# Concatenated coding for packet transmission over the collision channel

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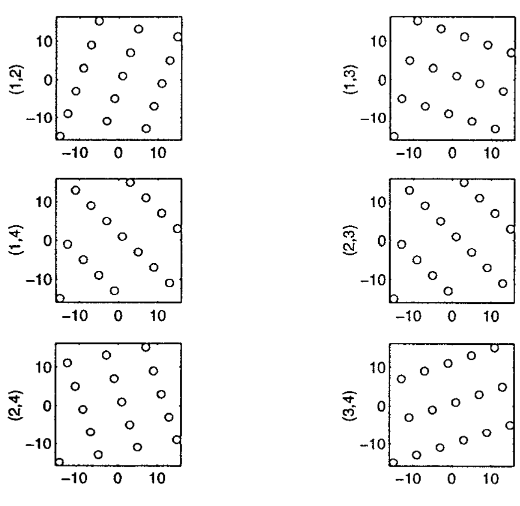
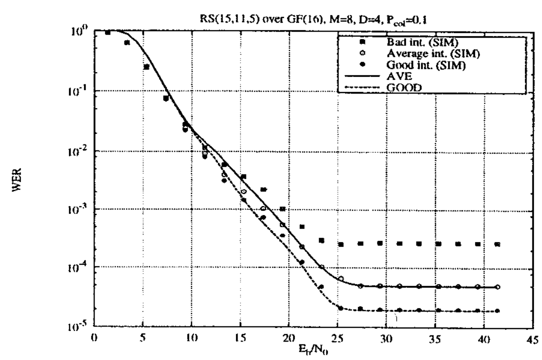
## I. Abstract

We consider a collision channel [1] with additive white Gaussian noise (AWGN) and slow fading. We assume that data on a collided slot are completely lost. In [2], we proposed a combination of signal-space coding and slow time-frequency hopping for this channel. Code vectors (or equivalently, signals) are points in a $D$-dimensional real Euclidean space. The main idea is that, under certain conditions on the signal-space code and provided that signal points are transmitted so that their $D$ components belong to different time-frequency slots, even if $k < D$ slots collide the signal can be correctly detected from its $D - k$ uncollided components. We defined a class of signal-space codes called Collision Resistant Modulation (CRM) with the above property. The following figure shows the six 2-dimensional projections of a 4-dimensional CRM.




On its own, the modulator can be seen as a signal-space encoder, so that modulation acts as an inner code. In order to apply the CRMs for reliable transmission of long data packets, additional outer coding (possibly combined with interleaving) is required. This, in turn, will introduce a decoding delay which has to be taken into account for delay constrained transmission such as real-time speech. The main issue of this paper is the analysis of the performance of a coding system formed by a CRM scheme and a block outer code (e.g., a Reed-Solomon code) with hard decoding, concatenated through an interleaver. Usual analysis of fraquency-hopped coded systems assume infinite (i.e., perfect) interleaving, so that errors at the inner decoder output are assumed to be statistically independent. However, real systems are often delay-constrained, so that infinite interleaving is not possible. Normally, the performance analysis with finite interleaving is much more complicated or unfeasable. Here, we use a "random coding"-like approach and we average the packed error probability over the ensemble of all interleavers with a fixed delay (measured in terms of slots). In this way we can derive closed-form formulas for the average packet error probability. From the standard random coding argument we get that the error probability averaged over the interleaver ensemble is an upper bound on the performance of the best possible interleaver with the same delay. This provides a tool for studying the trade-off between decoding delay and the packet error rate, and for the interleaver optimization. Finally we provide some guidelines for the design of good interleavers, and we get an asymptotically tight performance approximation for them.

The following figure shows the packet error rate (WER) vs. $E_b/N_0$ obtained by Monte Carlo simulation and closed-form analysis, with interleaving depth $M = 8$ and slot collision probability $P_{col} = 0.1$. A Reed-Solomon (RS) code with parameters $(15, 11, 5)$ over GF(16) is concateneted with a 4-dimensional CRM with 16 points through different interleavers. We observe that our analytical bounds match very well the simulation for both the average interleaver and the optimized good interleaver.




## References

[1] J. L. Massey and P. Mathys, "The Collision Channel Without Feedback," *IEEE Trans. on Information Theory*, pp. 192–206, vol. 31, no. 2, March 1985.

[2] G. Caire, E. Leonardi and E. Viterbo, "Collision Resistant Modulation," accepted for presentation at *ICT '98*, Porto Carras, Greece, 22 – 25 June 1998.