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Simulation of QAM and QPRS systems for Land Mobile Satellite Communications Channels

Salah El-Agooz, Gamal Mabrouk and Eweda E. Eweda
Military Technical College, Kobry El - Koppa, Cairo, Egypt

ABSTRACT

Computer modeling of land mobile satellite communications channels is a valuable adjunct to analytical modeling for predicting and verifying communication systems performance. The simulations considered in this paper are concerned with the evaluation of the error rate performances of 16-ary quadrature amplitude modulation (16-QAM) and quadrature partial response signaling (QPRS) in a shadowed multipath Rayleigh fading channel. A frequency non-selective fading has been assumed. In this paper the effect of transponder nonlinearity has not been taken into account, since the aim of these simulations is to verify analytical results obtained recently in the same channel conditions. Simulation results show a good agreement with the analytical ones within the conventional permissible confidence interval that extends from half to twice the symbol error probability.

I. INTRODUCTION

Recently, there has been an upsurge of interest in low-earth orbit mobile satellite communications, that provide various services on a world-wide basis. The signal transmitted between satellite and land mobile station suffers amplitude attenuation and phase variation caused by multipath fading and shadowing beside the transponder nonlinearity. The channel impairments are usually described in terms of the Rayleigh and log-normal fading, which characterizes signal propagation through typical environments such as urban, suburban, rural and hilly areas. In fact, a line-of-sight (LOS) path is achieved in most open and suburban areas. The signal envelope exhibits a Rician distribution when minor reflected and diffused components obstruct the LOS path. The resulting envelope, however, exhibits a Rayleigh distribution if the received signal mainly consists of reflected and scattered components. Further, signal attenuation caused by long-term variations superimposed on signal fading, which is called shadowing, results in signal variations in the order of 8 to 12 dB in some suburban and rural areas [1].

As a vehicle moves from one location to another, the environment properties vary resulting in nonstationary statistical character of the received signal. Experimental data [1], however, indicates that real land mobile satellite channels can be viewed as quasistationary. The quasistationary nature of the model is based on the assumption of slowly varying environment

characteristics such as elevation angle, obstacle type, and surface roughness. However, the environment attributes are almost constant within small areas. In such a case, the channel can be approximated by a stationary model [1].

The aim of this paper is to simulate the performance of 16-ary quadrature amplitude modulation (16-QAM) and quadrature partial response signaling (QPRS) when used in a shadowed multipath Rayleigh fading channel. The simulations are intended for evaluating the error rate performances of these systems and comparing them with the analytical results obtained recently in the papers [2] and [3]. The paper is organized as follows. Section II describes the signal and channel models used in the simulations. Section III presents the simulation results. Section IV provides the conclusions.

II. SIGNAL AND CHANNEL MODELS

2.1. Signal Generation

The first step in the simulations is the generation of data sequence to be passed through the elements of the channel. The in-phase and quadrature components of a 16-QAM data sequence are independently generated using uniformly distributed random variable ξ in the range [0,1], then applying the following transformation:

$$a_k \ or \ b_k = \begin{cases} -3 & if \quad 0.0 \le \xi < 0.25 \\ -1 & if \quad 0.25 \le \xi < 0.5 \\ 1 & if \quad 0.5 \le \xi < 0.75 \\ 3 & if \quad 0.75 \le \xi \le 1.0 \end{cases} \tag{1}$$

where a_k and b_k are the in-phase and quadrature components of the data. For QPRS a_k and b_k are generated according to the following transformation.

$$a_k \ or \ b_k = \begin{cases} -2 & \text{if} \quad 0.0 \le \xi < 0.25 \\ 0 & if \quad 0.25 \le \xi < 0.75 \\ 2 & if \quad 0.75 \le \xi \le 1.0 \end{cases} \tag{2}$$

2.2. Mobile Channel

For reasons of simplification, we restrict our attention to systems, where the signal bandwidth is much smaller than the coherence bandwidth of the channel, so that the frequency non-selective channel model will be appropriate. Hence, the received signal is simply obtained by multiplying the transmitted signal by the appropriate stochastic process, which represents the time variant characteristic of the channel [4]. Furthermore, we will also restrict our attention to suburban and rural areas where roads are surrounded by trees, houses, or small buildings. All of these obstacles near the mobile unit cause signal shadowing. As the vehicle moves along the road, the attenuation of the direct signal varies. It has been experimentally observed that the attenuation of the direct wave undergoes log-normal distribution [5-6].

