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# Sub-Terahertz Low Power UWB Communication Link for WPAN

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**Abstract** – proposed is ultra-wideband (UWB) wireless communication system for transmitting digital information in the terahertz frequency range on the basis of analog noise carrier with a low level of radiation. The digital information at the transmitter is inserted using code spectrum modulation of noise signal. The bit error rate (BER) performance is analyzed for different signal to noise ratios at the receiver at different bit rates. The proposed UWB wireless communication system is characterized by high noise immunity and the ability to secure transmission of information "in the noise" for the received information signal below the noise level. The designed UWB sub-terahertz communication link at 70 microwatt transmit power is suitable for wireless personal area networks.

**Keywords:** ultra-wide band UWB, WPAN, code spectrum modulation.

## 1. Introduction

The development of microwave communication systems and the increased demand for high speed communication through fast growing networks have led to the need for new higher-frequency ranges of electromagnetic waves. In this case, a broadband channel for short distances in large cities is the most appropriate use of terahertz waves (frequency range from 100 GHz to 3000 GHz) (Bulgakov2001; Ilchenko 2008; Ilchenko2010; Kuzmin 2009; Ilchenko2000). The special feature of the terahertz range is its significant dependence on meteorological conditions of its absorption in the atmosphere. This reduces the reliability of communication over long distances. However, at small distances (equal to or less than five kilometers) this disadvantage does not affect the reliability of communication, but it may even be useful. This is due to the reduced likelihood of one channel interfering with other channels, thereby reducing the electromagnetic background in the environment that leads to environmental safety of the telecommunications systems. In addition, the UWB systems offer more capacity than the microwave systems. Furthermore, reduced size and weight of the equipment make them portable, and easy to install.

It may be noted that the THz system may not completely replace the cable and fiber optic systems. However, since these systems are based on modern solid state electronics technology, they can be economically more viable than cable and optical fiber. Moreover, the cable systems are difficult to install in cities and significant funds are spent on cable padding in addition to their initial cost.

One of the promising areas to create a new terahertz technology is the development of digital telecommunications systems to transmit ultra-high (more than 1 Gb / s)Data rate (Kuzmin 2009: Ilchenko 2000; Akihinko 2006; Song 2009). Another important application of terahertz technology is the WPAN (wireless personal area network).

UWB multiple access communication links, designed for wireless personal area networks (WPAN) are characterized by their enhanced noise performance when many wireless devices operate simultaneously in the same vicinity. The use of ultra wideband noise-modulated continuously waveforms as a carrier signals provides interference immunity, electromagnetic compatibility and transmit covertness of wireless communications because they have very low transmit intensity(Ilchenko 2011; Narayanan 2007).

This paper presents a new approach to design UWB wireless sub-terahertz communication system based on spread spectrum and transmitted reference techniques.

## 2. Results and discussion

The development of high quality terahertz systems requires the usage of new electronic devices and components of the terahertz range based on nano-electronics, which in its turn is based on the latest achievements in semiconductor electronics, and telecommunication technologies. During the last years great research efforts were put in the development of such devices . These efforts were specifically focused on the development and creation of new types of electromagnetic terahertz wave oscillators with high frequency stability and low phase noise, frequency up and down converters, low-noise amplifiers and power amplifiers, power combiners (adders) and antenna devices.

One of the challenges in creating wireless communication systems working in the terahertz range is the choice of modulation type (Ilchenko 2010). The Application of multi-position modulation, in particular QAM modulation, to increase the data transmission rate in the terahertz range is not possible because of the deficit in communication channel bandwidth , whereas the use of simple methods of modulation DBPSK, QPSK, FM allows implementing - the available in this range -wide bandwidth for transmission Gigabit Ethernet streams. In (Ilchenko 2007) authors have analyzed the principles of efficiency and noise immunity of digital modulation methods, and proposed a combined digital-analog modulation QAM / FM with extremely high frequency modulation index in the microwave range.

Development of ultra-wideband (UWB) systems with low levels of radiation in the terahertz frequency range is an important task for the development of personal wireless LAN (WPAN) and sensor networks transmitting digital information. A promising direction in the development of wireless WPAN systems is the use of complex noise signals with high information capacity (Ilchenko 2011; Narayanan 2007). During the development of terahertz waves a serious technical challenge arises. It is the creation of solid-state RF generators with a capacity greater than 10 MW. Improving the efficiency of communication systems and reducing the radiated power in the channel is achieved through the use of spread spectrum techniques (Ilchenko 2011; Narayanan 2007).

In this paper we propose a UWB wireless communication system working in the sub-terahertz frequency range. It uses spread spectrum technique of code spectrum modulation of continuous noise carrier at the transmitter and the double spectral processing at the receiver.

Block diagram of the communication link is presented in Figure 1. In the transmitter, a continuous signal n (t) of the noise source (NS) enters the modulator (M), which is delayed by the time $T_1$ = 10 ns when entering the character "1" or a time $T_0$ = 18 ns when entering the character "0". Delayed signals n (t-$T_1$), or n (t-$T_0$) are added to the reference noise signal n (t).

