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ABEP Upper and Lower Bound of BPSK System over OWDP Fading Channels

Suparna Goswami
Department of ECE, NERIST, Nirjuli, Arunachal Pradesh-791 109, India.

Shanjit Heisnam Singh
Assistant Professor, Department of Physics, RGU, Doimukh, Arunachal Pradesh-791 112, India.

Aheibam Dinamani Singh
Associate Professor, Department of ECE, NERIST, Nirjuli, Arunachal Pradesh-791 109, India.

Abstract

The upper and lower bounds for Average Bit Error Probability (ABEP) of Binary Phase Shift Keying (BPSK) modulation in OWDP fading has been derived. The OWDP fading model has one specular component and many diffused components. The probability density function (pdf) is used to obtain the expressions for the upper and lower bound conditions. The results are therefore obtained and are verified with the results found in literature.

Keywords: ABEP, BPSK, Lower Bound, OWDP, pdf, Upper bound.

I. INTRODUCTION

The one wave diffuse power (OWDP) consists of only one wave with constant amplitude. The OWDP fading Channel is come across in wireless sensor network that are mounted within a cavity such as tunnel, aircraft, public buses, trains etc. OWDP is a special case of Two wave diffuse power (TWDP) fading channels [1]. The Bit Error Rate (BER) performance in TWDP fading for Binary Phase Shift Keying (BPSK) has been obtained in [2]. The probability density function (pdf) expression of TWDP is expressed in [1]. The performance analysis of BPSK system in N TWDP channels with pre-detection maximal ratio combining (MRC) technique is done in [3]. The cumulative distribution function (cdf) based method has been used for the performance analysis of Quadrature Amplitude Modulation (QAM) over TWDP fading channel [4]. The performance analysis of Selection Combining (SC) receiver with L-branch in κ-μ and η-μ fading channel has been presented in [5]. In [6], the expression for Symbol Error Rate (SER) of the SC receiver with *M*-ary Phase Shift Keying (MPSK) and MQAM has been evaluated. The moment generating function (mgf) based approach is used to obtain the expression for symbol error probability (SEP) using *M*-ary rectangular QAM over TWDP fading channel in [7]. The capacity expressions have been obtained over TWDP for various adaptive transmission techniques in [8]. The expression of spectral efficiency for power and rate adaptive transmission techniques with uncoded MQAM over TWDP fading channel has been presented in [9]. The expression of outage probability and ABER for coherent and non coherent modulation with SC receiver has been derived [10]. The expression of pdf, mgf,and cdf has been obtained over κ-μ shadowed fading channel in [11].The expression of capacity for different adaptive transmission with Maximal Ratio Combining (MRC) over TWDP channels has been obtained in [12]. In [13], the expression of capacity for different adaptive transmission with Dual-MRC over non-identical TWDP channels has been evaluated. In [14], the authors have obtained the expression for outage probability and Average Symbol Error Rate (ASER) of a single channel system over TWDP fading channel. In [15], the ergodic capacity expression in κ-μ shadowed fading channel has been derived. The average capacity expression of channel with four adaptive transmission technique over log-normal distribution has been obtained in [16].

From the literature study it can be observed that no work on analysis of upper and lower bounds on ABEP has been presented over an OWDP fading channel. This gives the idea and motivation to work on the upper and lower bound on ABEP of BPSK system over OWDP Fading Channels.

The remaining part of the paper is organized as follows. The channel and system has been discussed in section II. In section III, the upper and lower bounds on ABEP over OWDP fading channel have been evaluated. In section IV, numerical results and discussions are presented. The conclusion is given in section V.

II. CHANNEL AND SYSTEMS

The OWDP fading channel contains only specular components with many diffused components. The channel has been considered to be slow, frequency nonselective, with OWDP fading statistics. The complex low pass function of the received signal over one symbol duration *Ts* can be expressed as

$$r'(t) = re^{j\varphi}s(t) + n(t), \tag{1}$$

where $s(t)$ is the transmitted bit signal with energy E_b and $n(t)$ is the complex Gaussian noise having zero mean and two sided power spectral density $2N_0$. Random variable

φ represents the phase and r is the OWDP distributed fading amplitude. The envelope pdf of OWDP fading can be written as

$$f_r(r) = \sum_{i=1}^{5} a_i \left(\frac{r}{\sigma^2} e^{-\left\{\frac{r^2}{2\sigma^2}+K\right\}} I_0\left(\frac{r}{\sigma}\sqrt{2K} \right) \right), \tag{2}$$

where $I_0(\cdot)$ is the Bessel function of the first kind and zeroth order, K is the ratio of total specular power to diffused power. The order of approximation is represented by i. Performing the square and random variable transformation, the signal-to-noise ratio (SNR) pdf of OWDP fading channel is given as

$$f_\gamma(\gamma) = \sum_{i=1}^{5} \sum_{p=0}^{\infty} a_i \frac{K^p \eta^{p+1}}{(p!)^2} e^{-K} \gamma^p e^{-\eta\gamma}, \tag{3}$$

where $\eta = \frac{K+1}{\bar{\gamma}}$.

