Performance Analysis of Optimum Diversity Combining for Partially Coherent Frequency-Selective Fading Channel With Intersymbol Interference

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Abstract—The performance of coherent BPSK and QPSK systems in the presence of frequency-selective fading and carrier phase errors is analyzed. Frequency-selective fading channels are modeled as multipath Rayleigh, Nakagami-\(m\), or Rician two-ray fading models wherein the presence of a delayed ray causes intersymbol interference (ISI). A diversity system with \(L\)-branches is used for signal detection using an optimum equal-gain-combining receiver. The effect of ISI on system performance is assessed using a truncated pulse train of the ISI signal. For Rayleigh-faded channels, the simulation result that demonstrates the influence of Doppler spread on system performance was also included. The following two performance criteria are considered: the average bit error probability and the signal-to-noise-ratio (SNR) gain penalty due to ISI.

Index Terms—Frequency-selective channel, intersymbol interference (ISI), optimum coherent receiver, partially coherent detection.

I. INTRODUCTION

INTERSYMBOL interference (ISI) is a signal-dependent form of interference that arises when digital data are transmitted over a band-limited channel. In wireless environments, ISI basically occurs if the difference of the path delays (i.e., the delay spread) is significant compared with the symbol period. Furthermore, the receiver must perfectly recover symbol timing, and jitters in the receiver sampling instants may result in ISI whether the transmitted signals are timedly distorted or not. On the other hand, due to the time-variant characteristic of wireless channels, the carrier phase cannot perfectly be recovered (i.e., partially coherent detection), which results in system performance degradation. Thus, noncoherent or differentially coherent systems [differential BPSK (DBPSK) and differential QPSK (DQPSK)] could become attractive alternatives to partially coherent systems [1]. In conclusion, neither the carrier phase nor the delay spread of the received signals can perfectly be derived in wireless environments. Since the exact evaluation of performance and resulting degradation is a formidable task, we present a unified methodology to analyze the performance of frequency-selective partially coherent PSK systems in the presence of ISI. Our analysis considers an optimum spatial equal-gain-combining (EGC) diversity receiver to provide wireless link improvement at relatively low cost. The optimum receiver, in this case, employs matched filtering or cross correlation of the received signal through estimation of the instantaneous response of the channel and then comparison of the received signal with the reference signals [2].

A considerable amount of work has been done to evaluate the performance of digital communication systems corrupted by ISI. The error rate performance of coherent nonfaded PSK systems in the presence of ISI due to symbol timing jitters and Gaussian noise was studied in [3] and [4]. For a frequency-nonselective fading environment, the effects of ISI (due to asynchronous cochannel interference (CCI) signals) on the performance of single-channel BPSK systems were investigated in [5] and [6] for Rayleigh and Nakagami-\(m\) fading, respectively, and in [7] for MPSK in dual-branch EGC reception under Nakagami-\(m\) fading. More generally, the performance of frequency-selective fading channels for both coherent and differentially coherent PSK systems has received a lot of attention, including the following studies. The performance of digital transmission over frequency-selective Rayleigh fading systems was investigated in [8]. The error-rate probability for coherent two-ray Rayleigh fading systems has been analyzed for both optimum and suboptimum receivers in [9]. Mazo [10] derived the matched filter bound (i.e., the effect of ISI is neglected) for BPSK and QPSK systems in a two-ray Rayleigh fading channel. Analytical expressions for the average bit error probability (BEP) of a two-ray Rayleigh fading channel were obtained for DBPSK in slow fading with cochannel and adjacent-channel interferences in [11] and for DQPSK in fast fading with CCI in [12]. Simulation results for the average BEP of the frequency-selective DQPSK system are also presented in [13]. Adachi [14] provided quasi-analytical simulation results for the error rates of perfect coherent BPSK and QPSK frequency-selective slow Rayleigh fading channel without diversity.

All the aforementioned studies assumed perfect coherent recovery of the carrier phase. The impact of carrier phase errors on the BEP performance of coherent PSK fading channels was analyzed in [15] for Rayleigh fading systems and, more generally, in [16] for Rician and Nakagami-\(m\) fading systems.

Manuscript received March 22, 2006; revised July 22, 2007, January 3, 2008, and February 27, 2008. First published March 31, 2008; current version published November 12, 2008. The review of this paper was coordinated by Prof. G. Saulnier.

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Digital Object Identifier 10.1109/TVT.2008.921614