The formed total noise signal (in the range of 3,1-4,1 GHz) carrying binary information is applied to the input of the mixer (Mx1), to the other input of which the signal from the reference oscillator OS is applied through power divider (PD). Reference oscillator frequency is 130 GHz. Noise signal with a code spectral modulation is shifted to terahertz range (133.1-134.1 GHz) by the converter, without changing its spectral structure. With highly directional antenna TA, this signal is transmitted over the wireless link to one or more subscribers. Radiated power is about 70 microwatts. To achieve this initial UWB. the signal was amplified by 12 dB to compensate for signal loss when converting up.

At the receiver the terahertz signal is converted back into UWB noise signal in the range of 3.1 - 4.1 GHz by the mixer (Mx2) with preservation of the contained information.

In the linear summing device the reference signal n(t) is summed with one of the delayed by T1 or T0 signals according to the applied symbol «1 » or «0 ».

$$z_{1,0}(t) = n(t) + H_{1,0}n(t - T_{1,0}) \qquad (1)$$

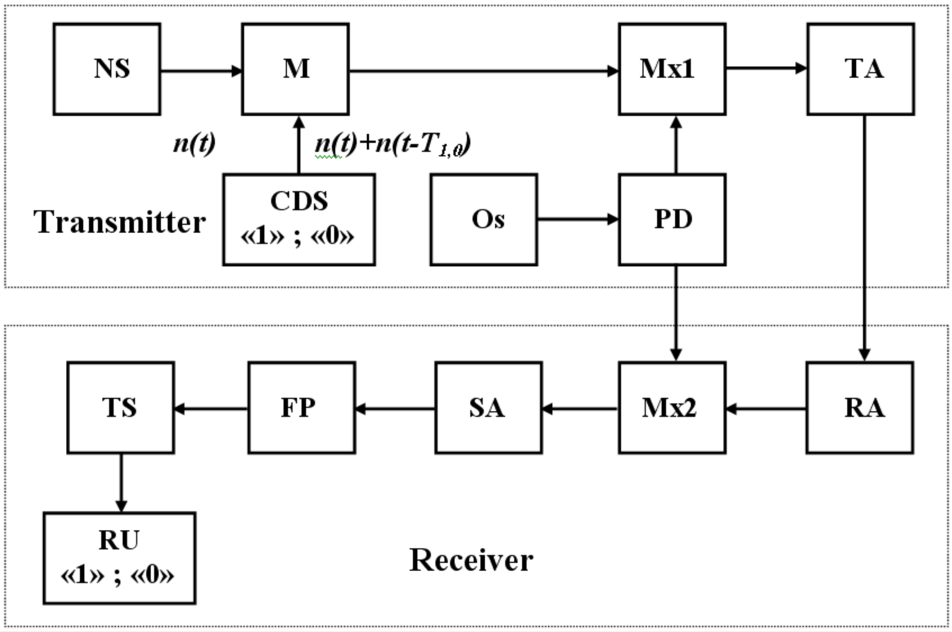


Fig.1. Block diagram of transmitter with code spectrum modulation and receiver with double spectrum processing.

The converter in the transmitter and the mixer in the receiver are the same but they perform different functions. The design of the converter is shown in Figure 2.

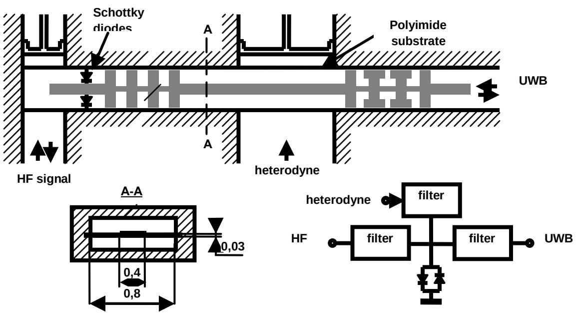


Fig.2. Up and down Converter over 133.1-134.1GHz frequency range.

At the receiver, the received UWB noise signal is compressed in the frequency domain by performing double spectral analysis (Ilchenko 2011) .The power spectrum of the received signal at the output of the panoramic spectrum analyzer (SA) contains an additive mixture of the desired code spectral modulated signal and noise of the receiver (Fig. 3). Digital Fourier processor (FP) performs inverse fast Fourier transform of the measured power spectrum and calculates the correlation function of the received signal, which contains information peak on the delay time $T_1$ or $T_0$ depending on the transmitted bit

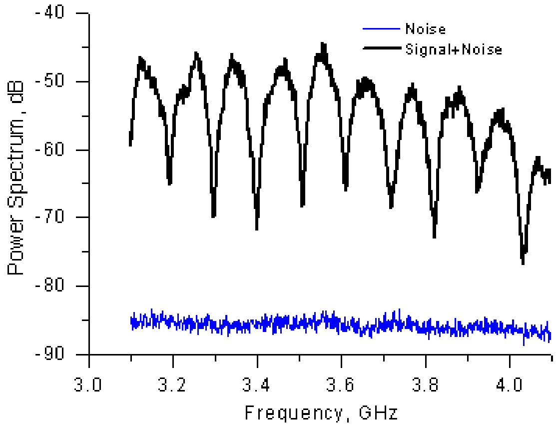


Fig. 3 - Power spectrums of received UWB noise waveform with code spectrum modulation and receiver noise at «1» bit transmission.

