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Abstract

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Keywords

coding, source, awgn, trellis, methods, optimised, channel

Disciplines

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Methods of Channel-Optimised Trellis Source Coding for the AWGN Channel

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Abstract — Improvements to channel-optimised trellis source coding for the AWGN channel are obtained by using, in various forms, real or 'soft' channel information. The proposed 1 bit/sample systems use a channel-optimised encoder matched to 1) a simple decision feedback detector, 2) an expanded codebook with 2-bit quantized information and 3) an optimum non-linear estimator decoder. The third system is further improved by considering vector alphabets and both constant and average energy constrained 2D signal constellations.

I. INTRODUCTION

Channel-optimised trellis source coding is well developed for the discrete channel (eg. BSC) [1]. To perform well on the Gaussian (AWGN) channel, consideration must be given to using real or 'soft' information as opposed to 'hard' quantized information. This work describes a number of systems that, variously, use different degrees of quantized channel information [2]. Not surprisingly, the more finely this information is quantized, the better the performance. For the optimum decoder, which accepts unquantized information, consideration is also given to modifying the modulation system. A vector trellis enables indexing of signal points in greater than one dimension. The extension to vector alphabets coupled with an average energy constrained 2D modulation system yields substantial gains over a standard system with BPSK modulation and hard decision detection. All systems are designed for a GM source ($\rho = 0.9$) at 1 bit/sample. Comparisons are made with the equivalent hard quantized BPSK system.

II. SYSTEMS

The first system is detection based. A simple decision feedback (DF), symbol-by-symbol detector is proposed. The detector forms a trellis with the same number of states as the decoder. Each state consists of two decision regions that are based on a-priori encoder transition probabilities. The trellis decoder accepts the resulting hard quantized information. The detector may be modelled by two Markov matrices describing the state transition probability for a given encoder output bit. This allows the encoder to determine the probability of any sequence error and hence minimize the expected distortion across the channel. Note that further performance improvements may be made to the hard decision and DF systems by substituting a Maximum-A-Posteriori (MAP) detector even though the encoder is not matched to it.

The second system partitions the channel output space into four regions (symmetric about the origin) converting the channel into a binary input, 4-ARY output DMC. It is found that the optimal quantization levels are close to those levels which maximise channel capacity.

The third system is estimation based. The optimum MMSE estimator decoder $c(\mathbf{v})$ is given by

$$c(\mathbf{v}) = E[\mathbf{X}|\mathbf{V} = \mathbf{v}]$$

$$= \sum_{\mathbf{u}} E[\mathbf{X}|\mathbf{u}]p(\mathbf{v}|\mathbf{u})P(\mathbf{u})/p(\mathbf{v})$$

for source $\mathbf{X}$ (dimension β) and transmitted and received vectors $\mathbf{u}, \mathbf{v}$. Hence for a given $\mathbf{v}$ the reconstruction value is a non-linear combination of centroids $E[\mathbf{X}|\mathbf{u}]$. Further improvements to this system are obtained by extending the scalar trellis ($\beta = 1$) to a vector trellis with 2-dimensional vectors ($\beta = 2$) and using 2-bit (QPSK) signalling. A quite reasonable improvement results without increased encoder complexity.

A system representing a joint design of channel-optimised trellis encoder, estimation-based decoder and modulator is considered. By modifying the signal constellation, the costs associated with a signal point may be related to its position in the plane. Both constant energy, variable phase (4PSK) and average energy (4QAM) constraints are imposed on the constellation.

Finally, the gain each system makes over a hard decision system come at a cost. The DF system is burdened by high encoder complexity, the 4-ARY system has very large decoder codebooks while the estimation-based systems suffer from high decoder complexity.

III. RESULTS

The performance of these systems are presented in the following table for systems designed and operated on noise densities of $N_o = 0.25, 0.5, 0.75, 1.0, 1.25$ corresponding to channel SNRs ($10\log_{10} E_b/N_o$) of 6.0, 3.0, 1.25, 0.0 and -0.97 dB respectively. $E_b = 1.0$. The constraint lengths: scalar trellis $K = 4$, vector trellis $K = 2$.

Detection/ Modulation	β	SQNR (dB)				
		Noise Density N_o				
		0.25	0.50	0.75	1.00	1.25
Hard Dec.	1	9.77	7.87	6.38	5.34	4.71
DF	1	9.82	8.03	6.68	5.82	5.21
4-ARY	1	9.87	8.22	6.86	5.94	5.27
Est-BPSK	1	9.87	8.28	6.97	6.14	5.45
Est-QPSK	2	10.14	8.85	7.45	6.37	5.55
Est-4PSK	2	10.15	8.92	7.65	6.76	6.01
Est-4QAM	2	10.23	9.14	7.98	7.07	6.31
D(C) bound		16.8	14.2	12.8	12.0	11.3

Clearly the progression to more finely quantized channel information and less constrained signalling improves performance. Note, however, that 2-bit (4-ARY) channel information is only marginally inferior (< 0.2 dB) to the unquantized case (Est-BPSK). Of course, a similar analogy occurs with conventional channel coding.

REFERENCES

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