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Performance Analysis and Simulation of H-S/MRC using M-ary Digital Modulation Technology

Neelam Yadav[1], Jyoti Yadav[2] and Poonam Yadav[3]

[1]Asst. Prof. St. Margrate Collecge of Engineering, Neemarana, Alwar Rajesthan, India

neelamnuniwal@yahoo.com

[2]Banasthali Vidyapeeth, Jaipur, Rajesthan, India

nuniwal.jyoti@gmail.com

[3]Asst. Prof. St. Margrate Collecge of Engineering, Neemarana, Alwar Rajesthan, India

poonam_yd82@rediffmail.com

Abstract

Hybrid Selection / Maximal Ratio Combining is a diversity combing scheme where Lout 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. It is denoted such hybrid schemes as H-S/MRC-L\N. in the context of coherent wideband CDMA systems, these systems offer less complex receivers than the conventional MRC receivers since they have the fixed number of fingers independent of the number of multipath. In this project the exact expressions for the Symbol Error Probability (SEP) are derived for Hybrid Selection/Maximal Ratio Combining wireless systems in multipath fading environment. Coherent detection of several types of M-ary modulations is considered.

Keywords: *Diversity techniques, Symbole error probability, multipath fading, M-ary PSK*

1. Introduction:

The ability to communicate has differentiated mankind from other species like mobile communication. In mobile communication there is use of space wave propagation. In this we face multipath fading and diversity technique give improve performance in multipath fading.

Diversity Techniques: Diversity is a powerful communication receiver technique that provides wireless link improvement at relatively low cost. There are wide ranges of diversity implementations, many which are very practical and provide significant link improvement with little added cost.

Diversity exploits the random nature of radio propagation by finding independent (or at least highly uncorrelated) signal paths for communication. In virtually all applications, diversity decisions are made by the receiver, and are unknown to the transmitter.

The diversity concept can be explained simply. If one radio path undergoes deep fade, another independent path may have strong signal. By having more than one path to select from, both the instantaneous and average SNR s at the receiver may be improved, often by as much as 20 to 30 dB.

Depending on the land mobile radio propagation characteristics, there are a number of methods to construct diversity branches. Generally branches are classified into one of the following categories of diversity:

1. Space
2. Angular or direction
3. Polarization
4. Frequency
5. Time

Space diversity has been widely used because it can be implemented simply and economically, it has a single transmitting antenna and a number of receiving antennas. Spacing between adjacent receiving antennas is chosen so that multipath fading appearing in diversity branches becomes uncorrelated.

2. PRACTICAL SPACE DIVERSITY CONSIDERATIONS:

Space diversity, also known as antenna diversity, is one of the most popular forms of diversity used in wireless systems

Space diversity reception methods can be classified into four categories:

1 .Selection diversity
2. Feedback diversity
3. Maximal ratio combining
4. Equal gain diversity

2.1 Selection Diversity:

Selection diversity is the simplest diversity technique. In this technique m demodulators are used to provide m diversity branches whose gains are adjusted to provide the same average SNR for each branch. The receiver branch having the highest instantaneous SNR is connected to the demodulator. The antenna signals themselves could be sampled and the best one sent to a single demodulator. In practice, the branch with largest (S+N)/N is used, since it is difficult to measure SNR alone.

2.2 Feedback or Scanning Diversity:

Scanning diversity is very similar to selection diversity except that instead of always using the best of m signals, the m signals are scanned in a fixed sequence until is found to be above a predetermined threshold. This signal is then received until it falls below threshold and the scanning process is again initiated. The resulting fading statistics are somewhat inferior to those obtained by the other methods, but the advantage with this method is that very simple to implement only one receiver is required.

2.3 Maximal Ratio Combining:

In this method the signal from all of m branches are weighted according to their individual signal voltage to noise power ratios and then summed. Here, the individual signals must be co-phased before being summed (unlike selection diversity) which generally requires an individual receiver and phasing circuit for each antenna element. Maximal ratio combining produces an output SNR equal to the sum of the individual SNRs.