III. PERFORMANCE OF SINGLE CHANNEL RECEIVER

In this section, the expression of lower bound and upper bound on ABEP of BPSK modulation over OWDP fading channels are derived.

A. *Upper and Lower bounds on ABEP of BPSK in OWDP fading channel*

The ABEP of different modulation scheme can be derived by averaging the product of conditional bit error probability (BEP) and the pdf of fading channel from *0* to ∞. Mathematically, ABEP can be expressed as

$$P_E = \int_0^\infty p_e(\varepsilon/\gamma) f_\gamma(\gamma) d\gamma, \tag{4}$$

where $p_e(\varepsilon/\gamma)$ is the conditional BEP of any modulation scheme in Additive White Gaussian Noise (AWGN). The expression for upper bound and lower bound is obtained below.

1) *Upper Bound:* The expression for upper bound is obtained by using an exponential upper bound derived in [19] as

$$erfc(x) = \frac{1}{2}\left(e^{-2x^2} + e^{-x^2}\right). \tag{5}$$

The conditional BEP of BPSK over AWGN is expressed as

$$p_e(\varepsilon/\gamma) = \frac{1}{2} erfc\left(\sqrt{\gamma}\right), \tag{6}$$

where $erfc(\cdot)$ is complementary error function and γ is the instantaneous SNR. Therefore, by using the upper bound condition (5) and the conditional BEP expression (6) of BPSK can be given as

$$p_e(\varepsilon/\gamma) = \frac{1}{4}\left(e^{-2\gamma} + e^{-\gamma}\right). \quad (7)$$

Substituting $p_e(\varepsilon/\gamma)$ and $f_\gamma(\gamma)$ into (4), the expression can be obtained as

$$P_E(\bar{\gamma}) = \frac{1}{4}\sum_{i=1}^{5}\sum_{p=0}^{\infty} a_i \frac{K^p \eta^{p+1}}{(p!)^2} \times e^{-K}\left[\int_0^\infty \gamma^p e^{-(2+\eta)\gamma} d\gamma + \int_0^\infty \gamma^p e^{-(1+\eta)\gamma} d\gamma\right]. \quad (8)$$

The integral is solved using [18, 3.351.3]. Final expression for upper bound on ABEP of BPSK over OWDP fading channel can be obtained as

$$P_E(\bar{\gamma}) = \frac{1}{4}\sum_{i=1}^{5}\sum_{p=0}^{\infty} a_i \frac{K^p \eta^{p+1}}{p!} \times e^{-K}\left[\frac{1}{(2+\eta)^{p+1}} + \frac{1}{(1+\eta)^{p+1}}\right]. \quad (9)$$

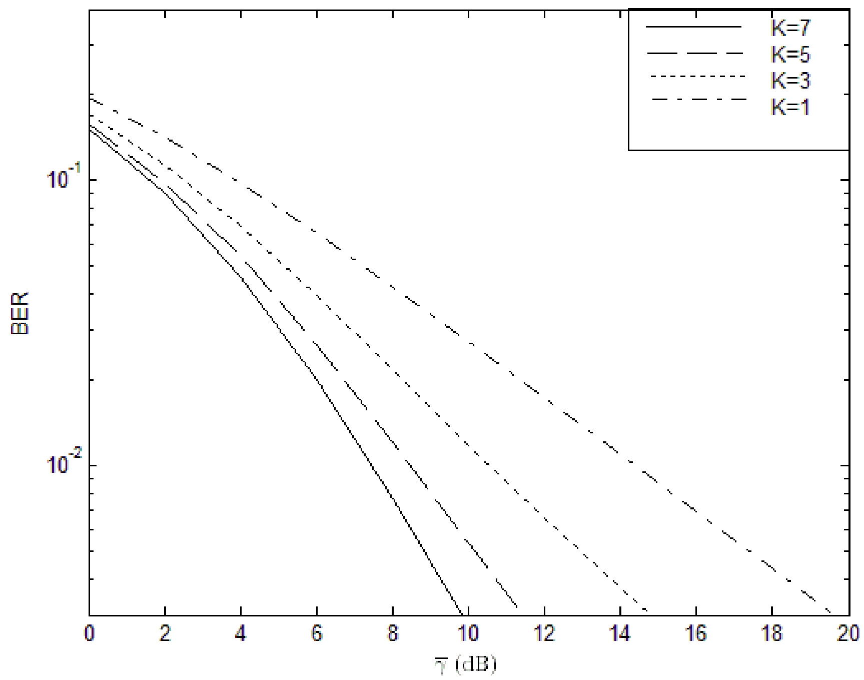

Fig.1. BER of Single Channel system for upper bound condition in OWDP fading

2) *Lower Bound:* The expression for lower bound is obtained by using an exponential lower bound derived in [20] as

