SIMULATION OF MULTIPATH PROPAGATION OF MULTISTATE MODULATIONS

Ladislav Polák

Department of Radio Electronics, Brno University of Technology
Purkyňova 118, 612 00 BRNO

Abstract

The contribution is focused on the development of an appropriate algorithm in MATLAB, which is capable to simulate the impact of the multipath propagation on received signal on the basis of given parameters of the transmission channels. Characteristics of the communication environments are described in the first part of the paper. The second part is focused on the simulation itself. Created GUI (Graphical User Interface) is able to display constellation diagrams of the transmitted and received signals, as well as their BER (Bit-Error Rate). It is also possible compare these data with the data of signal, which is passed by a non-fading channel. Finally, obtained results are discussed.

1 Introduction

At the transmission of radio signals several transmission effects exist between the transmitter and receiver side. Signal can be propagated directly, if it is secured optical visibility between the transmitter and receiver. Generally, there are many obstructions in communication environments, like houses, industrial objects and other objects are. This situation is typical especially for urban areas. Some of the mentioned obstructions may have occurred in rural areas too. In the environment like this, there are exist beyond the direct propagation of the signals other possibilities and combinations. If the transmitted signal is propagated into a big surface with proportions larger than its wavelength, the reflection occurs. This event makes situation, when several reflected signals are present simultaneously with the direct signal at the receiver side. This effect is called multipath propagation and it is a main reason of the fading conception.

2 Transmission Channels

2.1 Gaussian Channel (AWGN)

Model of the Gaussian channel describes a case, which is based on a direct signal path from transmitter to receiver only. In this case the received signal is only attenuated and includes a definite level of noise. This channel is overlaid with AWGN (Additive White Gaussian Noise), which is mainly produced in the receiver itself. The best condition for the received data is defined as Gaussian channel.

2.2 Rice Channel

When reflected signals are added to a direct signal then the quality of the reception get worse. Multipath propagation of the signals makes a variance of signal intensity and causes ISI (Inter Symbol Interferences). On this variance the signal is also influenced with the movement of the receiver and changes of the environment. These situations are modeled in channel, which is defined as a Rice channel. In this type of channel the Gaussian channel and its characteristics also exists. The signal is completed with reflection of signals from different ways. A case like this is in real conditions most frequent. Influence of the channel on received signal is possible described with the following mathematical equation (1)

$$y(t) = \frac{\rho_0 x(t) + \sum_{i=1}^{N_e} \rho_i e^{-j2\pi\Theta_i} x(t-\tau_i)}{\sqrt{\sum_{i=0}^{N_e} \rho_i^2}}, \tag{1}$$

where ρ_0 is the attenuation in the direct signal path, N_e is the certain number of echoes, ρ_i is the attenuation in echo path i, Θ_i is the phase rotation in echo part I, and τ_i is the relative delay time in echo part i. The Rice factor K denotes the ratio of the signal in the direct path to the sum in all echo paths (2)

$$K = \frac{\rho_0^2}{\sum_{i=0}^{N_e} \rho_i^2} . \tag{2}$$

Rice channel has higher requirements than Gaussian channel. For the compensation of multipath propagation effects it is necessary raise achievement of the transmitter power [1].

2.3 Rayleigh Channel

There are very often cases, when the direct signal path is not secured as dominate signal at the antenna of the receiver. Channel model which simulates these cases, has a direct signal fully attenuated. The transmission channel model with only echo signals is called Rayleigh channel. This channel model presents worst conditions for the gains of signals on the antenna receiver. The mathematical equation (3), which described the influence of Rayleigh channel on the signal, is following

$$y(t) = \frac{\sum_{i=1}^{N_e} \rho_i e^{-j2\pi\Theta_i} x(t-\tau_i)}{\sqrt{\sum_{i=0}^{N_e} \rho_i^2}} . \tag{3}$$

Rayleigh channel compared with Rice channel needs even higher level of SNR (Signal-to-Noise Ratio). It requires a multiple increase of the transmitting power from the transmitter. This case is every time hardly feasible [2], [3]. Methods of signal propagation in all mentioned and described cases are illustrated in Fig. 1.

