Performance Evaluation of Hybrid Diversity Technique Using Pulse Amplitude Modulation

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Abstract- **In this paper, the design and analysis (by deriving the exact expression for SEP) of Hybrid Selection/Maximal Ratio Combining (H-S/MRC) is carried out. Independent Rayleigh fading diversity branch is assumed for analysis with equal Signal-to-Noise Ratio averaged over the fading channels and coherent detection of M-ary Pulse amplitude modulation (MPAM) is considered. Virtual branch technique is used. It transforms the ordered physical branches, which are dependent into independent, and identically distributed virtual branches.**

Keywords- **diversity reception, virtual branch technique, Rayleigh fading channel, Symbol error probability**

I. INTRODUCTION

Diversity combining has been considered as an efficient way to combat multipath fading because the combined signal-to-noise ratio (SNR) is increased compared with the SNR of each diversity branch. The optimum combiner is the maximal ratio combiner (MRC) whose SNR is the sum of SNR's of individual diversity branch. The Selection combiner (SC) selects the signal from that diversity branch with the largest instantaneous SNR. In this paper we design and analyze a hybrid diversity scheme in which both MRC and SC were combined. In H-S/MRC scheme 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, H-S/MRC has been considered as an efficient means to combat multipath fading [1],[2],[3]. The bit error rate (BER) performance of an H-S/MRC 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-S/MRC 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-S/MRC diversity system.

In this paper we extend [4], [5] to derive analytical symbol error probability (SEP) for M-ary Pulse amplitude modulation with H-S/MRC 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 binary pulse amplitude modulation (BPAM), quadrature pulse amplitude modulation (QPAM) and finally remarks and conclusions are presented.

II. SYSTEM MODEL

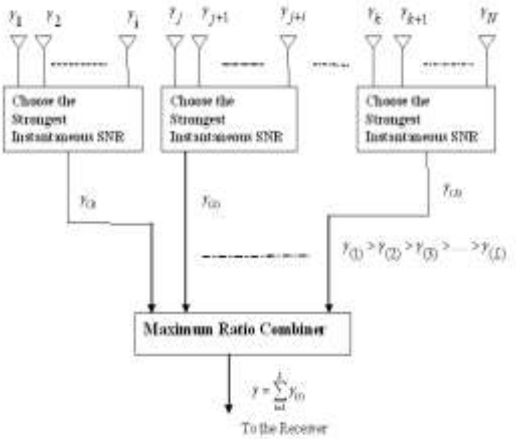

Fig.1 System Model of Hybrid diversity technique

Fig.1 shows the system model of H-S/MRC in which L out of N diversity branches are selected using selection diversity (SC) and combined using Maximal Ratio Combining (MRC).

III. SEP OF M-ARY MODULATION WITH H-S/MRC

Symbol error probability (SEP) for M-ary pulse amplitude modulation with H-S/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]

$$p_{e,S/MRC} = \sum_{k=1}^{K} \int_{0}^{\theta_k} a_k(\theta) \left[\frac{1}{1+\phi_k(\theta)\Gamma} \right]^{L} \times \prod_{n=L+1}^{N} \left[\frac{1}{1+\phi_k(\theta)\Gamma \frac{L}{n}} \right] d\theta \qquad (3.1)$$

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 coherent modulations.

LIMITING CASES

A. Limiting Case1: SC System

SC is the simplest form of diversity combining whereby the received signal from one of N diversity branches is selected [6]. The output SNR of SC is

$$\gamma_{SC} = \max\{\gamma_i\} = \gamma(1). \qquad (3.2)$$

Note that SC is limiting case of H-S/MRC with L=1. Substituting L=1 into (3.1), the SEP with SC becomes

$$p_{e,S/MRC} = \sum_{k=1}^{K} \int_{0}^{\theta k} a_k(\theta) \prod_{n=1}^{N} \left[\frac{1}{1+\phi_k(\theta)\Gamma \frac{1}{n}} \right] d\theta \qquad (3.3)$$

B. Limiting Case 2: MRC System

In MRC the received signals from all diversity branches are weighted and combined to maximize the SNR at the combiner output [7]. The output SNR of MRC is

$$\gamma_{MRC} = \sum_{i=1}^{N} \gamma_i = \sum_{i=1}^{N} \gamma(i) \qquad (3.4)$$

