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THE MODELING OF RADIO BASED TELETRANSMISSION NETWORKS APPLIED TO RAILWAY MANAGEMENT AND CONTROL

The paper deals with modeling and simulation of radio transmission (GSM, GPS) towards estimation of time and probabilistic parameters used in analysis of safety systems. The included examples of typical railway systems correspond to ERTMS/ETCS concept. The obtained results allow to, verify the functional parameters and safety criteria required in such systems.

MODELOWANIE RADIOWYCH SIECI TELETRANSMISYJNYCH WYKORZYSTYWANYCH W ZARZĄDZANIU I STEROWANIU RUCHEM KOLEJOWYM

Tematem pracy jest modelowanie i symulacja transmisji drogą radiową (GSM, GPS) w celu wyznaczenia parametrów czasowych i probabilistycznych wykorzystywanych w analizie bezpieczeństwa systemów. W przykładach uwzględniono typowe aplikacje kolejowe zaproponowane w projekcie ERTMS/ETCS. Uzyskane wyniki pozwolą sprawdzić spełnienie kryteriów oraz wskaźników bezpieczeństwa wymaganych parametrów funkcjonalnych.

1. INTRODUCTION

The paper corresponds to previous works [1], [2] on modelling, analysis and simulation of computer railway control and management systems. These works are related to simulation of transmission channels using Network Simulator 2/Linux to evaluate time parameters (delay and queues of messages) corresponding to capacity, intensity of messages and end-off of link.

The main aim of this paper is estimation of probabilistic parameters of railway control and management systems with respect to ERTMS requirements and safety analysis.

Three typical railway applications with advanced transmission link: MultiComputer Dispatcher Systems (WSKR), Remote Control of Warsaw Underground (METRO) and GSM-R based Railway Management (ETCS) are chosen to modelling and simulation in MATLAB/SIMULINK environment. The input dates are treated as typical stochastic process with Poisson distribution.

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2. THE PROBABILISTIC MODELS OF TRANSPORT COMMUNICATION SYSTEMS

For simulation purpose the "Data Random Generator" has been applied for modelling the real date input.

The transmitters correspond to user terminals (Transceiver) and receivers allow to detection and demodulation of chosen signal. These models contain the bit error rate (BER) to determinate the efficiency of transmitted and received signals. The generator signal is given to Differential Quaternary Phase Shift Keying (DQPSK) modulator.

The system models have been analyzed with respect to given method of random sequence generation in the non-linear channel with Additive White Gaussian Noise (AWGN) or in the Multipath Rayleigh Fading Channel (MRFC).

The simulation results the transmission quality and BER are function of Energy per Bit/ Noise Power per 1Hz of bandwidth (Eb/No) and data generation method.

2.1. THE SYSTEM STRUCTURES AND SIMULATION SCHEMAS

In each system model from Fig.1 as a data input the random number generators (with assumed rate) are applied in the input of AWGN channel. The simulation process gives the possibility of the noise level change and signal to noise ratio Eb/No. For GSM-R the date are transmitted through MRFC channel because it is recommended for wireless networks. The relative movement between transmitter and receiver is expressed by Doppler Shift:

$$fd = \frac{v \cdot fc}{c} \tag{1}$$

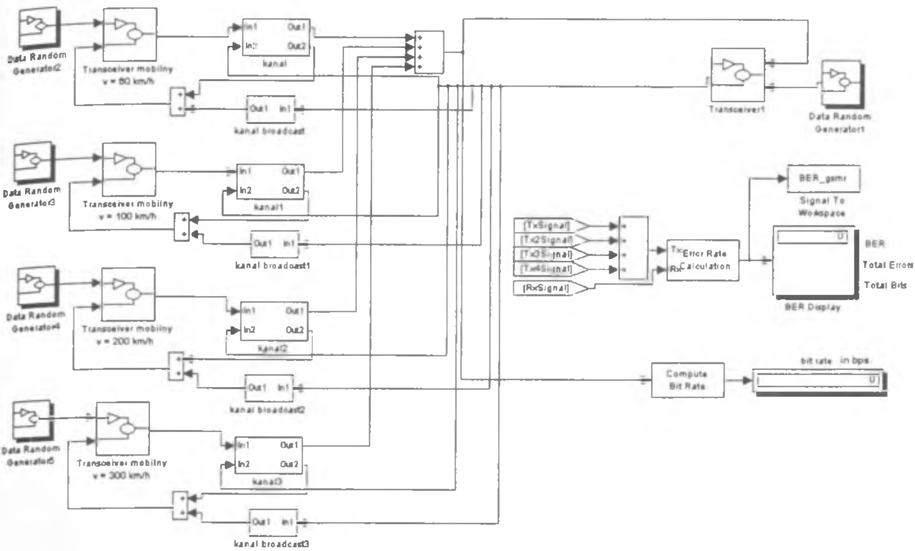
where v is a velocity of terminal, $c = 3 \cdot 10^8$ m/s is constans, and fc is a carrier frequency of transmission (for example in GSM 900MHz, the fd = 60 Hz when v = 72 km/h,). In the Table 1 the values of fd and BER are depended on the v of mobile terminals.

Table 1

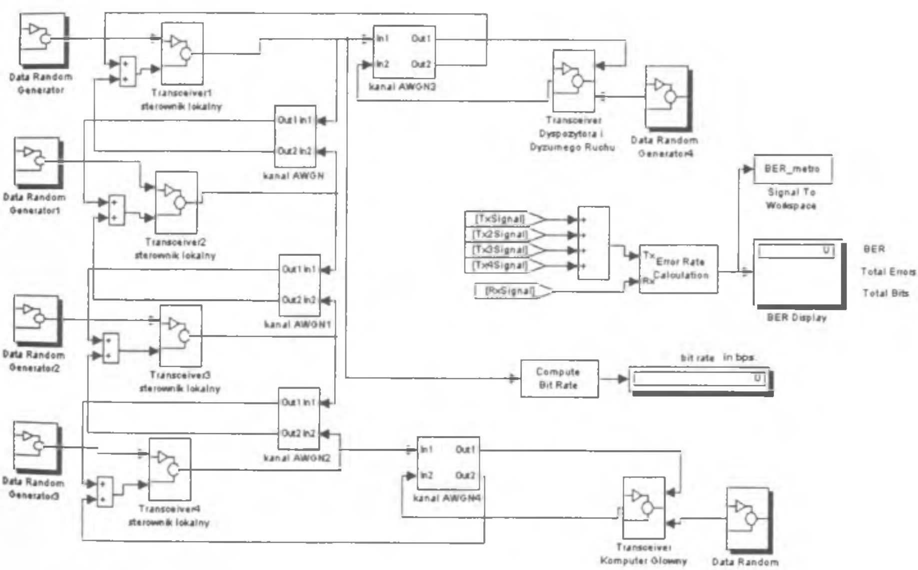
The values of fd and BER for analysis velocity terminals

random sequence generation	Doppler shift fd [Hz]	velocity of terminal v [km/h]	values BER
Poisson			
	60	72	0.7524
	83.1	100	0.7524
	125.1	150	0.7544
	166.5	200	0.7517
	208.5	250	0.7542
	250	300	0.7535

a)


Data Random Generator2
Transceiver mobilny v = 60 km/h
In1 Out1
In2 Out2
kanal
Out1 In1
kanal broadcast
Transceiver1
Data Random Generator1
Data Random Generator3
Transceiver mobilny v = 100 km/h
kanal1
kanal broadcast1
BER_gsmr
Signal To Workspace
[TxSignal]
[Tx2Signal]
[Tx3Signal]
[Tx4Signal]
[RxSignal]
Tx
Rx
Error Rate Calculation
BER
Total Errors
Total Bits
BER Display
Data Random Generator4
Transceiver mobilny v = 200 km/h
kanal2
kanal broadcast2
Compute Bit Rate
bit rate in bps
Data Random Generator5
Transceiver mobilny v = 300 km/h
kanal3
kanal broadcast3

b)


