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Symbol Error Probability Analysis of Quadrature Phase Shift Keying Using Hybrid Diversity Technique over Rayleigh Fading

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Abstract

The exact expressions for the symbol error probability (SEP) of hybrid selection maximal ratio combining wireless systems for quadrature phase shift keying (QPSK) is derived and analyzed in multipath fading environment. Independent rayleigh fading diversity branch is assumed for analysis with equal Signal-to-Noise ratio averaged over the fading channels and coherent detection of quadrature phase shift keying(QPSK) is considered. Virtual branch technique, which transforms the ordered physical branches, which are dependent into independent, and identically distributed virtual branches is used, there by permitting the derivation of exact symbol error probability (SEP) expressions.

Keywords: Error probability, diversity reception, quadrature phase shift keying, virtual branch technique, rayleigh fading channel

INTRODUCTION

Hybrid- selection maximal ratio combining (H-SMRC) is a diversity combing scheme where L out of N diversity branches are selected and combined using maximal ratio combining (MRC). This technique provides improved performance over L branch MRC when additional diversity is available. Recently, Hybrid- selection maximal ratio combining (H-SMRC) has been considered as an efficient means to combat multipath fading [1],[2],[3]. The bit error rate (BER) performance of an (H-SMRC) with L=2 and L=3 out of N branches was analyzed and it was pointed out that "the expressions become extremely unwidely" for L>3. The average signal-to-noise ratio (SNR) of H-SMRC was derived in [2]; in [3], a virtual branch technique is introduced to succinctly derive the mean as well as the variance of the combiner output SNR of the H-SMRC diversity system.

In this paper we extend [4] to derive analytical symbol error probability (SEP) for binary Phase Shift Keying modulation with H-SMRC for any L and N under the assumption of independent rayleigh fading on each diversity branch with equal SNR averaged over the fading. Selection combining (SC) and MRC are shown to be special cases of our results. Numerical results are illustrated for quadrature phase shift keying (QPSK) and finally remarks and conclusions are presented.

SYSTEM MODEL

Figure 1 shows the system model of HS-MRC in which L out of N diversity branches are selected and combined using Maximal Ratio Combining (MRC).

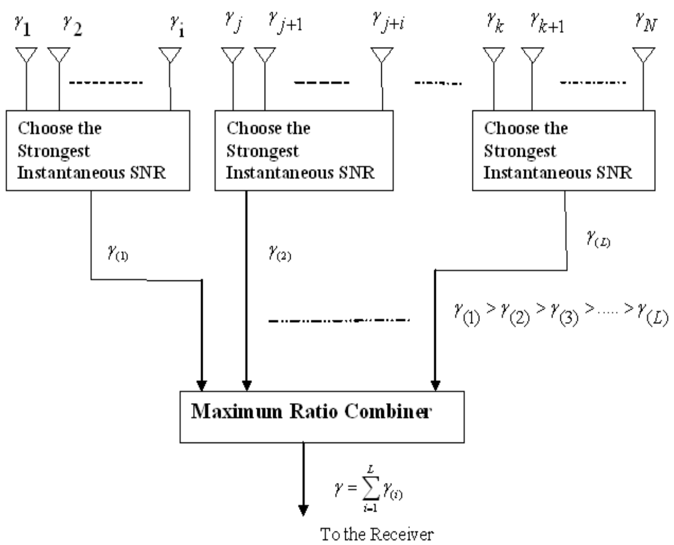

Figure 1: System Model of HS-MRC

SEP FOR DIGITAL MODULATION WITH HS-MRC

Symbol error probability (SEP) for digital modulation with HS-MRC for any L and N under the assumption of independent rayleigh fading on each diversity branch with equal SNR averaged over the fading is given by [4]

$$p_{e,HS-MRC} = \sum_{k=1}^{K} \int_{0}^{\theta k} a_k(\theta) \left[\frac{1}{1+\phi_k(\theta)\Gamma} \right]^L \times \prod_{n=L+1}^{N} \left[\frac{1}{1+\phi_k(\theta)\Gamma \frac{L}{n}} \right] d\theta \qquad (1)$$

Where $a_k(\theta), \theta_k, \phi_k(\theta)$ are the parameters particular to a specific modulation format and are independent of the instantaneous. These parameters are different for different modulations. M-ary phase shift keying (MPSK), M-ary quadrature amplitude modulation (MQAM) with M= 2^l and l is even, M-ary pulse amplitude modulation (MPAM), binary frequency shift keying (BFSK), BFSK with minimum correlation (BFSK min), coherent detection of differentially encoded BPSK (DE-BPSK), and minimum shift keying(MSK)

LIMITING CASES

Limiting Case 1: Selection Combining (SC) System

Selection combining (SC) is the simplest form of diversity combining whereby the received signal from one of N diversity branches is selected [5]. The output SNR of SC is

$$\gamma_{SC} = \max\{\gamma_i\} = \gamma(1) \qquad (2)$$

Note that SC is limiting case of HS-MRC with L=1. Substituting L=1 into (1), the symbol error probability with SC becomes

$$p_{e,HS-MRC} = \sum_{k=1}^{K} \int_{0}^{\theta k} a_k(\theta) \prod_{n=1}^{N} \left[\frac{1}{1+\phi_k(\theta)\Gamma \frac{1}{n}} \right] d\theta \qquad (3)$$

Limiting Case 2: Maximal Ratio Combining (MRC) System

In maximal ratio combining (MRC), the received signals from all diversity branches are weighted and combined to maximize the SNR at the combiner output [6]. The output SNR of MRC is

$$\gamma_{MRC} = \sum_{i=1}^{N} \gamma_i = \sum_{i=1}^{N} \gamma(i) \qquad (4)$$

MRC is a limiting case of HS-MRC with L=N. Substituting L=N into (1), the SEP with MRC is

$$p_{e,HS-MRC} = \sum_{k=1}^{K} \int_{0}^{\theta k} a_k(\theta) \left[\frac{1}{1+\phi_k(\theta)\Gamma} \right]^N d\theta \qquad (5)$$

SYMBOL ERROR PROBABILITY FOR QUADRATURE PHASE SHIFT KEYING

M-ary PSK is becomes QPSK for M=4.