MRC is a limiting case of H-S/MRC with L=N. Substituting L=N into (3.1), the SEP with MRC is

$$p_{e,S/MRC} = \sum_{k=1}^{K} \int_{0}^{\theta k} a_k(\theta) \left[\frac{1}{1+\phi_k(\theta)\Gamma} \right]^N d\theta \qquad (3.5)$$

IV. SEP OF M-ARY PAM

The generalized expression for SEP for coherent detection of M-ary pulse amplitude modulation using H-S/MRC is given by

$$p_{e,S/MRC} = \sum_{k=1}^{K} \int_{0}^{\Theta_k} a_k \left[\frac{1}{1+\phi_k(\theta)\Gamma} \right]^L \times \prod_{n=L+1}^{N} \left[\frac{1}{1+\phi_k(\theta)\Gamma \frac{L}{n}} \right] d\theta \qquad (3.6)$$

Where $\phi_k(\theta) = \frac{3}{(M^2-1)} \csc^2(\theta)$, $K=1$, $a_k = \frac{2}{\pi}(1-\frac{1}{M})$,

$\Theta_k = \frac{\pi}{2}$, M=2,4,8,16…

V. RESULTS AND DISCUSSIONS

Fig.2, Fig.4 shows the performance of Binary PAM, Quadrature PAM of H-S/MRC for various L with N=4 respectively. 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-S/MRC is achieved for small L, e.g the SEP for H-S/MRC is with in 1 dB of MRC when L=N/2.

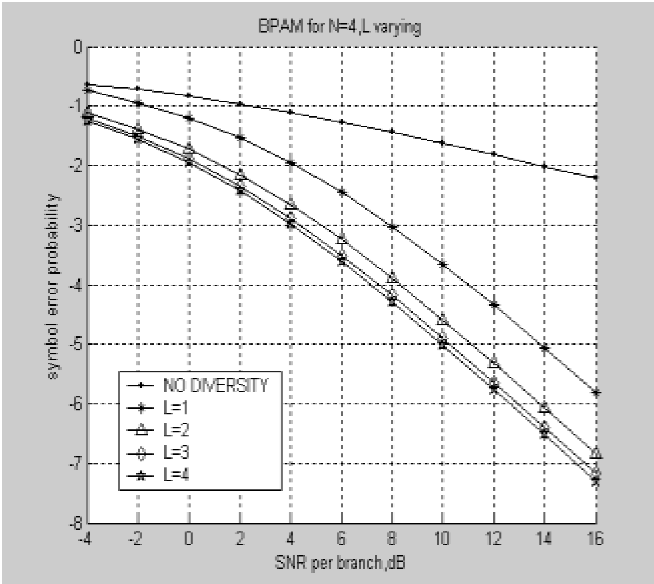

Fig.2. Symbol Error Probability of Binary PAM with H-S/MRC as a function of the average SNR per branch for various L with N=4.

Value of Selected Branches	L=1	L=2	L=3	L=4
Diversity Gain(dB)	10	12.5	13.2	14

Table.1 Diversity Gain of H-S/MRC using Binary PAM for various L with N=4 at 10^{-2}

Fig.3. shows the performance of BPAM of H-S/MRC for various N with L=2. Although the incremental gain with which additional combined branch becomes smaller as N increases, the gain is still significant even with N=8. Furthermore, for L=2 at a 10^{-4} SEP,H-S/MRC with N=8 requires about 11.5 dB lower SNR than 2-branch MRC.