The channel model as developed in [7] assumes that the LOS component under shadowing is log-normally distributed and that the multipath effect is Rayleigh distributed. The two processes are additive. Thus, the channel model as shown in figure 1, is given by the combination of the log-normal and the Rayleigh processes. Due to the frequency non-selective nature of the channel the data is multiplied by the channel gain c(t) resulting in y(t). The channel AWGN is added to y(t) to give the channel output r(t).

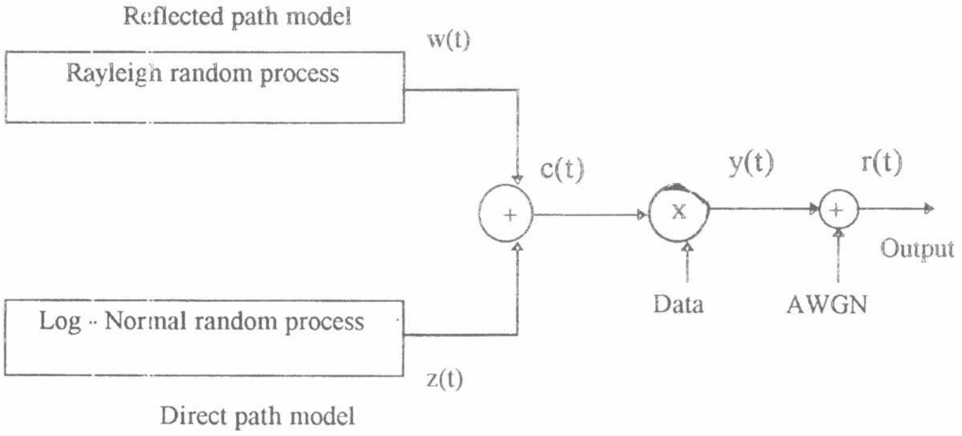

Fig.1 Model of the land mobile satellite channel.

2.2.1. Rayleigh Fading Model

The Rayleigh process w(t) is obtained [8] from the envelope of a narrow-band complex Gaussian random process x(t) given by.

$$x(t)=x_1(t)+j\,x_2(t) \tag{3}$$

where $x_1(t)$ and $x_2(t)$ are uncorrelated real normal processes with zero mean and identical variances b_o. Then, the Rayleigh process is given by

$$w(t)= |x(t)| = \sqrt{x_1(t)^2+x_2(t)^2} \tag{4}$$

The probability density function of the Rayleigh distribution is given by

$$P(w) = \frac{w}{b_o}\exp(-\frac{w^2}{2b_o}) \tag{5}$$

where b_o represents the average scattered power due to multipath.

2.2.2. Log-Normal Fading Model

The log-normal process z(t) is generated from a real Gaussian process $x_3(t)$ with zero mean and unit variance according to

$$z(t) = \exp[\mu+\sqrt{do}x_3(t)] \tag{6}$$

where μ is the mean value due to shadowing and $\sqrt{d_o}$ is the standared deviation due to shadowing.

The probability density function of the Log-Normal distribution is given by

$$P(z) = \frac{1}{z\sqrt{2\pi d_o}}\exp(-\frac{(\ln z-\mu)^2}{2d_o}) \tag{7}$$

Figure 2 shows the simulation model for shadowed and faded signal generation.

