periodic reference pulses generated by the receiver. In other words, for the transmission of a logical "0", the working pulse is sent, for example, a little earlier than its "standard" time position in the pulse sequence, and for the transmission of "1" – a little later. The typical value of the time shift is 1/4 of the pulse duration.

In Binary PPM modulation, the synchronization change of each pulse is transmitted for data transmission instead of information about the amplitude change. A time-shifted pulse sequence is a "1", evenly distributed pulse sequence represents "0". The principle of binary pulse—position modulation is shown in Fig. 1 [4].

The advantage of this modulation is that each pulse in time does not depend on each other. In this way, the time can be broken down to search for each pulse within a given time interval. Modulation provides the best performance for errors, and also has the advantages in the resolution of incoherent reception.

The disadvantages of this type of modulation are the high requirements for system synchronization and for the stability of the reference pulse generator.

The modulation is susceptible to inter-character interference, because more positions need to be used to transmit data at a higher speed. It is necessary to reduce the frequency of transmitted pulses to
account for this effect. Even if there is a reduction in intermodulation interference in the transmitter by reducing the pulse frequency, multipath propagation causes errors on the receiving side.

The next type of modulation is binary modulation. A simple modulation method in which a "1" is transmitted in the presence of a pulse, and a "0" is transmitted in the absence of a pulse. The principle of binary modulation is shown in Fig. 2 [4, 5].

![Unmodulated sequence](image)

**Figure 2. OOK modulation [3]**

The obvious advantage of using this type of modulation is the ease of implementation, since only one pulse generator is needed. A single analog switch can control the pulses transmitted when "1" or "0" is turned on. The disadvantage of modulation is the possibility of losing time synchronization at the moment when the data stream contains a long chain of "0".

In two-phase modulation, data is transmitted by changing the sign value of the amplitude of each pulse based on binary data. The positive pulse is transmitted by "1", and the negative pulse is transmitted by "0". The principle of binary phase modulation is shown in Fig. 3 [4, 7-9].

![Unmodulated sequence](image)

**Figure 3. Binary phase modulation**

This type of modulation has an advantage over binary modulation. It consists in a lower signal-to-noise value of 3 dB and a lower probability of bit errors (BER).

The disadvantage of this modulation is a more complex implementation, since it is necessary to use two pulse generators, one of them with the opposite polarity. If there is no time stabilization in the pulse generator, then when trying to transmit pulses, there may be a non-periodic time between them.
5. Conclusion
In ultra-wideband systems, energy efficiency is a priority. In two-phase modulation, by changing the pulse polarity, it is possible to eliminate the spectral components, thereby reducing the amount of interference from conventional radio stations. Thus, two-phase modulation is an effective way to transmit UWB pulses [4, 5].

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