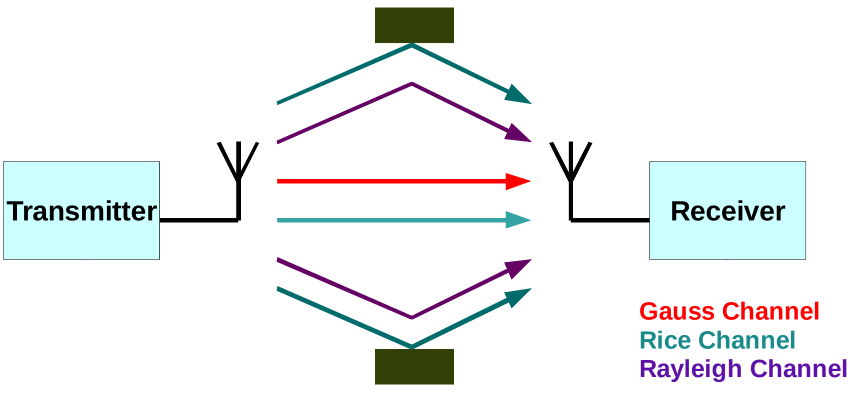

Figure 1: Propagation of the signal in Gaussian, Rice and Rayleigh channel.

3 Simulation of Multipath Propagation of Signals in MATLAB

Resources for the simulation of particular type of modulations are included in MATLAB in packet of Communication Toolbox functions [4]. The Communication Toolbox also includes functions for simulation and characteristics of digital multistate modulations and demodulations. Also the models of a different type of transmission channels with many adjustable parameters are included in this toolbox. In the developed program were explored characteristics of the multistate modulations: BPSK (Binary Phase Shift Keying), QPSK (Quadrature Phase Shift Keying), 8PSK (8-Phase Shift Keying), BFSK (Binary Frequency Shift Keying) and 16QAM (Quadrature Amplitude Modulation) in fading channels. There was created a GUI in MATLAB for the easier simulation and its example is in Fig. 2.

