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Modeling of communication channels with multipath propagation of signals by noise-immunity coding procedures in the frameworks of LTE standard

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Abstract: **A scheme of orthogonal frequency division multiplexing technologies with a cyclic prefix was used, using the fast Fourier transform algorithm and amplifiers on the transmitter side and a normalizer on the receiver side. By adjusting the gains of the transmitting and receiving sides, the circuit practically makes it possible to reduce situations when intersymbol interference (ISI) is affected to situations where it does not exist. The proposed model is modeled using Simulink based on MATLAB. The scheme was investigated for the bit error rate (BER) using the additive white Gaussian noise (AWGN) channel and the multipath Rice fading channel operating under the influence of ISI and different parameters for the channel were investigated, where cases of signal delay similar to the EPA standards (Extended Pedestrian A model) were considered. Data transmission in the system includes a Relay channel and AWGN with different values of signal-to-noise ratio (SNR, dB) and different values of Gain, dbGain amplifier. Result: A graph of data transmission performance in a multipath channel with fading with respect to BER and SNR (BER ≈ 0 with values of SNR –21dB) was obtained. The effect of intersymbol interference on the receiver side is also considered by analyzing eye diagrams. The research data can be used in the design of radio engineering devices for data transmission over a wireless network.**

Keywords: **wireless communication, standard LTE, turbo codes, intersymbol interference, FFT, relay channel, amplifiers, noise-immunity coding, digital signal processing**

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Contents

1. INTRODUCTION

Standard for wireless high-speed data transmission LTE (Long-Term Evolution) was developed by 3GPP consortium (France) [1] and presented in its Release 8 (2008) and Release 9 (2009) specifications.

LTE technology is an evolution of GSM/UMTS standards based on digital signal processing and modulation methods developed at the turn of the millennium. According to the specifications, LTE provides download speeds of up to 3 Gbit/s with a decrease in latency to 2 ms; supported bandwidth of 1.4 MHz to 20 MHz; frequency division of channels (FDD – Frequency-Division Duplex) and time division (TDD – Time-Division Duplex).

There are two main differences between LTE-TDD and LTE-FDD: in terms of input and output data and network deployment frequency spectra. LTE-FDD channel splitting uses paired frequencies for input and output data, while LTE-TDD uses a single frequency, alternating between data loading and processing over time. The LTE-TDD network's load-to-process ratio can vary dynamically, depending on the relation between input and output data volumes. The different bandwidths are due to LTE-TDD performing better at higher frequencies and LTE-FDD at lower frequencies. LTE-TDD networks use bands ranging from 1850 MHz to 3800 MHz, which is cheaper for access and has more freedom in terms of bandwidth.

At the physical layer, OFDM (Orthogonal Frequency Division Multiplexing) circuit with a cyclic prefix is used for the transmission.

The following pilot signals are used in the transmission:

A reference signal consisting of a set of known symbols is transmitted at a well-defined OFDM symbol position in the interval. This helps the user terminal to evaluate the impulse response of the channel to compensate for the distortion of the channel on reception. One reference signal is sent to each antenna port of the receiver, and an exclusive symbol position is assigned to the antenna port (when one antenna port transmits a reference signal, the other ports are silent).

Synchronization signal: Primary and secondary synchronization signals are transmitted in a fixed sub-frame position (first and sixth) in the frame and assist in the cell search and synchronization of the user's terminal. Each cell is assigned a unique primary synchronization signal [2].

For receiving, the signal uses SC-FDMA (Single-carrier Frequency-Division Multiple Access – FDMA with a single carrier). The SC-FDMA scheme is implemented as a two-stage process, where the first stage of the input signal is converted to a frequency domain (represented by DFT coefficients), and the second stage DFT coefficients are converted to OFDM signal using OFDM scheme. Therefore, the SC-FDMA scheme is also often referred to as DFT-Spread OFDM.

The following pilot signals are used for reception:

Demodulation Reference Signal (DM-RS – Demodulation Reference signal): a signal sent by the user terminal to evaluate the impulse response of the channel for receiving packets to efficiently demodulate the incoming signal.