By substituting the values, $\phi_k(\theta) = \sin^2(\frac{\pi}{M}) \csc^2(\theta)$,

$K = 1$ $\theta_k = \pi(1 - \frac{1}{M})$ in (1)

The SEP expression for QPSK reduces to

$$P_{e(H-SMRC)} = \int_{0}^{\frac{3\pi}{4}} \frac{1}{\pi} \left[\frac{1}{1+0.5\csc^2(\theta)\Gamma} \right]^L \times \prod_{n=L+1}^{4} \left[\frac{1}{1+0.5\csc^2(\theta)\Gamma \frac{L}{n}} \right] d\theta \qquad (6)$$

RESULTS AND DISCUSSIONS

Fig.2. shows the performance of QPSK of H-S/MRC for various L with N=4. When L=1 the diversity system becomes selection combining and when L=4, it becomes maximal ratio combining. It is seen that most of the gain of H-SMRC is achieved for small L, e.g the SEP for H-S/MRC is with in 1 dB of MRC when L=N/2.

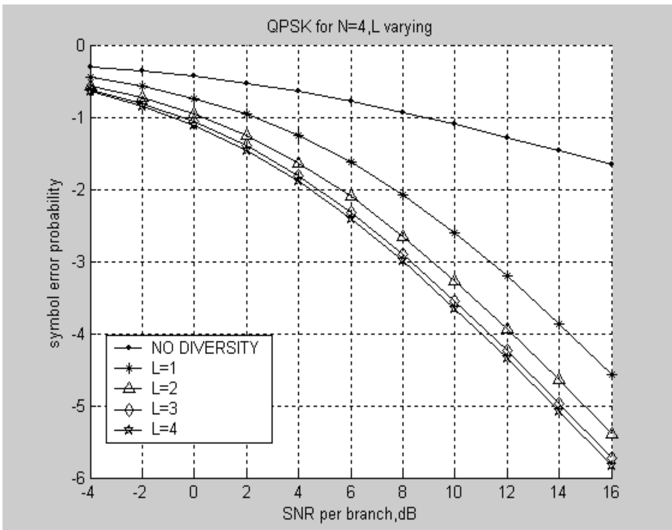

Figure 2: Symbol Error Probability of QPSK with HS-MRC as a function of the average SNR per branch for various L with N=4.

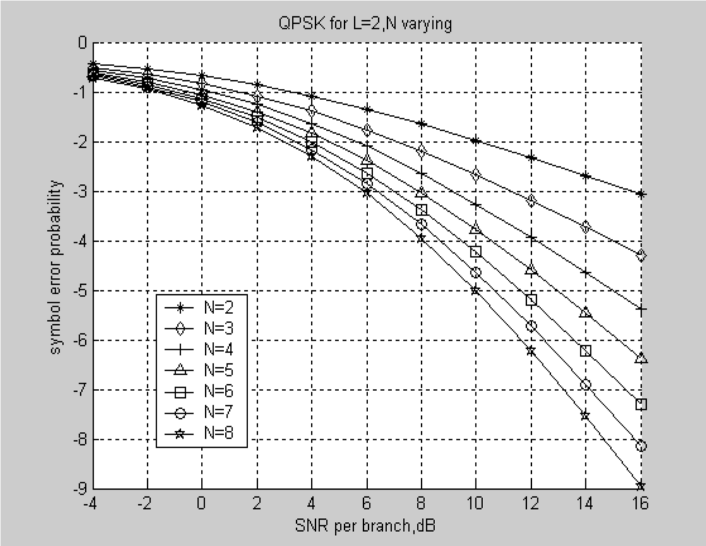

Figure 3: Symbol Error Probability of QPSK with H-SMRC as a function of the average SNR per branch for various N with L=2.

Fig.3. shows the performance of QPSK of H-SMRC for various N with L=2. Although the incremental gain with which additional combined branch becomes smaller a N increases, the gain is still significant even with N=8. Furthermore, for L=2 at a 10^{-3} SEP, H-SMRC with N=8 requires about 10dB lower SNR than 2-branch MRC

Table shows the Diversity Gain of H-SMRC for various L with N=4 at 10^{-1}

Table 1: Diversity Gain of H-SMRC for various L with N=4 at 10^{-1}

	L=1	L=2	L=3	L=4
Diversity Gain(dB)	**7**	**8.5**	**8.8**	**9**

Conclusions

The exact SEP expressions for coherent detection of Quadrature Phase Shift Keying (QPSK) modulation with H-SMRC in multipath-fading wireless environments are derived. A general expression was derived in terms of the parameters of the specific modulation schemes. With H-SMRC, L out of N diversity branches are selected and combined using MC. This technique provides improved performance over L branch MRC when additional diversity is available. We considered independent rayleigh fading on each diversity branch with equal SNR's, averaged over the fading. We analyzed this system using a "virtual branch" technique which resulted in a simple derivation of the SEP for arbitrary L and N.

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