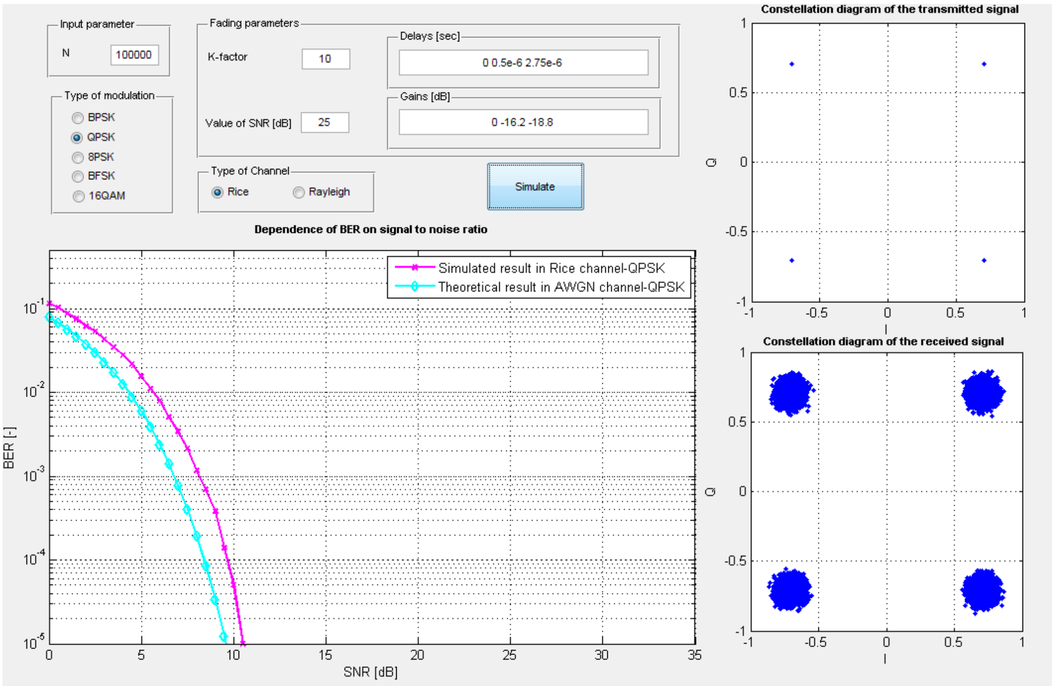

Figure 2: Multipath propagation of multistate modulations - GUI applied in MATLAB.

3.1 Matlab Application Description

In the first step it is necessary to order a number of bits for the input sequence generation (parameter *N*). In the simulations presented below there were used a number of 100000 bits. It is visible in the Fig. 2 that the in tables *Delays* and *Gains* are given delays in seconds and gains in dB of reflected transmission paths. For the direct signal path there are used values of time 0 sec and gain 0 dB. The delay values used in the simulation are moving among 100 ns and 10 ms (typical delay in outdoor environment) and values of gains are in the interval of -20 dB to 0 dB [2]. Table *K - factor* allows setting of parameter *k* in case of Rice channel simulation. For the simulations there was used *K* = 10, as it is suggested in [2]. *Value of SNR* in window of GUI enables display of constellation diagram of the received signal for selected value of *SNR* and the value is given in dB. The *Type of modulation* and *Type of channel* options enable choose of already mentioned types of modulations (5 cases) and transmission channels (2 cases). After set-up of all parameters the simulation can be started. The results of simulation are shown in the Fig.2: constellation diagram of transmitted signal, constellation diagram of received signal and dependence of *BER* on *SNR* (in fading and non-fading channel).

4 Simulation of Multipath Propagation of Multistate Modulations

As an example, there have been tested four simulations for the exploration of multistate modulations characteristics in described two channels (fading and non-fading). Four examples were accomplished in Rice and Rayleigh channel with 3 and 6 paths calculation. Parameters of paths used in the simulation for all examples are given in Tab. 1 (Rice Channel with 3 and 6 paths) and Tab. 2 (Rayleigh channel with 3 and 6 paths).

Dependence of *BER* as a function of *SNR* in non-fading channel (AWGN) is in Fig. 3. The simulation results of the Rice channel with 3 and 6 paths are in the Fig. 4 and Fig. 5. It is visible in Fig. 4, as well as at influence of noise in AWGN channel, that lower number of states of multistate modulations lead to a lower *BER*. That means that the higher number of states in multistate modulations are needed for higher achievement - higher *SNR* for smaller *BER*. These situations are represented in the Fig. 4 for the modulations BPSK, QPSK, 8PSK, BFSK and 16QAM. According to the results of the simulations it is possible to conclude, that in case of Rice channel with direct path and 2 reflected signals for e.g. *BER* = $1 \cdot 10^{-4}$ it is needed to increase the value of *SNR* at intervals 1 dB and 4 dB in comparison with values in the Gaussian channel (see Fig. 4). In case of direct path and 5 reflected signals in Rice channel it is needed increased *SNR* by 2 and 6 dB (see Fig. 5).

