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Multilevel Block Coded Modulation with Unequal Error Protection

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Abstract — **Multilevel block coded modulation (BCM) schemes with unequal error protection (UEP) are investigated. These schemes are based on unconventional set partitions that greatly reduce the error coefficients associated with multi-stage decoding of conventional BCM, at the expense of smaller intra-set distances.**

I. Introduction

This paper studies bandwidth efficient multi-level coding schemes [1] with unequal error protection (UEP) over AWGN channels. These schemes are useful for the transmission of information with different error performance requirements, such as digital video or speech. The advantages of unconventional partitions for UEP applications are illustrated with 8-PSK signaling in the following. A general approach for both PSK and QAM has been derived [2].

II. Unconventional partitions for 8-PSK

Optimum decoding of multi-level codes is often too complex to be implemented in practical applications. Therefore, various suboptimum decoding methods have been devised. Since only the error coefficients are increased, multi-stage decoding achieves asymptotically optimum decoding. However, these error coefficients can become very large and therefore, at practical bit error rates (BER), the performance degradation is important. For example, in a BCM scheme based on 8-PSK modulation, the number of signal point sequences at the minimum squared Euclidean distance (MSED) $0.586d_1$ is multiplied by the factor 2^{d_1}, where d_1 represents the minimum Hamming distance (MHD) of the code used at the first level [3]. As a result, even if the component codes are chosen to achieve UEP capabilities, the desired UEP levels may not be achieved at BER of practical interest.

A. Non-standard partition

Consider the non-standard labeling of an 8-PSK constellation shown in Fig. 1 (a). It is readily seen that the intra-set distances are the same at all levels of the underlying partition. Also note that the first (resp. second) label bit depends on the X-coordinate (resp. Y-coordinate) only. This fact is used to speed up the decoding since a parallel decoding of these stages is possible. In addition, the same correlation metrics as for BPSK transmission can be used. This results in simple soft-decision decoding implementations. Union bounds on the bit error probabilities at the first and second decoding stages show that, whereas the minimum error coefficient is scaled by a factor of 2^{d_j} with the standard partitioning method, this value is now scaled by 2^{-d_j}, where d_j is the MHD of the code used at level j, $j = 1, 2$. Consequently, for practical values of E_b/N_O, real coding gains can be provided which are even *greater than the asymptotic coding gain* associated with the first and second decoding stages. This is a very desirable feature for a coded modulation with UEP. On the other hand, the error performance for the last stage is quite poor due the fact that the intraset distances remain constant.

B. Hybrid partition

Fig. 1 (b) shows an 8-PSK constellation with labeling of signal points induced by a hybrid partition. The first partition level is the same as the non-standard partition while the partitioning method of [1, 4] is applied to the remaining levels. Therefore, the intra-set distances at the second and third partition levels are increased with respect to the non-standard partition. At the second decoding stage, the minimum error coefficient associated with the hybrid partition is smaller than for the standard partition: $(3/2)^{d_2}$ compared to 2^{d_2}.

III. Conclusion

Based on these results, a general procedure to label signal points in any 2^M-ary constellation, for a given number (between 1 and M) of levels of protection, can be devised. The standard partitioning of [1, 4] simply corresponds to the special case where one level of protection (or no UEP) is desired.

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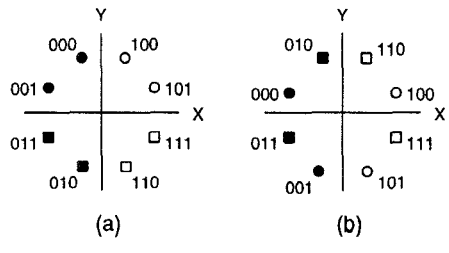

Fig. 1: (a) Non-standard and (b) hybrid labelings of an 8-PSK constellation.

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