Published in IET Communications
Received on 29th November 2010
Revised on 22nd February 2012
doi: 10.1049/iet-com.2011.0905

ISSN 1751-8628

Performance bound for generalised multilevel-quadrature amplitude modulations constellations in multipath Rayleigh fading channels with imperfect channel estimation

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Abstract: The authors derive a lower bound on the performance of generalised multilevel quadrature amplitude modulations (*M*-QAM) in time-discrete multipath Rayleigh fading environments with imperfect channel estimation. The bound can be regarded as an extension of the well-known matched filter bound (MFB), taking into account the impact of imperfect channel knowledge. The analytical expressions derived allow the computation of the bit error rate for the different bit streams that can be mapped simultaneously onto *M*-QAM symbols using a hierarchical approach when unequal bit error protection is desired.

1 Introduction

The scarceness of spectrum available for wireless communication networks is one of the main difficulties for achieving high bit rate transmissions. The usage of spectrally efficient modulations like uniform multilevel quadrature amplitude modulations (*M*-QAM) helps on overcoming this problem and has been studied for wireless systems by several authors [1, 2]. If instead of a simple point-to-point transmission the objective is the broadcast of information to several users then a more general and versatile hierarchical *M*-QAM constellation (*M*-HQAM), with uniform or non-uniformly spaced signal points, can be used as an alternative. The idea is based on the work of Cover [3] who showed that in broadcast transmissions it is possible to exchange some of the capacity of the good communication links to the poor ones and this tradeoff can be worthwhile. *M*-HQAM constellations constitute a very simple method to provide unequal bit error protection and improve the efficiency of a network in broadcast transmissions. Depending on the propagation conditions, a given user can attempt to demodulate only the more protected bits or also the less protected bits carrying additional information. This approach is possible whenever the information is scalable like the cases of coded voice and video signals, as studied in [3] and [4]. Hierarchical 16-QAM and 64-QAM constellations have already been incorporated into digital video broadcasting-terrestrial (DVB-T) [5] and digital video broadcasting-satellite services to handheld (DVB-SH) [6] standards. Hierarchical constellations have also been shown to be advantageous in relay communications [7].

A great deal of attention has been devoted to obtaining analytical expressions for the bit-error-rate (BER) performance of *M*-QAM [8–16] and also for *M*-HQAM [17, 18], with some authors also addressing the effects of imperfect channel estimation ([12–16, 18]). However, owing to the difficulty in dealing with multipath channels they all assume flat fading channels. Instead of trying to obtain exact expressions for multipath channels it can be satisfactory to simply compute the MFB, which represents a lower limit on the BER for a particular communication channel. The MFB is found assuming perfect channel knowledge and the transmission of only one pulse, that is, no intersymbol interference occurs. MFB expressions for binary- and quadrature-phase shift keying (QPSK) transmission over two-beam Rayleigh fading channels were obtained in [19]. These expressions were then extended to continuous time-delay profile channels in [20] and also to time-discrete multipath channels in [21] and [22]. Diversity reception was also taken into consideration in [20] and [22]. Using an approach similar to [22], MFB expressions were derived for the symbol error probability of QAM in [23] and for the individual BERs of *M*-HQAM constellations in [24]. If one of the assumptions of the MFB is removed, namely the perfect channel knowledge, we can obtain a tighter lower bound which is useful for evaluating the performance degradation caused by imperfect channel estimation. Therefore in this paper we take into account the presence of channel estimation errors and derive bounds for the BERs of the different types of bits in hierarchical QAM constellations. The expressions obtained are valid in time-discrete multipath Rayleigh fading channels with correlated