Table 1: RICE FADING CHANNEL SETTINGS

Rice channel						
	Example 1					
	Example 2					
Path	1	2	3	4	5	6
Delays [sec]	0	0.5e-6	2.75e-6	1.95e-6	0.45e-6	3.25e-6
Gains [dB]	0	-16.2	-18.8	-16.3	-19.0	-17.5

Table 2: RAYLEIGH FADING CHANNEL SETTINGS

Rayleigh channel						
	Example 3					
	Example 4					
Path	1	2	3	4	5	6
Delays [sec]	0.5e-6	2.75e-6	1.95e-6	0.45e-6	3.25e-6	0.85e-6
Gains [dB]	-6.2	-8.8	-6.4	-9.0	-7.5	-10.0

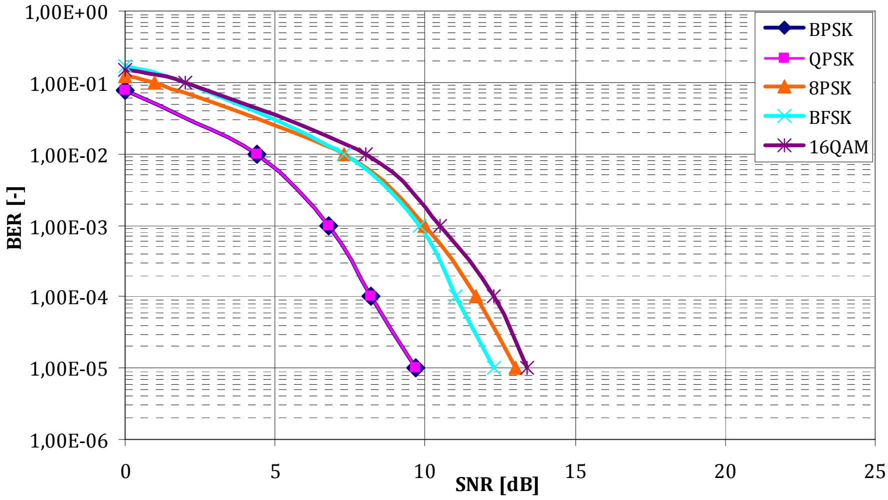

Figure 3: AWGN channel results of BER as a function of SNR ratio.

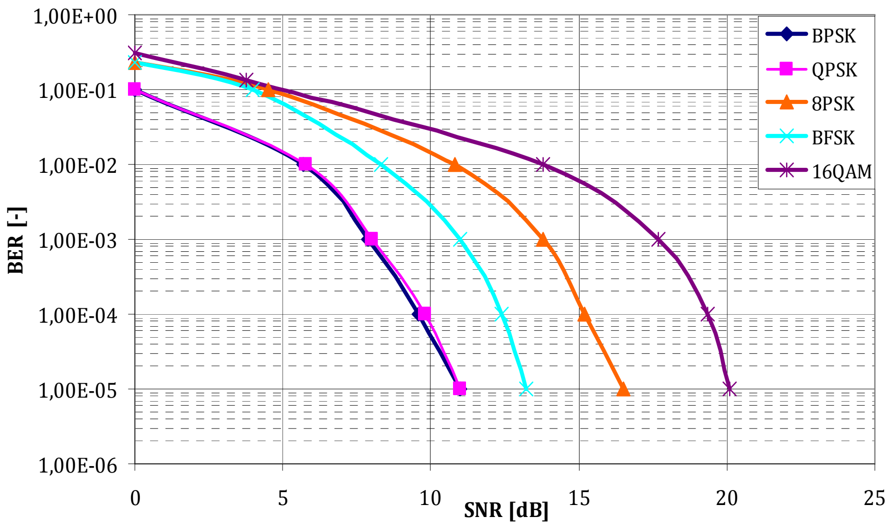

Figure 4: Rice channel results of BER as a function of SNR ratio for fading channel with 3 paths.