Sounding Reference Signal (SRS – Sounding Reference Signal): a signal sent by the user terminal to evaluate the overall state of the channel and to allocate appropriate frequency resources for signal reception.

As of May 2019, LTE networks have more than 90% coverage in 15 countries; the top five are South Korea (97.5%), Japan (96.3%), Norway (95.5%), Hong Kong (94.1%), and the United States (93.0%) [3].

The purpose of this paper is to improve the efficiency of suppression of the negative impact of inter-symbol interference (hereinafter ISI) when using data transmission over multibeam channels with fading based on the LTE data transmission standard. The efficiency criterion in this paper shall be the required signal-to-noise ratio of the communication channel to provide a given probability of bit error of the system.

2. TASK STATEMENT

In this work, a physical layer of the LTE standard is developed using Simulink, and its performance is evaluated under the conditions of Rayleigh fading and AWGN noise effects. This system incorporates SISO technology, and ways to improve transmission quality are considered using a Converter of size and type of transmitted and received data, Gain amplifier and normalizer, dBGain, and the use of Fast Fourier Transform (FFT, FFT) algorithm. Applied Models are simulated by transmitting and receiving data through the developed system. The performance of the system is then measured against the BER.

For the channel parameters we adopted the standard EPA model (Extended Pedestrian A model) [4]. [4]. This model is used to form a multibeam channel in wireless communication systems, in

Table 1.

Multibeam channel parameters

Max Doppler shift (f)	1/1000
Doppler spectrum type	Jakes
Path delay vector (s)	$[0\ 30\ 70\ 90\ 110\ 190\ 410]\cdot 10^{-9}$
Average Path gain vector (dB)	[0 -1 -2 -3 -8 -17 -20.8]

LTE/4G networks and can be generalized to the 5G standard [5]. Parameters of the model: 7 beams, the beam parameters are given in **Table 1** (Path delay vector (s) and Average Path gain vector (dB)).

The following **Tables 1 and 2** present the design specification for the fixed LTE standard

Because the multibeam channel reflects signals in multiple locations, the transmitted signal travels to the receiver along multiple paths, each of which may have different distances and time delays. In the block dialog box, the discrete vector delay parameter determines the delay time for each path. Unless you set the gain vector parameter to 0 dB in the Normalize parameter, the total gain will take the average gain value for each path. When you check the box, the unit uses a multiple of the path average gain vector instead of the path average gain vector itself, selecting the scaling factor so that the effective channel gain, given all paths, is 0 dB. The number of paths indicates the length of the discrete path delay vector or the average path gain vector. If both of

Table 2.

Noise characteristics of the AWGN channel

Initial Read	67
Mode	Signal to Noise rate (Eb/No)
Eb/No(dB)	-40-20
No. of bits/symbol	1
Input signal power	1
Symbol Period	1

these parameters are vectors, they must have the same length; if only one of these parameters contains a scalar value, then the unit converts it to a vector with the same size as the other vector.

Turbocodes and Unipolar to Bipolar Converter block are used in the system for noise-immunity coding.

In the block *Free space path loss* we specify distance and carrier frequency value:

Distance (km): 10; Carrier frequency (MHz): 800.

Taking into account additional energy losses (e.g. thermal noise) we add an additional block *Free space path loss*, indicating a loss of 180 dB.

Power dB Gain - 120 and Gain - 10^6.

3. ANALYSIS OF SIMULATION RESULTS

The performance of the developed model is evaluated under the condition of the channel with fading and the BER values at small values of SNR (Eb/N0) are analyzed, also the eye diagrams are analyzed to effectively reduce the negative effect of inter-symbol interference.

Theoretical values are obtained using the BER calculation module available in MATLAB software. **Fig. 1** shows a screenshot of the MATLAB generated project for the data transmission system.