Threshold device TS attached to the output of Fourier processor FP determines the highest peak of the correlation function with a shift $T_1$ or $T_0$ such that decision making device RU detects one of the binary symbols 0 or 1. Thus, the transmitted binary information is recovered at the receiver.

The proposed broadband transmission using code spectrum modulation is based on transmitted-reference technique (Ilchenko 2011). The reference noise signal n (t) emitted at the same time with the delayed information signals H1n (t-T1), or $H_0$n (t-$T_0$) is the form of mixture (1). Transmitted-reference technique is used in broadband systems when the signal or the channel parameters are uncertain or random in order to significantly simplify the receivers and the whole system (Ilchenko 2011). With the simultaneous transmission of information and reference signals in a wireless communication link it is not required to generate copies of the reference signal at the receiver with a local oscillator. The need for precise phase synchronization between the reference and the information signals is eliminated. Synchronization at the receiver is conducted with fewer requirements according to the incoming stream of bits. In addition, full recovery of UWB noise signals in the microwave range at a remote receiver is physically impossible (Ilchenko 2011). Therefore, the development of terahertz UWB radio systems based on spread spectrum technology with a code spectral modulation is justified (Narayanan 2007).

Using statistical estimation theory. the bit error probability can be determined. An important parameter of a radio communication system is the signal to noise ratio qb = Eb / Ns. Where the bit signal energy is Eb and Ns is the background noise power spectral density. According to the proposed method of transmission (shown in Fig. 1) and based on equation (1) the traditional S / N ratio will have the following form:

$$q_b = E_b / N_s = 2\sigma_n^2 T_b \big/ N_s \qquad (2)$$

Where $\sigma_n^2$ is the variance of continuous noise signal n (t), Tb is bit duration.

For communication system characteristics evaluation channel signal-to-noise ratio is frequently used in practice

$$q = 2\sigma_n^2 \big/ \sigma_s^2 \qquad (3)$$

The energy ratio $q_b$ and the channel signal noise ratio q are related to each other by the simple relation

$$q_b = \Delta f\, T_b\, q \;= Bq \qquad (4)$$

Where the coefficient $B = \Delta f T_b = \Delta f/C_b$ is the base of noise carrier in the bandwidth $\Delta f$ with data rate $C_b = 1/Tb$

The noise immunity, electromagnetic compatibility, transmission range and data rate for terahertz wireless communication system with spectral code modulation is determined for the signal to noise ratio q in the channel at a given bit error rate BER= $10^{-5}$-$10^{-6}$ and frequency band noise signal carrier $\Delta f$ = 1000 MHz . The conducted analysis showed that the transfer of information with low bit error rate 10-5-10-6 should be based on ultra-wideband signals with a large enough base B = 500-1000. From the expression of the signal base $B= \Delta f/C_b$ at a given bandwidth $\Delta f$ = 1000 MHz the bit rate can be estimated Cb = 1-2 Mb / s.

The achieved BER $10^{-5}$-$10^{-6}$ for signal to noise ratio q in the range [-3 to -7] -when the message signal at the output of the receiver's antenna several times less than the internal noise of the receiver or external noise-shows high noise immunity and electromagnetic compatibility of the proposed sub-terahertz UWB communication link .

The coverage area of the proposed system at the band width of 133.1-134.1 GHz when low power transmitter of 70 mWatt and high directivity antenna with a diameter of 40 mm are used reaches up to 2000 m, while it reaches 150 m for small 10 mm antennas .

Terahertz range radio valued at low output power of the transmitter is about 70 microwatts in the band., the use of small antennas with a diameter of the circular aperture of 10 mm in the communication range of 150 meters.

## 3. Conclusion

The current research confirm the ability to create terahertz communication system for wireless data transmission at data rate of 1-2 Mb / s with bit error rate less than $10^{-5}$, based on UWB noise carrier with a low output power of 70 microwatts in the frequency range 133.1-134.1 GHz. Terahertz range radio up to 2000 meters using high directivity antennas and 150 meters when using small antennas of moderate directivity. The proposed UWB noise carrier communication link enables reliable transmission of information "in the noise". The system is characterized by high noise immunity and electromagnetic compatibility and environmental safety. The proposed UWB radio system is intended for use in wireless personal area networks (WPAN) in terahertz frequency range.

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