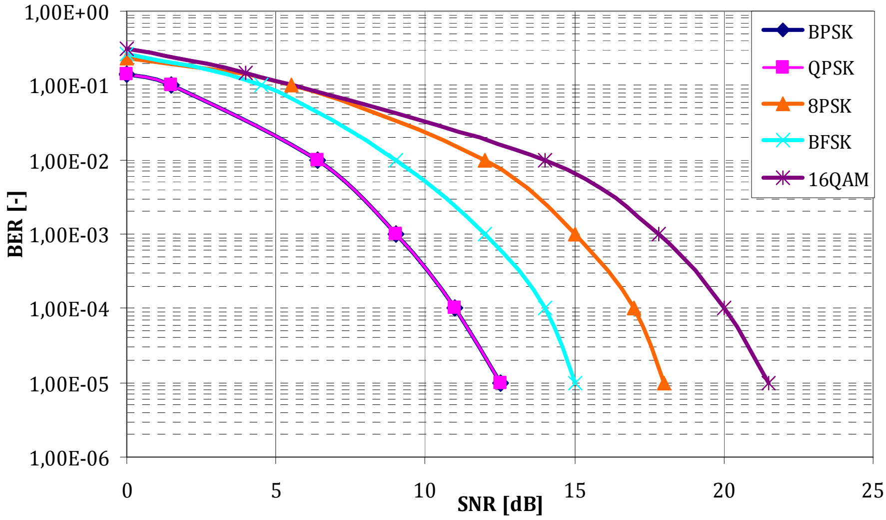

Figure 5: Rice channel results of BER as a function of SNR ratio for fading channel with 6 paths.

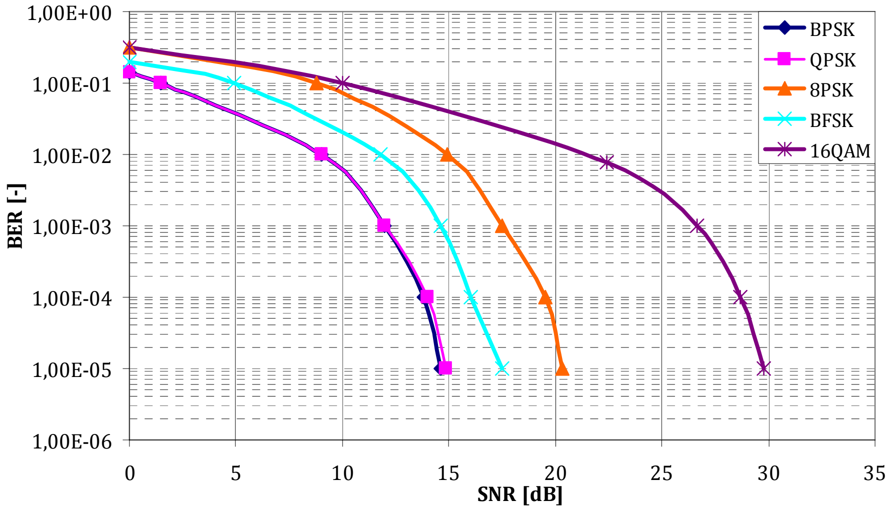

Figure 6: Rayleigh channel results of BER as a function of SNR ratio for fading channel with 3 paths.

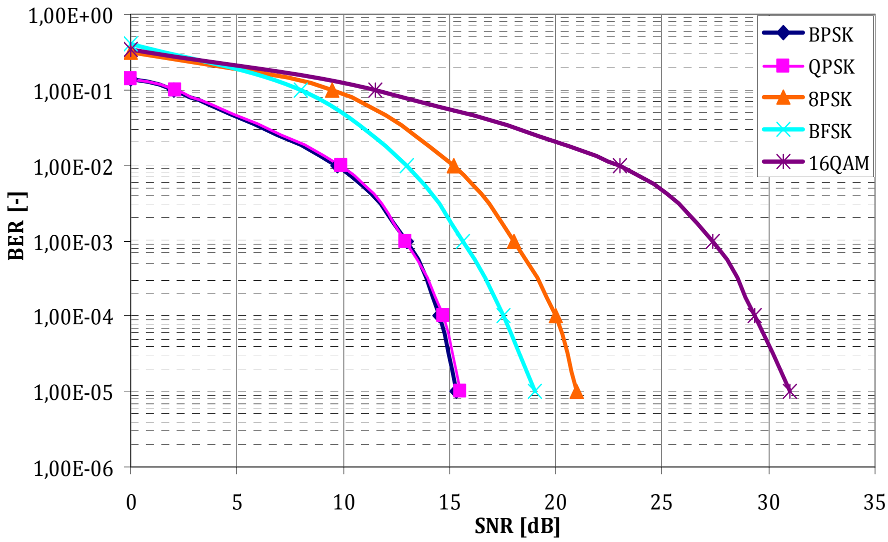

Figure 7: Rayleigh channel results of BER as a function of SNR ratio for fading channel with 6 paths.