The fixed data transmission with fading is shown in **Table 3** and **Fig. 2.**

Table 3.
Probability of erroneous bit at small signal to noise ratio (hereinafter referred to as SNR)

SNR (dB)	BER	SNR (dB)	BER
-40	0.382	-27	0.04777
-39	0.3	-26	0.04
-37	0.2552	-25	0.03256
-35	0.1908	-24	0.015
-33	0.1756	-23.5	7.876^{-3}
-31	0.1113	-23	3.15^{-5}
-29	0.07986	-21	0.0

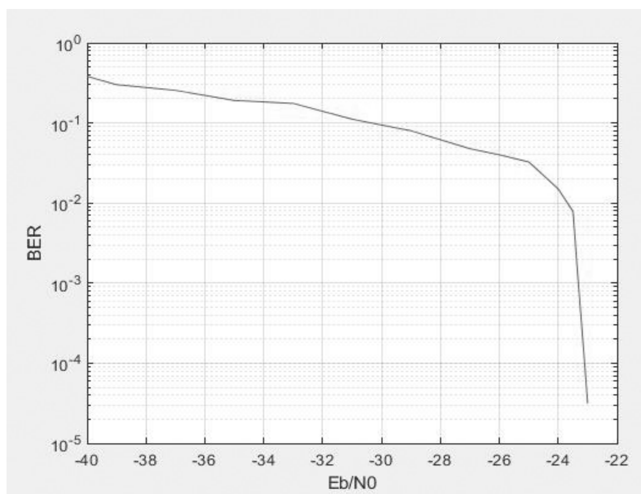

Fig. 2. *Rayleigh and Gaussian channel error probabilities.*

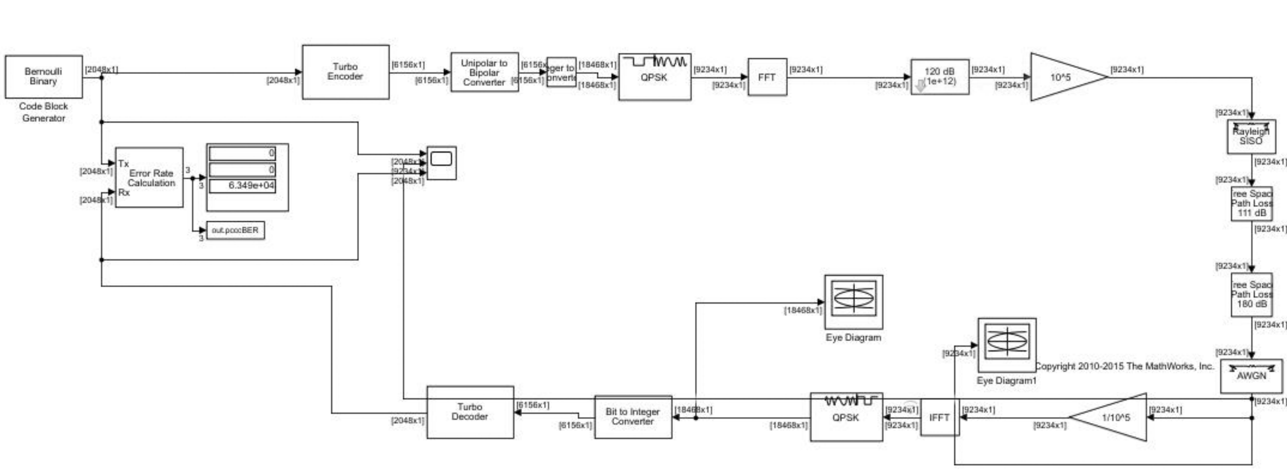

Fig. 1. *Transceiver for data based on LTE standard.*

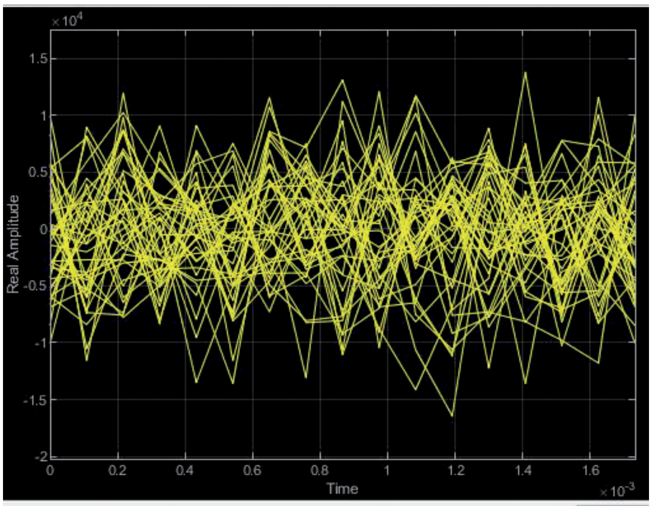

Fig. 3. *The eye diagram of received signal SNR = –21 after AWGN channel.*

Fig. 3 shows the eye diagram of the received signal at SNR = –21 (after AWGN channel), we see an obvious superposition of the waves at each other – the phenomenon of interference.

In **Fig. 4**, the eye diagram at SNR = –21 after IFFT and QPSK modulator, we can see the "open eyes".

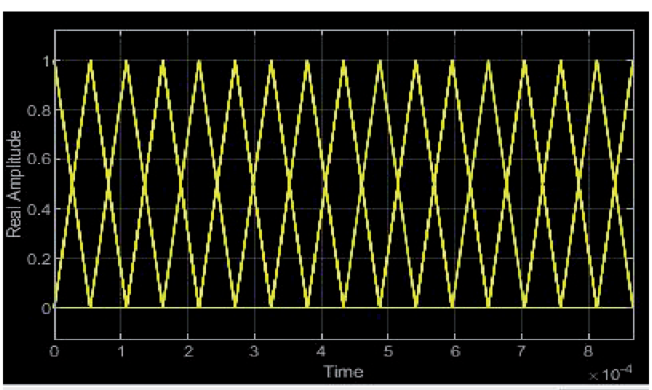

Fig. 4. *The eye diagram at SNR = –21 after the OFDM modulator.*