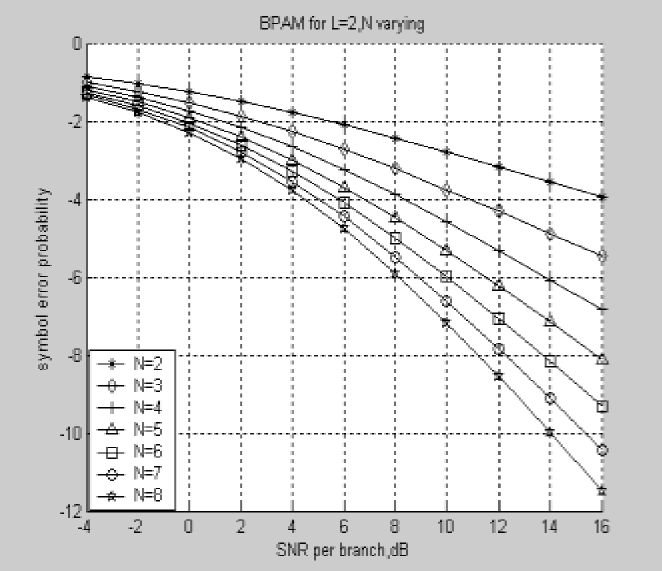

Fig.3. Symbol Error Probability of Quadrature PAM with H-S/MRC as a function of the average SNR per branch for various N with L=2

Value of Selected Branches	L=1	L=2	L=3	L=4
Diversity Gain(dB)	11.5	13	13.2	14

Table.2 shows the Diversity Gain of H-S/MRC for various L with N=4 at $10^{-0.5}$

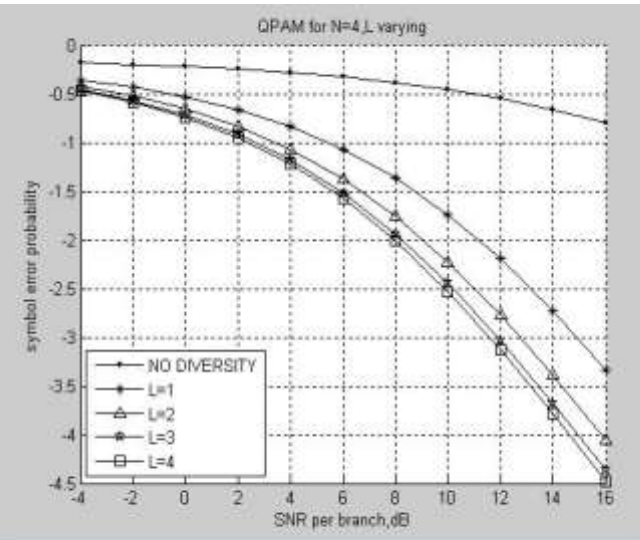

Fig.4. Symbol Error Probability of Quadrature PAM with H-S/MRC as a function of the average SNR per branch for various L with N=4

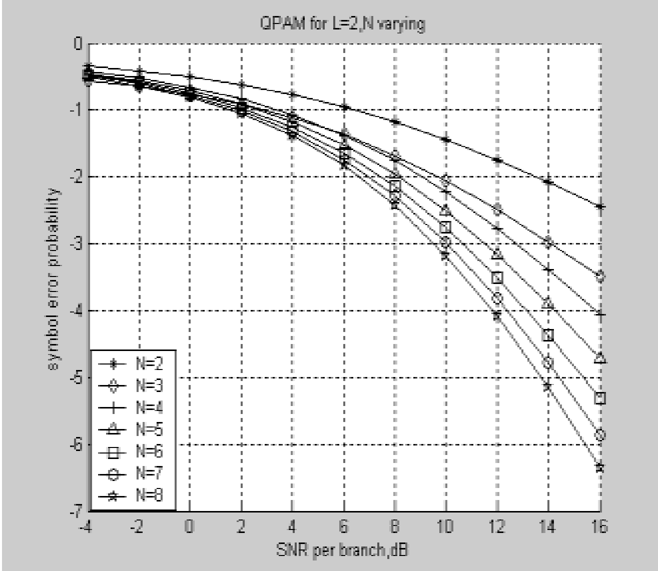

Fig.5. Symbol Error Probability of Quadrature PAM with H-S/MRC as a function of the average SNR per branch for various N with L=2.

Fig.5. shows the performance of Quadrature PAM of H-S/MRC for various N with L=2. Although the incremental gain with which additional combined branch becomes smaller as N increases, the gain is still significant even with N=8. Furthermore, for L=2 at a 10^{-2} SEP, H-S/MRC with N=8 requires about 6dB lower SNR than 2-branch MRC.

VI. CONCLUSIONS

We design and analyzed the exact SEP expressions for coherent detection of M-ary pulse amplitude modulation (MPAM) with H-S/MRC in multipath-fading wireless environments. A general expression was derived in terms of the parameters of the specific modulation schemes. With H-S/MRC, 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.

VII. REFERENCES

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