Dependences of *BER* as a function of *SNR* in Rayleigh channel with 3 and 6 reflected signals are shown in Fig. 6 and Fig. 7. The simulation results in Rayleigh channel are worse, because in this type of channel the direct path between the transmitter and receiver is attenuated. In case with 3 reflected paths it is needed increase of *SNR* at interval from 4 dB to 11 dB (see Fig. 6) again for $BER = 1\cdot10^{-4}$ in comparison with values in the Gaussian channel. Rayleigh channel with 6 paths needs increase of value of *SNR* at interval from 5 dB to 13 dB (see Fig. 7).

5 Conclusion

In this paper there were described characteristics of several communication environments. The characteristics of multipath propagation and their impact on the multistate modulations in different transmission channels without Doppler's shift were shown in four simple examples. It was presented developed application wit GUI in MATLAB too. In first two examples there were simulated signals in transmission environment of Rice channel with 3 and 6 paths. In other two examples there were simulated transmissions of signals in Rayleigh channel similarly with 3 and 6 paths. From the results it is easy to see that the multistate modulations with less number of states are more robustness than modulations with more number of states in fading channels environment. Results achieved in Rice channel are better than in Rayleigh channel (see Fig. 4 to Fig. 7). It makes especially the presence of the direct path in Rice channel.

Acknowledgement

This contribution was supported by the grant project of Research programme of Brno University of Technology MSM0021630513 "Electronic Communication Systems and New Generation Technology (ELKOM)" and the grant projects of the Czech Science Foundation no. 102/08/H027 "Advanced methods, structures and components of the electronic wireless communication".

References

[1] ŠTUKAVEC, R., KRATOCHVÍL, T. *DVB-T Digital Terrestrial Television Transmission over Fading Channels*. Radioengineering. 2008, vol. 17, no. 3, p. 96-102.

[2] ETSI EN 300 744 V1.4.1 (2001-2 01). *Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television.* 2001.

[3] COLLINS, G. W. *Fundamentals of Digital Television Transmision.* New Jersey: John Wiley & Sons, Inc., 2001. 267 p. ISBN 0-47-39199-9

[4] Communication Toolbox v Matlabu *Mathworks Support* [online]. Dostupné na WWW: < http://www.mathworks.com/products/communications/description1.html>.

[5] MARVIN, K.S., MOHAMED-SLIM, A. *Digital Communication over Fading Channels.* USA, John Willey & Sons, 2000. 551 p. ISBN 0-471-20069-7

[6] ZAPLATÍLEK, K., DOŇAR, B.: *Matlab – Začínáme se signály*. Praha, BEN, 2006. 272 p. ISBN 80-7300-200-0

[7] ZAPLATÍLEK, K., DOŇAR, B.: *Matlab – Tvorba uživatelských aplikací*. Praha, BEN, 2004. 216 p. ISBN 80-7300-133-0

[8] POLÁK, L.: *Simulace vícecestného šíření vícestavových modulací*. Diplomová práce. Ústav radioelektroniky, FEKT VUT v Brně. Brno, 2009.

CONTACT

Ladislav Polák, Ing.

Department of Radio Electronics, Brno Univ. of Technology, Purkyňova 118, 612 00 BRNO
E-mail: xpolak18@stud.feec.vutbr.cz, Tel: +420 541 149 162, Fax: +420 541 149 244