Fig. 5 shows the comparative analysis of the transmitted, distorted and received signal with Time Scope block at SNR = –21.

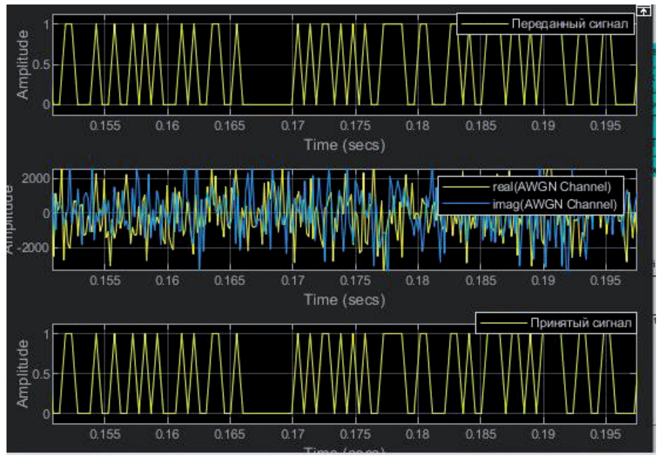

Fig. 5. *Analysis of transmitted and received signal with.*

4. CONCLUSION

In this paper, we investigated and evaluated the performance of a wireless system based on the LTE standard with OFDM technology, using the Fast Fourier Transformation (FFT) algorithm. The proposed system was evaluated for data transmission in a 7-beam delayed wireless network using an EPA model, taking into account the antenna spacing and additional energy loss during Rayleigh channel transmission. The proposed model was simulated using MATLAB-based Simulink. A graph of data transmission performance in a multibeam channel with fading versus BER and SNR was obtained, and inter-symbol interference on the receiver side was also considered by analyzing eye diagrams.

The data from the study can be used in the design of radio devices for transmitting data over a wireless network.

In addition, the developed model can be used as a teaching aid to study various features of LTE-based systems.

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