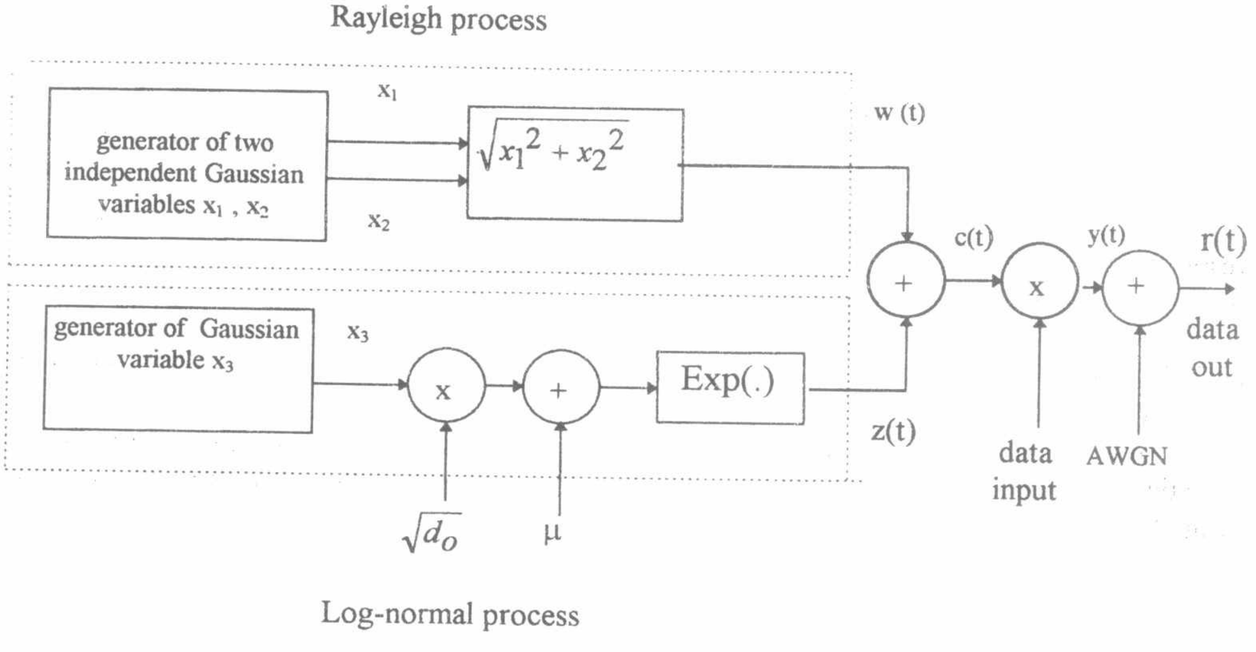

Fig.2. Simulation model for generating a shadowed and faded signal.

2.2.3 Fading Parameters

The values of b_o , μ, and d_o considered in the simulation are given in the following table.

Table I. Channel Model Parameters

	Light shadowing and fading	Average shadowing and fading	Heavy shadowing and fading
b_o	0.158	0.126	0.0631
μ	0.115	-0.115	-3.91
$\sqrt{d_o}$	0.115	0.161	0.806

2.3 Noise Model

The channel noise is modeled as a white zero mean Gaussian process with variance σ_n^2 .

2.4. Demodulation and Symbol Error Calculation

The optimum demodulator for 16-QAM and QPRS utilizes maximum likelihood detection in which the Euclidean distances between the received signal and all members of the transmitted (stored) signal set are calculated. The closest member is chosen to be the transmitted symbol. This demodulation is used in our simulation. In each simulation run we generate N symbols and we use a fixed value of the SNR. The received symbols are compared with the corresponding transmitted ones and errors are counted. The probability of error P_e is estimated as the number of symbols in error divided by N. N should be in the order of $10/P_e$. For a confidence level greater than 90% the confidence interval range from half to twice P_e is generally considered a reasonable uncertainty [9].

III. SIMULATION RESULTS

In each simulation run, 100000 symbols are generated. Simulation results in terms of symbol error rate for QPR and 16-QAM for the channel parameters given by table I are provided in the following figures.

Fig.3 and fig.4 provide the symbol error probabilities of QPRS and 16-QAM respectively for light, average and heavy shadowing. In both systems the performance gets poorer as the channel becomes more severe.