2.4 Equal Gain Combining:

In certain cases it is not convenient to provide for the variable weighting capability required for true maximal ratio combining. In such cases, the branch weights are all set to unity, but the signals from each branch are co-phased to provide equal gain combining diversity.

3. HYBRID SELECTION/MAXIMAL RATIO COMBINIG DIVERSITY TECHNIQUES

Hybrid selection / maximal ratio combining (H-S/MRC) is considered an effective combining technique for achieving a good compromise between system performs and complexity, by coherently combining L largest signals form N available branches.

Hybrid selection / maximal ratio combining (H-S/MRC) is a diversity combining 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. H-S/MRC has been considered as an efficient means to combat multipath-fading. [12].

As the name indicates H-S/MRC, it is combination of both selection and maximal-ratio combing diversity technique. Hybrid model that acts as bridge between SC and MRC. SC is the simplest diversity technique because it uses only one branch which has highest performance among all braches. So its performance is less. In MRC Diversity technique circuit complexity is more but its performance is high. So H-S/MRC is the compromising technique between circuit simplicity and performance. In H-S/MRC, it consists of two sections. At first SC is performed and selects only L branches which are having highest SNRs from all N available branches. Later, each branch of L is multiplied with weights. The signal from all of L branches are weighted according to their individual signal voltage to noise power ratios and then summed. Here, the individual signals must be co-phased before being summed (unlike selection diversity) which generally requires an individual receiver and phasing circuit for each antenna element. All L weighted branches are then added and the output is given to the receiver.

Therefore Hybrid selection / maximal ratio combining (H-S/MRC) is considered an effective combining technique for achieving a good compromise between system performance and complexity, by coherently combining L largest signals form N available branches.

We know that SEP for the coherent detection of M-ary modulation using H-S/MRC is

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

4. 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 [15]. The output SNR of SC is

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

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

$$p_{e,S/MRC} = \sum_{k=1}^{K} \int_0^{\theta k} a_k(\theta) \prod_{n=1}^{N} \left[\frac{1}{1+\phi_k(\theta)\Gamma \frac{1}{n}} \right] d\theta$$

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 [16]. The output SNR of MRC is

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

(2)

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

$$p_{e,S/MRC} = \sum_{k=1}^{K} \int_0^{\theta k} a_k(\theta) \left[\frac{1}{1+\phi_k(\theta)\Gamma} \right]^N d\theta$$

(3)

5. M-ARY PHASE SHIFT KEYING (MPSK)

In M-ary PSK, the phase of the carrier takes on one of the M possible values, namely, $\theta_i = 2(i-1)\pi / M$, where i=1,2,…..M.

The SEP expression for M-ary PSK using H-S/MRC is given by

$$p_{e,S/MRC} = \sum_{k=1}^{K} \int_0^{\theta k} a_k(\theta) \left[\frac{1}{1+\phi_k(\theta)\Gamma} \right]^L \times \prod_{n=L+1}^{N} \left[\frac{1}{1+\phi_k(\theta)\Gamma \frac{L}{n}} \right] d\theta$$

(4)

Where $\phi_k(\theta) = \sin^2(\frac{\pi}{M})\csc^2(\theta)$, $K=1$, $a_k(\theta) = \frac{1}{\pi}, \theta_k = \pi(1-\frac{1}{M})$, M=2,4,8,16…

Where N is total available branches out of which we are selecting L branches.

6. RESULTS

Fig.1. shows the Performance of BPSK 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-S/MRC is achieved for small L, e.g. the SEP for H-S/MRC is within 1 dB of MRC when L=N/2.

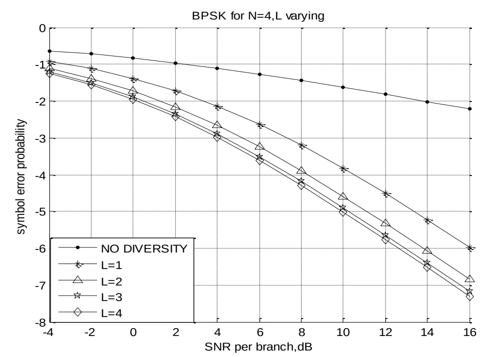

Fig.1. Symbol Error Probability of BPSK with H-S/MRC as a function of the average SNR per branch for various L with N=4.