Data Random Generator
Transceiver1 sterownik lokalny
In1 Out1
In2 Out2
kanal AWGN3
Transceiver Dyspozytora i Dyzurnego Ruchu
Data Random Generator4
kanal AWGN
Data Random Generator1
Transceiver2 sterownik lokalny
BER_metro
Signal To Workspace
[TxSignal]
[Tx2Signal]
[Tx3Signal]
[Tx4Signal]
[RxSignal]
Tx
Rx
Error Rate Calculation
BER
Total Errors
Total Bits
BER Display
kanal AWGN1
Data Random Generator2
Transceiver3 sterownik lokalny
Compute Bit Rate
bit rate in bps
kanal AWGN2
Data Random Generator3
Transceiver4 sterownik lokalny
kanal AWGN4
Transceiver Komputer Glowny
Data Random Generator5

c)

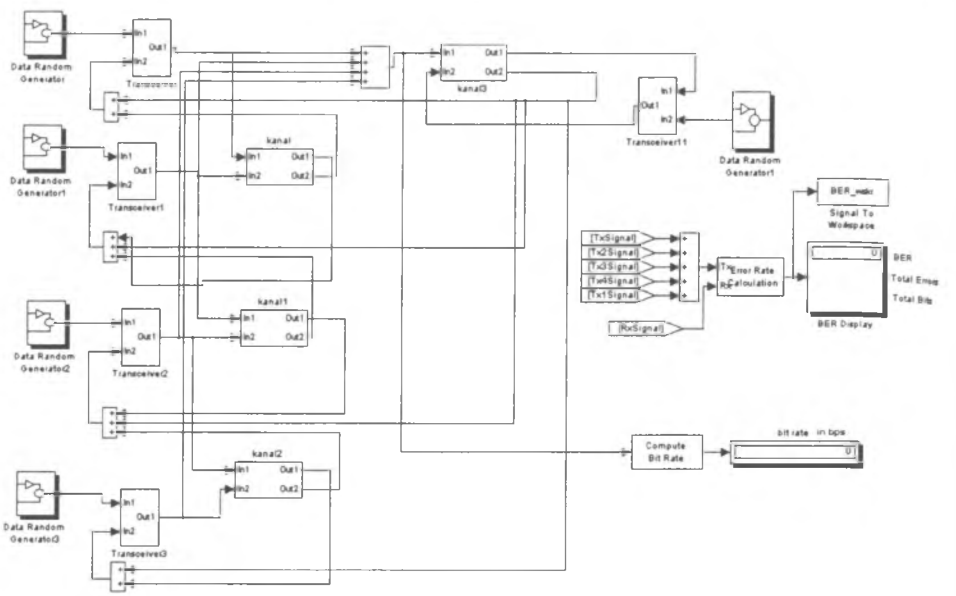


Fig.1. The model of computer networks: a) GSM-R connected ERTMS/ETCS structure for train monitoring, b) Remote control of Warsaw Underground METRO, c) Multicomputer Dispatcher System WSKR

2.2. INPUT DATA GENERATORS

For simulation experiment were used Poisson Integer Generator. The Poisson distribution of events is a typical solution for telecommunication systems and computer network [3]. Poisson distribution, which generation the events with probability *Pn* according to:

$$P_n(t) = e^{-\lambda t} \frac{(\lambda t)^n}{n!} \tag{2}$$

where λ is a intensity of events, n is a number of terminals and t is assumed time period.

2.3. SIMULATION RESULTS

The general relation between BER and Eb/No for Poisson distribution of events, three railway systems is shown on the Fig.3. It is obvious that for Eb/No higher then 20[dB] the influence of noise to failure rate is important. Such relation is the same for mobile systems (Fig.3).

The influence of Doppler Shift *fd* on the BER is shown on the Fig.2. From this chart it is obvious that Eb/No greater then 30[dB] in critical, and the greater velocity of mobile terminal give the greater shift of BER.