Fig.5 and fig.6 compare the simulation results of QPRS with the corresponding analytical ones obtained in [1,2] for the average and heavy shadowing. Fig.7 and fig.8 compare the simulation and analytical results of 16- QAM .

As shown in the figures the simulation results are in a reasonable agreement with the analytical ones within the permissible confidence level that extends from half to twice the symbol error probability.

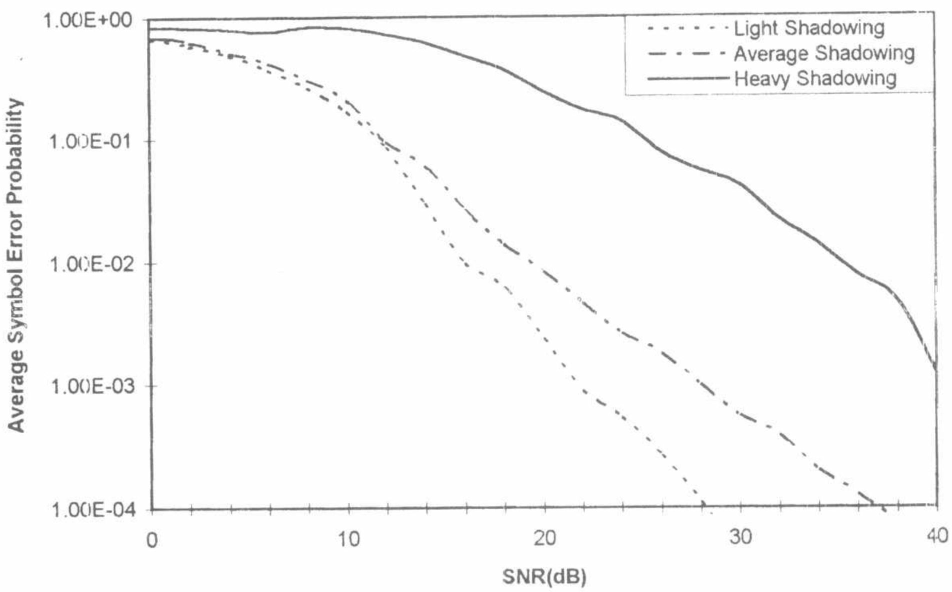

Fig.3 Symbol Error Probabilities of QPRS.

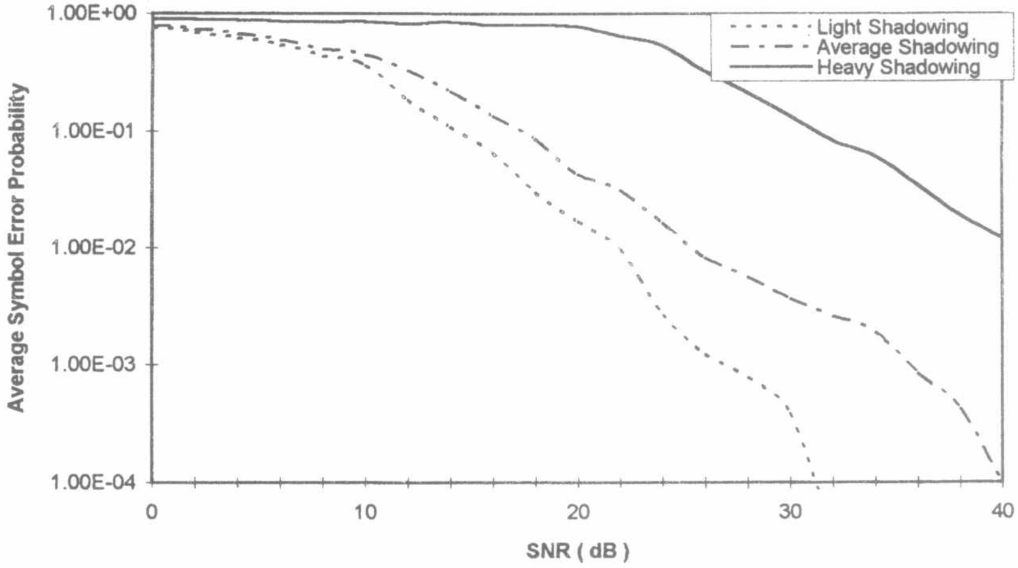

Fig.4 Symbol Error Probabilities of 16-QAM.