Fig.2. shows the performance of BPSK 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 11dB lower SNR than 2-branch MRC.

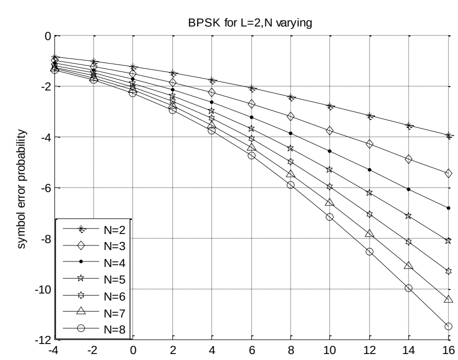

Fig.2. Symbol Error Probability of BPSK with H-S/MRC as a function of the average SNR per branch for various N with L=2.

Fig.3. 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-S/MRC is achieved for small L, e.g the SEP for H-S/MRC is within 1 dB of MRC when L=N/2.

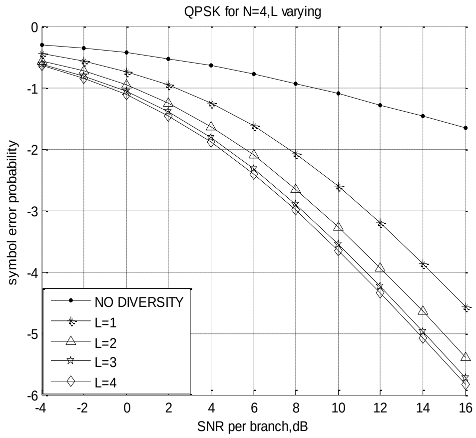

Fig.3. Symbol Error Probability of QPSK with H-S/MRC as a function of the average SNR per branch for various L with N=4.

Fig.4. shows the performance of QPSK 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^{-3} SEP, H-S/MRC with N=8 requires about 10dB lower SNR than 2-branch MRC.

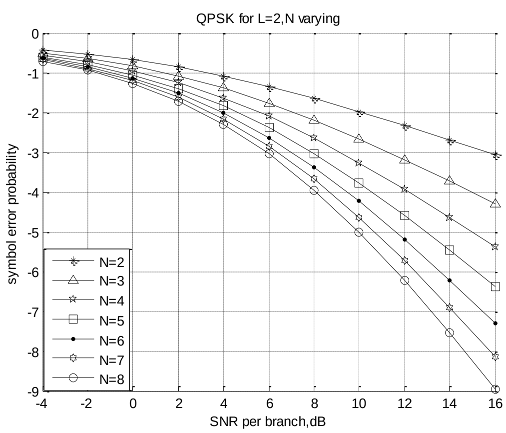

Fig.4. Symbol Error Probability of QPSK with H-S/MRC as a function of the average SNR per branch for various N with L=2.

7. CONCLUSIONS:

Among the family of M-ary PSK signals, QPSK (corresponding to M=4) offers the best trade-off between power and bandwidth requirements. For this reason, we find that QPSK is widely used in practice. For M>8, power requirements becomes excessive; accordingly, M-ary schemes with M>8 are not as widely used in practice. Also, coherent M-ary PSK schemes require considerably more complex equipment than coherent binary PSK schemes for signal generation or detection, especially when M>8. (Coherent 8-PSK is used in digital satellite communications) [24].

We can observe from results that in an M-ary modulation schemes as M value increases symbol error probability (SEP) also increases. Hence smaller the value of M, smaller the probability of error and better is the performance. But the advantage with the large value of M is that the more the value of M, more the data can be transmitted. Hence, there should be compromise between the SEP and the data rate, which is possible by medium values of M. So diversity techniques is bridging the gap between these two extremes by proposing the H-S/MRC, which adaptively combines (following the rules of MRC) the N strongest (highest SNR) paths among the L available ones. It is denoted such hybrid schemes as H-S/MRC-L\N. in the context of coherent wideband CDMA systems, these systems offer less complex receivers than the conventional MRC receivers since they have the fixed number of fingers independent of the number of multipath.

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