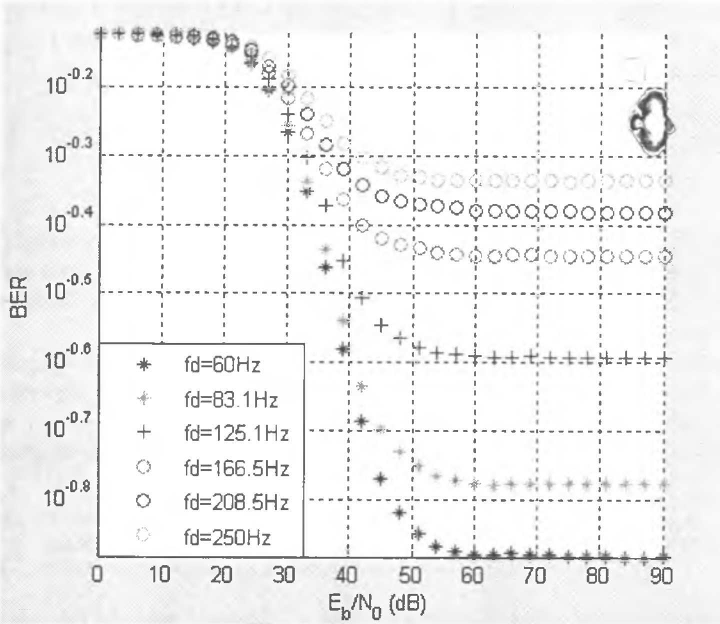


Fig. 2. The influence of Doppler Shift *fd* on the BER for the model with the Poisson generator

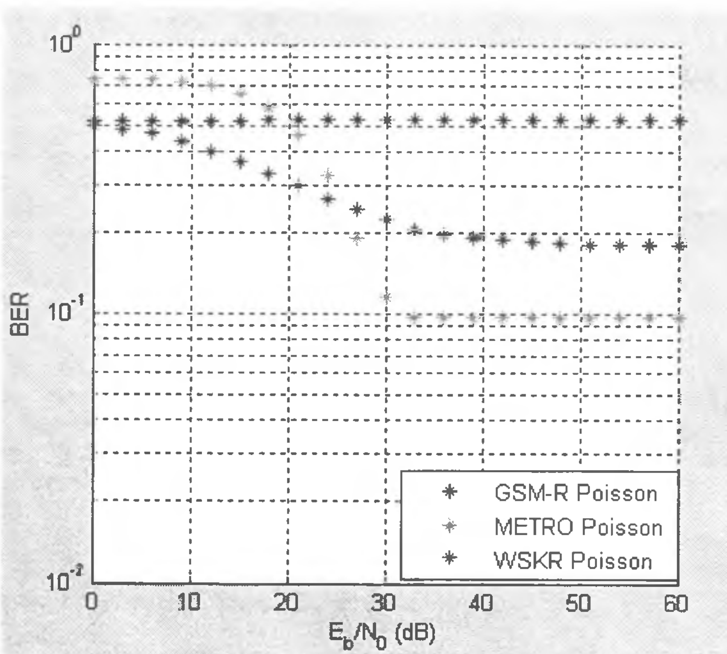


Fig.3. The ratio Eb/No for three analysed systems: WSKR, METRO, GSM-R with Poisson generator

Fig.3 shown that Eb/No must be less then 20 – 30 [dB] for stationary (with cable connections) systems. The constant higher BER value for mobile system is connected with type of transmission DQPSK (with assumed level of interferences).

3. CONCLUSION

The ratio Eb/No is critical for each from three analysed systems, for mobile systems, the movement has a small constant shift of failure rate. The future experiments may estimate a number of terminals in these systems (work simulations) as a upper limit, assuming the assumed level of system safety.

From applied Poisson distribution of events is a simple vary to exponential distribution of time (when the event takes place). The simulation of time relations in the systems gives the results in form of delay and time of processing the messages. Such approach correspond to Markov process theory and safety analysis of make control and management systems.

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