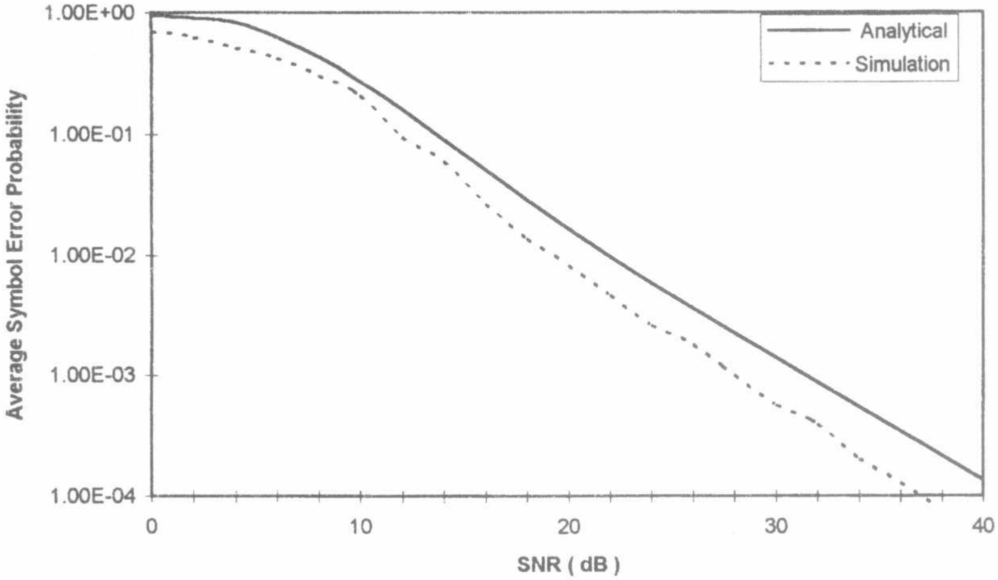

Fig.5 Symbol Error Probabilities of QPRS for Average Shadowing.

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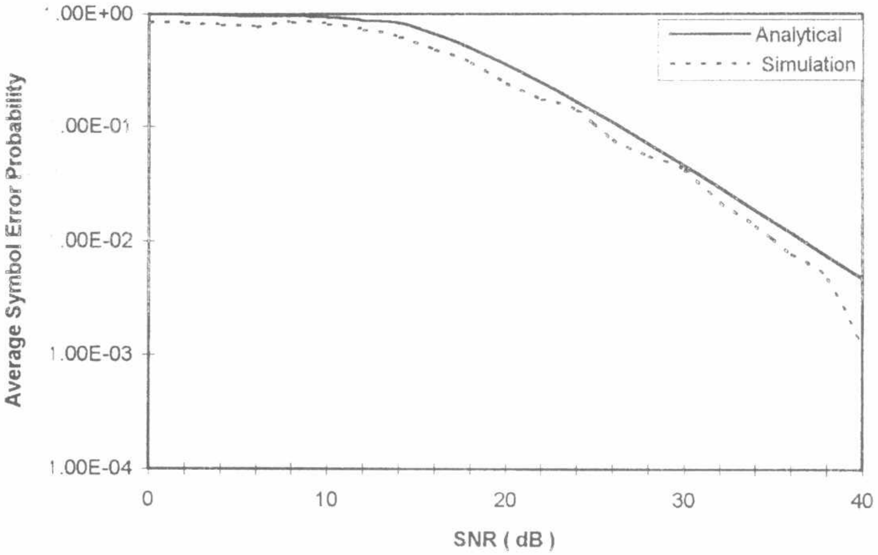

Fig.6 Symbol Error Probabilities of QPRS for Heavy Shadowing.