$$erfc(x) = 0.56 e^{-1.275 x^2}. \tag{10}$$

The conditional BEP of BPSK in AWGN by using lower bound condition (10) can be given as

$$p_e(\varepsilon/\gamma) = \frac{0.56}{2}\left(e^{-1.275\gamma}\right). \tag{11}$$

Substituting $p_e(\varepsilon/\gamma)$ and $f_\gamma(\gamma)$ into (4), the expression can be obtained as

$$P_E(\bar{\gamma}) = \frac{0.56}{2}\sum_{i=1}^{5}\sum_{p=0}^{\infty} a_i \frac{K^p \eta^{p+1}}{(p!)^2} e^{-K} \int_0^\infty \gamma^p e^{-(1.275+\eta)\gamma} d\gamma. \tag{12}$$

The integral is solved using [18, 3.351.3]. Final expression for lower bound on ABEP of BPSK over OWDP fading channel can be obtained as

$$P_E(\bar{\gamma}) = \frac{0.56}{2}\sum_{i=1}^{5}\sum_{p=0}^{\infty} a_i \frac{K^p \eta^{p+1} e^{-K}}{p!(1.275+\eta)^{p+1}}. \tag{13}$$

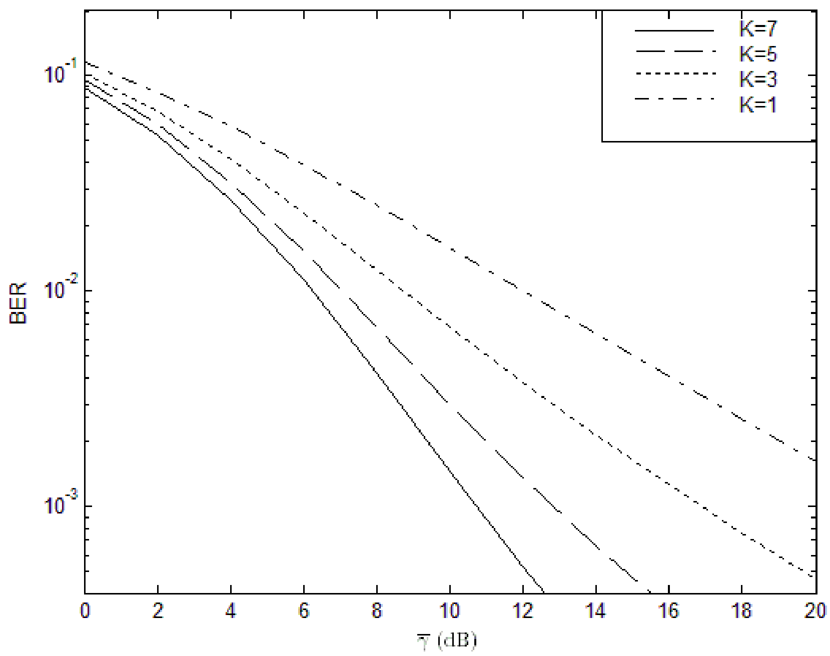

Fig.2. BER of Single Channel system for lower bound condition in OWDP fading

IV. NUMERICAL RESULTS AND DISCUSSIONS

Numerical calculation of the expressions of Upper and Lower bounds on ABEP of BPSK in OWDP fading channel are given in section 3. Results are obtained by varying the values of parameter *K*.

In Fig.1, the BER vs. $(\bar{\gamma})$ in dB for upper bound have been plotted. The plot is for different values of parameter *K*. In Fig.2, the BER vs. $(\bar{\gamma})$ in dB for lower bound have been plotted. The plot is for different values of parameter *K*. It can be observed from both the plot that when the value of *K* increases, the ABEP of the BPSK scheme decreases.

V. CONCLUSIONS

In this paper the expressions for complementary function to obtain the upper and lower bounds for ABEP of BPSK system in OWDP fading has been presented. The expressions are obtained by using the pdf of output SNR of the system. The results are verified and are found to be correct.

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