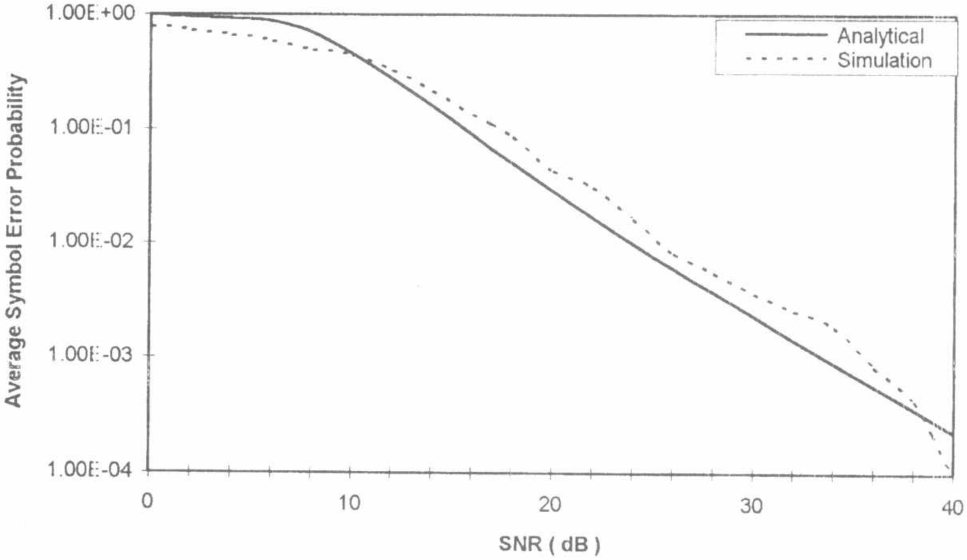

Fig.7 Symbol Error Probabilities of 16-QAM for Average Shadowing.

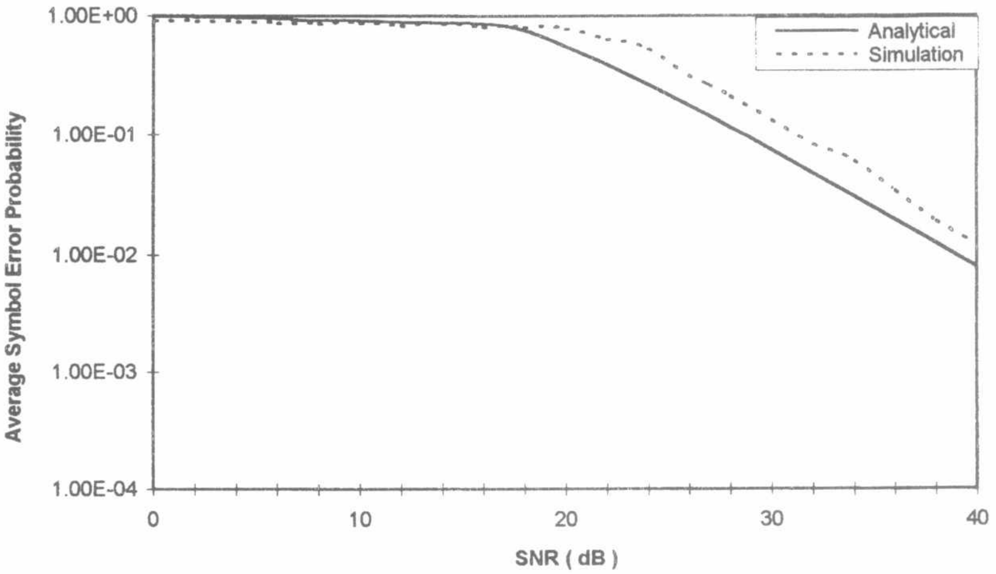

Fig.8 Symbol Error Probabilities of 16-QAM for Heavy Shadowing.

IV. CONCLUSIONS

The paper provides simulation results for the symbol error probability of QPRS and 16-QAM systems due to the combined effect of fading and shadowing as encountered in a land mobile satellite channel. Light , average , and heavy fading and shadowing are considered in the simulations. The simulation results are compared with recently obtained analytical results. The comparison shows a good agreement between the two sets of results.

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